J. Int. Environmental Application & Science, Vol. **19**(2): 110-120 (2024)
Research Paper

Effect of Domestic Sewage Sludge on the Botanical Composition of Eroded Pastures

Ramazan Acar[1, *], Osman Mücevher[2], Mehtap Öztekin[3], Sukru Dursun[4], Ayşen Akay[5], Salih Bitgi[2], Serap Ulutaş[6], Serdar Koyuncu[7]

[1] Selcuk University, Agriculture Faculty, Field Crops Department, Konya, Türkiye,[2]Directorate of Soil, Water and Combating Desertification Research Institute, Konya, Türkiye, [3]Directorateof National Botanical Garden of Türkiye, Ankara, Türkiye,[4]Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Environmental Engineering, Konya, Türkiye,[5]Selcuk University, Faculty of Agriculture Department of Soil and Plant Nutrition, Konya, Türkiye, [6]State Hydraulic Works 4th Regional Directorate, Konya, Türkiye,[7]Metropolitan Municipality KOSKİ General Directorate Konya, Türkiye

Received June 02, 2024; Accepted June 26, 2024

Abstract: This research to evaluate the use possibilities of sewage sludge in eroded pasture areas, the effects of stabilized treatment sludge (biosolid) from the Konya domestic wastewater treatment plant on soil and plants were monitored in marginal and eroded pasture areas in field trials for 3 years period. In this study, analysis processes of soil fertility parameters, micro and macro elements, and toxic heavy metals were examined. The enrichment factors of heavy metals in soil and plants, their effects on heavy metal accumulation and leaching in the soil profile, and their effects on erosion parameters were examined. In addition, biomass yield, protein ratio, botanical composition parameters, heavy metal contents and heavy metal risks in terms of animal health in pasture plants were investigated. In this article, the effects of sewage sludge on the development parameters of plant species that grow predominantly under natural conditions were evaluated. In the experiment, an increase in plant coverage area, height and especially the number and diversity of species were observed in the plots. Provided the necessary precautions are taken, it turns out that the D application has a feasible result of 1 ton da^{-1} (dry matter) in the method of mixing into the soil to a depth of 0-5 cm, once every 3 years. This recommended dose is valid for the ecological conditions in this region where the research was conducted, and similar studies are needed to recommend it in different ecological regions of Turkey.

Keywords: *Sewage sludge, biosolid, erosion, degraded pasture, botanical composition, heavy metal.*

Introduction

Development of urbanization and the growth of the population, significant increases are observed in the amount of stabilized treatment sludge generated from domestic wastewater treatment plants. The most economical method of disposal of sewage sludge for cost is land disposal. Serious problems may arise in the disposal of sewage sludge on land due to the salinity and heavy metals contains. However, if sewage sludge is used in a controlled and conscious manner in accordance with national standards, its useful part can be used as biosolids (fertilizer) for soil improvement (Mücevher *et al.*, 2020).

Pastures are important for animal husbandry, and they provide great benefits to the country's economy by preventing wind and water erosion and soil loss. For this purpose, legal regulations must be made to implement the necessary plans, including pasture improvement (Çepel, 2008). Compared to forests and other ecosystems, relatively little is known about the ecological status of grasslands. The crisis in global soil health is also closely related to the management of natural and semi-natural grasslands around the world. Both the destruction and creation, composition, and renewal of natural and semi-natural grasslands have been greatly affected by human management (Johnson *et al*., 2017). One of the measures to be taken against wind erosion in dry places with sparse vegetation is to protect the vegetation, and another is to enrich the soil in terms of organic matter. Organic matter is useful in resisting erosion because it has a high-water retention power (Eyce, 1995). Although rangelands are an important carbon sink with great potential to achieve environmental and development goals, they are often neglected in the land restoration agenda (Johnson *et al*., 2017).

**Corresponding: E-Mail: racar@selcuk.edu.tr; Tel: +90 5363403637, +90 3322410008*

The Central Anatolia Region is a region with the least productive pastures, annual rainfall is between 250-500 mm, pastures dry quickly, and grazing pressure is very high (Sutie et al., 2005). In the south of this region, the altitude generally varies between 700-1050 mm in the places including Çumra, Cihanbeyli, Karapınar and Konya Ereğli. In these places, natural steppe areas have been destroyed in the last 15-20 years (66-80% has disappeared) and a radical change has occurred (Akman *et al*., 2014). In these pastures, where vegetation has been degraded on a large scale, production is attempted at the expense of erosion. In some cases, although improvements are tried to be made through controlled grazing, additional measures (furrowing, shaping, fertilizing, seeding, *etc*.) are needed (Akyürek, 1986). It is known that sewage sludge (biosolid) is also used with good control in special areas with different methods to fertilize or increase organic matter in the soil. However, it should not be forgotten that it must be dried and processed, and this is important for health and the environment. It has been stated that the main values in the use of biosolids as fertilizer are due to the slowly absorbable nitrogen and phosphorus from the nutrients therein (Ignatieff & Page, 1965). It has been stated that treatment sludge is used in Spain and that productivity increases and soil properties improve with the application (Altın *et al*., 2005). It has a positive effect on the establishment of vegetation and the productivity of pasture vegetation, especially in pastures degraded by erosion. However, it has also been stated that it should be used in a way and to an extent that does not harm the environment (Altın *et al*., 2005).

In arid and semi-arid regions, the inadequacy of crop production negatively affects animal husbandry. In addition to the lack of precipitation in arid (25-200 mm precipitation) and semi-arid (200-800 mm precipitation) places, evaporation caused by high temperatures is an important problem. All of these create harsh environmental conditions for humans, animals and plants. Water deficiency is very evident in arid areas and rainfall is irregular. It is typical for these regions to have low precipitation, low air humidity and high evapotranspiration. In addition, the organic matter content of the soil is low. Even if the soil depth is high, the amount of usable water stored in the soil is low because rainfall is insufficient. In arid areas, there are flora and fauna that have adapted to the ecological conditions described. As a result of this information, this research was conducted to see the effects of the application of sewage sludge in a pasture that is eroded, marginal and fragile, and classified as weak.

Material and Method

Climate Condition

The climate of the region is defined as semi-arid continental, with dry and hot summers and cold and rainy winters. Most of the snowfall falls in January and February. The average precipitation is 275 mm, and 40% of it falls during the winter months. The average rainfall from July to September is 15 mm (Şimşekli, 2012). In the project area, high temperatures in summer and low humidity in the soil profile throughout the year negatively affect the amount of organic matter in the soil and ultimately the physical and chemical quality of the soil (Bot & Benites, 2005). These decreases in vegetation due to temperature differences play a role in increasing degradation, desertification and ultimately wind erosion due to the decrease in the organic matter cycle to the soil. The distribution and amount of precipitation throughout the year is of great importance in terms of soil moisture, plant productivity and the amount of soil organic matter. The values of the 10-year average rainfall data of the research area are given below (Table 1; MGM, 2018). When Karapınar precipitation data is examined, excluding snowfall in December in 2016, there is 132.6 mm of precipitation, especially in terms of water year. 2016 was a very dry year has happened.

Location and Soil Condition

In this research, as a trial site was established by surrounding the Karapınar Desertification and Erosion Research Center land with wire fences in the eroded, weak, fragile and degraded Yenice Pastureland right next to it. The area where the project will be implemented was surrounded by a concrete wire fence and parcelization work was carried out. As a result of the preliminary survey land determination of the area where the trial site will be established, Yenice Pasture with its soil structure, degraded pasture, flat and sandy loam soil was chosen

as the most suitable place (Table 2). Especially in our country, a sandy loam soil structure was chosen in accordance with the regulation on the use of sewage sludge in soil.

Table 1. Karapınar rainfall data –last 10 years mm

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total (mm)
2008	17,9	9,7	29,2	26,5	20,4	5,7	0	0	20,2	30,8	22,5	49,2	232,1
2009	63,8	47,8	26,1	43,8	25,8	5,9	59	0	10,9	14,7	44,8	52,3	394,9
2010	37,4	18,9	7,5	28,4	10	46,8	0	3,4	1,2	52,8	1,2	69,8	277,4
2011	34,9	52,6	35,3	28,8	73,3	26,4	0	0	7	16,5	13,3	25,7	313,8
2012	51	25	24	6,6	12	18,4	2,8	7,8	1	32,6	26,6	70,7	278,5
2013	21,2	43,4	9,4	57,4	33,4	24,4	2,4	0,6	12,8	15,2	12	7,6	239,8
2014	40,4	18,4	47,2	3,2	18,4	26	0	9,8	17,2	48,2	33,8	29,8	292,4
2015	13,2	24,9	45,4	16,6	28	46,4	0	5,2	0,8	3,6	1,6	0,6	186,3
2016	25,8	0,4	28	4,6	27,6	19,2	0,4	0,2	20,6	0,2	13	100	240,0
2017	12,2	2,2	11,8	39,8	33	15,6	0	29,4	0	26	63,8	15,8	249,6
Mean	31,8	24,3	26,4	25,5	28,1	23,4	6,4	5,64	9,17	24,0	23,2	42,15	270,5

Table 2. Constitution classification of soil samples taken from pastures

Region	Coordinates	% Sand	% Clay	% Silt	Class
Yenice Pasture	N 37.6512304, E 33.4628130	68,45	13,55	18,00	Sandy loam (SL)

Table 3. Konya KOSKİ Wastewater Treatment Plant, 1 and 2 treatment sludge samples analysis results, limit values and analysis methods

Parameter / Example	Sewage Sludge 1 no.	Sewage Sludge 2 no.	Limits	Analysis Methods
Lead (Pb mg/kg furnace dry matter)	56,2	47,06	750	EPA 6020 A (ICP-MS)
Cadmium (Cd mg/kg)	8,13	8,52	10	
Chromium (Cr mg/kg)	500	598	1000	
Cupper (Cu mg/kg)	298	261	1000	
Nikel (Ni mg/kg)	175	165	300	
Zink (Zn mg/kg)	1735	1534	2500	
Mercury (Hg mg/kg)	0,617	0,596	10	TS 2537 EN 1483
Nitrogen (TKN mg/kg)	27669	25483		SM-4500-$N_{org.}$ B
Phosphorus (P mg/kg)	10297	9834		Method ofburning(Olsen et al.)
PCB (mg/kg)	<0,1	<0,1	0,8	EN 12766
PCDD/F (ng TE/kg furnace dry matter)	0,183	0,44	100	TS EN 1948/2-3
pH	6,71	6,73		TS 8332 ISO 10390
C/N (%)	7,12	7,23		D.13.Y.04.24 (İnternal method)
Moisture (%)	72,57	38,29		TS 9546 EN 12280
dry matter (DM) (%)	27,43	61,71		
Loss on Combustion (glow), Organic Matter (at770 ºC) (%)	51,1	43,27	> 40	TS EN 12879
Conductivity (dS/m)	2,63	3,8		ISO 11265
E. coli (EMS/g)	1,8E+05 kob/g	1,9E+06 kob/g	least 2 Log10 (%99)	ISO 16649-2

Properties of Sewage Sludge

The sewage sludge from the dewatered domestic wastewater treatment plant unit used as material in the project was sent to the TÜBİTAK MAM Environment Institute Laboratory in accordance with the protocol with Konya KOSKİ General Directorate, one of the project partners, for the analysis of the sewage sludge. The analysis results of these samples were found to comply with Türkiye Regulation on the Use of Sewage Sludge in Soil (Table 3).

Method

The stabilized treatment sludge (biosolid) coming out of the sludge dewatering unit at the Konya Domestic Wastewater Treatment Plant was laid in a thin layer on the surrounded U-shaped concrete lagoons. Samples were taken from different points of the pile and sent to TÜBİTAK MAM Environmental Research Institute for analysis. As a result of the analysis processes, the stabilized domestic sewage sludge pile, which was following the regulation, was periodically turned upside down with a mixer scoop machine, crushed with a cylinder, and dried in an open pile in the sun, continued for 2 months. With this drying method, the dry matter ratio of sewage sludge was increased from 25% DM to 80% DM. The sewage sludge material was transported from Konya Center to the project area in Karapınar, Konya.

Ready-to-use biosolid material piles were created by grinding / shredding the sewage sludge with a rotary machine and sifting through a 10 mm sieve range. On 03-07 November 2014, the dose application in each parcel was carried out on 100% dry matter (DM) according to the moisture content of the sewage sludge, as stated in the project's pasture trial pattern plan. Protective gloves, masks and boots were used during the application of sewage sludge in the field experiment on eroded pasture soil.

A trial design plan was applied in a total of 40 plots in 2 main subjects, with 4 replications and 5 doses. The doses of treatment sludge are 0 (Control), 1, 2, 4 and 8 tons/da (DM) (Arvas et al., 2007). The trial parcel dimensions were set in an area of 8m in the parcels with the surface scattering process (subject S), the biosolid was distributed homogeneously. In the parcels with the mixing process (subject D), after it was distributed homogeneously with a rake, the soil was mixed to a depth of 0-5 cm.

1) Mixing process with a rake into the 0-5 cm layer of the soil (main topic D),
2) Sprinkling on the soil surface, (Main subject S),

The experiment was carried out according to the "Random blocks divided plots trial design" with 4 replications and gravel. In the project, before the application of sewage sludge (biosolid) to the pasture, natural plant survey study was carried out in the plots in June 2014, and physical and chemical analysis and soil sampling were carried out from the raw soil in October. 2014 (control year) is the natural data of the eroded and degraded pasture.

Sewage sludge (biosolid) application was applied once in November 2014. Subsequently, the effects of the sewage sludge were observed for 3 years (in June 2015, 2016 and 2017) after its application. In the project implemented in natural pasture, pasture plant vegetation survey studies were carried out in the parcels according to the Quatrat method in June 2014-2015-2016-2017.

The following procedures were followed in making measurements regarding pasture vegetation. Determination of botanical composition; a- Based on weight, samples are taken from the vegetation, divided into species, and species are weighed separately (Avcıoğlu, 1983). b- It is done in two ways, according to the coverage area. These are expressed as %. These measurements were made before and after treatment sludge application every year in June.

Result and Discussion

Before the treatment sludge application, a natural plant vegetation study was carried out in the eroded pasture in June 2014, and after the treatment sludge application was made in November 2014, the observations and sampling of the plants continued every year for 3 years, in June 2015, 2016 and 2017. (Özyazıcı & Özyazıcı, 2012).

Botanical composition of the pasture

The botanical composition of the pasture was determined in the plots before the application of sewage sludge, and then it was followed at the same time for three years (in June of 2015, 2016 and 2017) and the changes after the application of sewage sludge were determined. Data obtained before and after treatment sludge application; It is stated in Tables 4 -11.

The plant distribution in the natural pasture that was eroded before the application of sewage sludge (biosolid) in 2014 (control year) in the project is shown in Tables 4 and 5 below. The dominant plant species are generally *Salvia absconditiflora*, *Acantho limonulicinum* var. *ulicinum*, *Astragalus onobrychis*, *Noaea mucronate* and other species. The average plant coverage area of the parcels is 42.5%; The average plant height was found to be 7 cm. The plant distribution in the pasture in the parcels in the 1st year (2015) after the application of sewage sludge in the project is shown in Tables 6

and 7 below. The dominant plant species are *Salvia absconditiflora*, *Acantho limonulicinum* var. *ulicinum*, *Astragalus onobrychis, Noaea mucronata*, *Alyssum linifolium* var. *teheranicum*, *Alopecurus arundinaceus*, *Bromus tectorum*, *Stipa ehrenbergiana*, *Panicum* sp., have also emerged. The average plant coverage area of the parcels is 73%; The average plant height was found to be 15 cm. An increase in the plant coverage area, height, and number and diversity of species was observed in the parcels. The plant distribution in the pasture in the parcels in the second year (2016) after the application of sewage sludge in the project is shown in Tables 8 and 9 below. The dominant plant species are *Salvia absconditiflora*, *Acantho limonulicinum* var. *ulicinum*, *Astragalus onobrychis*, *Noaea mucronata*, *Alyssum linifolium* var *teheranicum*, *Bromus tectorum*, *Stipa ehrenbergiana*have also emerged. Since 2016 was a dry year, decreases in the plant population with rainfall are noteworthy. The average plant coverage area of the parcels is 48%; The average plant height was found to be 7 cm. There were decreases in plant coverage area, height, and number and diversity of species in the parcels compared to 2015. On the other hand, the number of plant diversity is higher compared to Control 2014. The plant distribution in the pasture in the parcels in the 3rd year (2017) after the application of sewage sludge in the project is shown in Tables 10, 11 below. The dominant plant species are *Salvia absconditiflora*, *Acantho limonulicinum* var. *ulicinum*, *Astragalus onobrychis*, *Noaea mucronata*, *Alyssum linifolium* var. *teheranicum*, *Alopecurus arundinaceus*, *Bromus tectorum*, *Eremopyrum bonaepartis* var. *sinaicum*, *Stipa ehrenbergiana*other species of the grass family that sheep like for grazing have also emerged. The average plant coverage area of the parcels is 52%; The average plant height was found to be 18 cm. There was an increase in the plant coverage area, height and especially the number and diversity of species in the plots.

Table 4. Botanical composition of 2014 (before application of sewage sludge)

Natural botanical composition-quatrate method in the parcels before the application of sewage sludge (biosolid) in the eroded pasture in June 2014																
Application method of the parcel			Vegetated area of the parcel -%					Average plant height in the plot -cm					Plant species in the plots***			
Subject	Dose	Block	1.Block	2.Block	3.Block	4.Block	Avg.	1.Block	2.Block	3.Block	4.Block	Avg.	1.Block	2.Block	3.Block	4.Block
S.s.Before mixing into the soil 0-5 cm with a rake	D0-Control	D0	40	40	45	40	41	7	7	7	7	7	1,3,4	1,3,4	1,2,3,4	1,2,3,4,5
	D1-1 tonda^{-1}	D1	50	45	50	50	49	7	7	7	7	7	1,2,4	1,2,5,9	1,2,3,4,6	1,2,4,5,10
	D2-2 tonda^{-1}	D2	40	50	40	35	41	7	7	7	7	7	1,2,3,4,7	1,2,4,5	1,2,4	1,2,4,10
	D4-4 tonda^{-1}	D4	35	50	40	45	43	6	7	7	7	6	1,2,4,5,6	1,2,3,4,9	1,2,4	1,3,4
	D8-8 tonda^{-1}	D8	50	50	40	40	45	7	7	7	7	7	1,2,3	1,2,3,4,8	1,2,3,4	1,2,4,6
S.s.Before spreading on the soil surface	S0-Control	S0	30	40	45	50	41	7	7	7	7	7	1,2,4	1,2,3,9	1,2,3,4,5	1,2,3,4,10
	S1-1 tonda^{-1}	S1	45	35	50	40	43	7	7	7	9	7	1,2,3,4	1,2,3,4	1,3,4,5,6	1,2,3,5
	S2-2 tonda^{-1}	S2	30	35	40	50	39	7	7	7	7	7	1,3,4,5,8	1,3,4,5	1,2,3,4,9	1,2,3,4
	S4-4 tonda^{-1}	S4	30	50	55	40	44	7	7	6	7	6	1,2,5,6	1,2,4,6	1,2,3,4,5	1,3,4
	S8-8 tonda^{-1}	S8	30	40	40	50	40	7	6	7	7	7	1,2,3,4	1,2,4	1,2,3,4	1,2,3,4
Cumulative		Average vegetated area of the parcels -%					42,5	Average plant height of the parcels-cm				7				

***The plant species in the table are listed below in numbers.

1	*Salvia absconditiflora*	6	*Thymus leucostomus*, endemic
2	*Acantho limonulicinum var. ulicinum*	7	cereals (50 %*agropyroncristatum*,50 %*stipa*)
3	*Astragalus onobrychis*	8	cereals (%one hundred*cynodondactylon*)
4	*Noaea mucronata*	9	cereals (% one hundred*stipa*)
5	*Alhagi maurorum subsp. maurorum*	10	*Onopordu macanthium*

Table 5. Areal distribution of plants in 2014

Types of plants	Cumulative number	%
Salvia absconditiflora	2220,5	55,51
Acantho limonulicinum var. ulicinum	627,5	15,69
Astragalus onobrychis	320	8,00
Noaea mucronata	426	10,65
Alhagi maurorumsubsp. maurorum	152	3,80
Thymus leucostomus, endemic	144	3,60
Onopordu macanthium	15	0,38
Cereals (other)	67	1,68
%one hundred *Cynodon dactylon*	5	0,13
Stipa	15	0,38
50 % *Agropyron cristatum*,50 % *Stipa*	8	0,20
Cumulative % one hundred	4000	100

Table 6. Botanical composition of 2015

Botanical composition-quatrate method in the parcels during the 1st year observation after the application of sewage sludge (biosolid) in the eroded pasture in June 2015.

Application method of the parcel			Vegetated area of the parcel - %					Average plant height in the plot -cm					Plant species in the parcel ***			
Subject	Dose	Bl	1.Bl	2.Bl	3.Bl	4.Bl	Avg	1.Bl	2.Bl	3.Bl	4.Bl	Avg	1.Bl	2.Bl	3.Bl	4.Bl
S.s.After mixing 0-5 cm into the soil with a rake	D0-Control	D0	55	50	70	60	59	9	8	8	14	10	1,3,4,5,9,13	1,2,3,4,8	1,2,3,4,8,16	1,2,3,4,5,6,8,9
	D1-1 tonda^{-1}	D1	65	70	75	70	70	16	11	13	17	14	1,2,4,5,9,16	1,2,3,4,6,7,14	1,2,4,5,8,9,14,18	1,2,3,4,5,6,8,14
	D2-2tonda^{-1}	D2	90	80	80	75	81	13	11	18	19	15	1,2,3,5,9	1,2,4,5,8,9	1,2,3,4,5,8,9,14,15	1,2,3,4,5,8,14
	D4-4 ton da^{-1}	D4	70	80	75	85	78	18	13	20	21	18	1,2,4,5,6,9,17	1,2,3,4,7,9,12,15,20	1,2,3,4,7,9,14,16	1,2,3,4,5,6,8,9,12
	D8-8 ton da^{-1}	D8	60	75	70	70	69	18	18	20	21	19	1,2,3,5,9,15	1,2,3,4,5,6,7,9,16	1,3,4,5,9,11,14,15	1,2,3,4,5,9,14,15,17
S.s.After sprinkling on the soil surface	S0-Control	S0	55	70	60	65	63	11	9	9	9	10	1,2,4,9,13	1,2,3,4,8,9	1,2,3,6,8,12,14	1,2,3,4,7,8,9,13,17
	S1-1 ton da^{-1}	S1	70	85	70	90	79	13	9	17	19	14	1,2,3,4,5,9,14	1,2,3,4,5,7,8,9,14	1,4,6,7,8,9,17	1,2,3,4,5,6,8,9,14
	S2-2 ton da^{-1}	S2	85	85	70	80	80	13	13	13	19	14	1,3,4,5,6,10,13,14	1,3,4,5,6,8,9,19	1,2,3,4,5,8,9,14	1,2,3,4,5,14,21
	S4-4 tonda^{-1}	S4	90	80	70	75	79	13	13	18	19	16	1,2,3,4,5,7,8,9	1,2,4,5,7,9,13,14,17	1,2,3,4,5,9,14,15	1,3,4,5,8,9
	S8-8 tonda^{-1}	S8	90	70	65	70	74	17	18	20	20	19	1,2,3,4,5,9,13,15,18	1,2,4,9,13,14,15,16	1,2,3,4,9,10,14	1,3,4,5,9,14,15,21
Cumulative		Average vegetated area of the parcels -%					73	Average plant height of the parcels -cm				15				

***The plant species in the table are listed below in numbers.

1	*Salvia absconditiflora*	12	*Eremopyrum bonaepartis* var.*sinaicum*
2	*Acantho limonulicinum var. ulicinum*	13	*Stipa ehrenbergiana*
3	*Astragalus onobrychis*	14	*Panicum sp*.
4	*Noaea mucronata*	15	*Polygonum arenastrum*
5	*Alyssum linifolium*var.*teheranicum*	16	*Onopordu macanthium*
6	*Alhagi maurorum subsp. maurorum*	17	*Thymus leucostomus*, endemic
7	*Alopecurus arundinaceus*	18	*Bromus erectus*
8	*Androsace maxima*	19	*Onobrychis sativa* lam
9	*Bromus tectorum*	20	*Lepidum sp.*
10	*Cynodon dactylon*var.*villosus*	21	*Scabiosa argentea* L.
11	*Chenopodium album* L.		

It has been stated that the effects of fertilizers on the botanical composition of pastures can be explained by the fact that the nutrient needs of pasture plants are different from each other and the ability or ease of plant species to absorb nutrients from the soil, and that it gives the opportunity to change the botanical composition due to their effects on plant species (Bakır, 1985). Çetik (1985) stated that there are many plants that are resistant to drought and salinity around Karapınar, and that there are differences depending on whether the soil is barren or sandy. While these plants include the species, we detected in the pasture we worked on (*Noaeamucronata, Bromus tectorum*, *etc*.), the existence of many perennial and annual plants of the same genus but different species has also been reported. In another study conducted in Karapınar (Akköz and Bayram, 2012), 82 families and their 378 genera and 616 species were identified, and 102 of the taxa were stated to be endemic. Among the species detected: *Noaea mucronata*, *Alopecurus arundinaceus*, *Bromus tectorum*, *Cynodon dactylon*, *Chenopodium album*, *Thymus leucostomus*, *Bromus erectus*. It has been stated that plants such as *Stipa ebrenbergiana* and *Polygonum arenastrum*, which are the same in terms of genus but different in terms of species, were also detected in the pastures we researched (6 pastures) in Konya's problematic pastures (6 pastures) (salty, alkaline, stony, etc.). In the study (Yılmaz, 1977), it was stated that while species such as *Cynodon dactylon*, *Bromus erectus, Androsace maxima* were encountered in these places, there were also many other species. In this research, it was also stated that the most species in the botanical composition were from other families (except the Wheat and Legume families).

Table 7. Areal distribution of plants in 2015

Average % of areal distribution of plant species in cumulative parcel doses in 2015 Quatrat method.										
Plant Types in Different Dosing Applications	Application of mixing sewage sludge into 0-5 cm soil D dosage issues					Application of scattering sewage sludge on the soil surface S dosage issues				
	D0	D1	D2	D4	D8	S0	S1	S2	S4	S8
Salvia absconditiflora	52,5	35	32,5	22,5	30	45	36,25	32,5	27,5	33,75
*Acantho limonulicinum*var.*ulicinum*	7,5	12,5	15	6,25	6,25	18,75	6,25	2,5	10	8,75
Astragalus onobrychis	12,5	2,5	8,75	7,5	7,5	8,75	10	8,75	8,75	5,5
Noaea mucronata	15	13,75	8,75	11,25	8,75	8,75	10	12,5	13,75	8,75
Alyssum linifolium var. teheranicum	1,25	7,5	8,25	4	11,25		5	7,5	8,75	3,75
Alhagi maurorumsubsp. maurorum	1,25	4		4	1,25	2,5	2,5	6,25		
Alopecurus arundinaceus		1,25		3,75	1,25		1,75		2,5	
Androsace maxima	4	6,25	8,25	1,25		3,75	8,75	6,25	6,25	
Bromus tectorum	2,5	6,25	10,75	14	17,5	4,5	7,5	3,75	8,75	19,5
Cynodon dactylon var.*villosus*								1,25		2,5
Eremopyrum bonaepartis var. *sinaicum*				4		1,25				
Stipa ehrenbergiana	1,25					2,5		2,5	2,5	3,75
Panicum sp.		5,75	4,5	3,75	7,5	1,25	3,25	6,25	2,5	3,75
Polygonum arenastrum				0,75	5				1,25	5
Onopordu macanthium	1,25	1,25		0,75	1,25					1,25
Thymus leucostomus, endemic				7,5	1,25	2,5	8,75		3,75	
Bromus erectus		1,25								1,25
Scabiosa argentea L.								3,75		2,5
Chenopodium album L.					1,25					
Other	1	2,75	3,25	8,75		0,5		6,25	3,75	
Cumulative-% one hundred	100	100	100	100	100	100	100	100	100	100

Table 8. Botanical composition of 2016

Botanical composition-quatrate method in the parcels during the 2nd year observation after the application of sewage sludge (biosolid) in the eroded pasture in June 2016.

Application method of the parcel		Vegetated area of the parcel-%						Average plant height in the plot-cm					Plant species in the parcel***			
Subj.	Dose	Bl	1.Bl	2.Bl	3.Bl	4.Bl	Avg	1.Bl	2.Bl	3.Bl	4.Bl	Avg	1.Bl	2.Bl	3.Bl	4.Bl
S.s.After mixing 0-5 cm into the soil with a rake	D0-Control	D0	40	40	40	40	40	5	6	7	6	6	1,3,4,9	1,3,4,5,9	1,2,3,4,22	1,2,3,4,5,6,9,13
	D1-1 tonda^{-1}	D1	40	40	60	60	50	5	6	6	7	6	1,2,4,5,9	1,2,4,5,6,9,13	1,2,3,4,9,17	1,2,4,9,22
	D2-2 tonda^{-1}	D2	50	50	50	55	51	9	9	9	9	9	1,2,3,4,9,13	1,2,4,5,6,9,12,13	1,2,3,4,5,9	1,2,4,5,6,9,10,22
	D4-4 tonda^{-1}	D4	50	60	60	55	56	9	9	9	9	9	1,4,5,6,7,9,12, 17	1,2,3,4,5,9,13	1,2,3,4,5,9	1,3,4,5,6,9
	D8-8 tonda^{-1}	D8	40	50	50	55	49	8	9	8	9	8	1,2,3,9,13	1,2,3,5,6,9,10,13	1,2,3,4,5,9	1,2,3,4,5,9
S.s.After sprinkling on the soil surface	S0-Control	S0	40	40	40	50	43	6	6	7	6	6	1,2,4,5,9	1,2,3,5,9,16,22	1,2,3,4,5,6,9	1,2,3,4,9,13,17
	S1-1tonda^{-1}	S1	50	40	50	40	45	6	6	7	7	6	1,2,3,4,5,9,13	1,2,3,4,9	1,4,5,6,10,17	1,2,3,4,6,9
	S2-2 tonda^{-1}	S2	50	50	40	50	48	9	6	9	9	8	1,2,3,4,5,9	1,3,4,5,6,9	1,2,4,5,9,13	1,2,3,4,9,17,23
	S4-4 tonda^{-1}	S4	40	60	50	60	53	6	6	6	9	7	1,2,4,5,6,9	1,2,4,9,17	1,2,3,4,9	1,3,4,9
	S8-8 tonda^{-1}	S8	30	40	60	60	48	7	7	9	9	8	1,2,3,4,9	1,2,4,9	1,2,3,4,5,9,10	1,2,3,4,9
Cumulative		Average vegetated area of the parcels-%					48	Average plant height of the parcels-cm				7				

***The plant species in the table are listed below in numbers.

1	*Salvia absconditiflora*	12	*Eremopyrum bonaepartis* var.*sinaicum*
2	*Acantho limonulicinum*var. *ulicinum*	13	*Stipa ehrenbergiana*
3	*Astragalus onobrychis*	14	*Panicum sp*.
4	*Noaea mucronata*	15	*Polygonum arenastrum*
5	*Alyssum linifolium*var.*teheranicum*	16	*Onopordumacanthium*
6	*Alhagi maurorum subsp. maurorum*	17	*Thymus leucostomus*, endemic
7	*Alopecurus arundinaceus*	18	*Bromus erectus*
8	*Androsace maxima*	19	*Onobrychis sativa lam*
9	*Bromus tectorum*	20	*Lepidum sp.*
10	*Cynodon dactylon*var.*villosus*	21	*Scabiosa argentea* L.
11	*Chenopodium album* L.	22	*Xeranthemum annuum*
		23	*Phlomis armeniaca*

In another study covering different parts of Konya (pastures of Sağlık, Yapalı, Alibeyhüyüğü, İnli, Karadona villages), the Lup-Transect method was applied, and in the findings, the areas covered with vegetation were found to be between 13.75-38.56%, and 67.72% of this vegetation was covered by other plants. It has been reported that 28.21% consists of plants from the family of wheat and 4.17% consists of plants from the legume family (Özmen, 1983). While some of the species detected

in the study conducted in Polatlı Acıkır natural pastures on the border of Konya, which are the continuation of steppe pastures (such as *Tyhmus leucostomus* var. *gypsaceus*, *Alyssum linifolium*, *Bromus tectorum*, *Noaea mucronata*), were the same as the species we found, some of them were found to have the same genus and different species. (Akman et al., 1990). In another study conducted in the pasture in Haymana-Yuvacık village, with fertilization at the end of 6 years of use, the rate of wild thyme (*Thymus squarrosus Fisch*.) in the vegetation decreased to less than 1% at the end of six years, while the rate of grasses increased from 20.5% to 73%. Here, the effect of fertilization was seen in terms of the ratios in the botanical composition (Tan, 1989). Since these results are under the same step conditions, they support the results determined in our research.

Table 9. Areal distribution of plants in 2016

Average % of areal distribution of plant species in cumulative parcel doses in the Quatrat method in 2016.										
Plant Types in Different Dosing Applications	Application of mixing sewage sludge into 0-5 cm soil D dosage issues					Application of scattering sewage sludge on the soil surface S dosage issues				
	D0	D1	D2	D4	D8	S0	S1	S2	S4	S8
Salvia absconditiflora	55	53,25	35	28,75	18,25	45	47	33,75	22,5	20
*Acantho limonulicinum*var.*ulicinum*	10	15	12,5	3,75	13	18,75	8,75	6,25	9,25	8,75
Astragalus onobrychis	10,75	1,75	5,5	3,75	7,5	8,75	8	10	5,5	3,75
Noaea mucronata	15	13,75	12	12,5	3,75	11,75	10,75	17,5	10,75	13,75
Alyssum linifolium var. teheranicum	1,25	1,75	8	12,5	7,5	2,75	2,5	8,75	2,5	1,25
Alhagi maurorumsubsp. Maurorum	1,25	1,25	3,75	2,5	1,25	2,5	3	2,5	2,5	
Alopecurus arundinaceus				1,25						
Androsace maxima										
Bromus tectorum	3,75	6,25	13	23,75	39,25	4,75	8,75	16,25	43,25	50
Cynodon dactylon var. *Villosus*			3,25		0,75		1,25			2,5
Chenopodium album L.										
Eremopyrum bonaepartis var.*sinaicum*			1,25	5						
Stipa ehrenbergiana	2,5	2,5	5	2,5	8,75	1,25	2,5	1,25		
Panicum sp.										
Polygonum arenastrum										
Onopordu macanthium						0,75				
Thymus leucostomus, endemic		3,75		3,75		2,5	7,5	1,25	3,75	
Bromus erectus,										
Onobrychis sativa lam										
Lepidum sp.										
Scabiosa argentea L.										
Xeranthemum annuum		0,75	0,75			1,25				
Phlomis armeniaca								2,5		
other	0,5									
Cumulative-% one hundred	100	100	100	100	100	100	100	100	100	100

Table 10. Botanical composition of 2017

Botanical composition-quatrate method in the parcels during the 3rd year observation after the application of sewage sludge (biosolid) in the eroded pasture in June 2017															
Application method of the parcel			Vegetated area of the parcel -%					Average plant height in the parcel - cm					Plant species in the parcel ***			
Subj.	Dose	Bl	1.Bl	2.Bl	3.Bl	4.Bl	Avg	1.Bl	2.Bl	3.Bl	4.Bl	Avg	1.Bl	2.Bl	3.Bl	4.Bl
S.s.After mixing 0-5 cm into the soil with a rake	D0-Control	D0	50	45	50	45	48	15	15	15	15	15	1,2,3,4,17	1,2,3,4,5,9,13	1,3,4,12,18	1,2,3,4,6,9,12,13
	D1-1 tonda^{-1}	D1	50	50	45	50	49	15	17	17	20	17	1,2,3,4,5,20	1,2,3,4,5,6,12, 13	1,2,3,4,5,9,12,13,17	1,2,4,5,6,8,9,13
	D2-2 tonda^{-1}	D2	50	45	60	50	51	17	17	20	18	18	1,2,3,4,5,7,9,10, 12	1,2,4,5,6,12,20	1,2,3,4,5,9,12,14,15,2 0	1,2,4,5,6,9
	D4-4 tonda^{-1}	D4	60	55	55	60	58	20	20	20	20	20	1,2,4,5,9,12,13, 17,20	1,2,3,4,5,7,9,1 2	1,2,3,4,5,7,11,12,15	1,3,4,5,9,12,20
	D8-8 tonda^{-1}	D8	60	55	60	60	59	20	20	22	22	21	1,2,4,5,9,12,13, 20	1,2,3,4,5,6,9,1 2,13	1,3,4,5,9,11,12,16	1,2,3,4,5,9,12,13,14
S.s.After sprinkling on the soil surface	S0-Control	S0	45	45	45	40	44	13	15	15	15	15	1,2,4,21	1,2,3,4,12,13,1 8,20	1,2,3,4,6,14,18,19	1,2,3,4,17
	S1-1 tonda^{-1}	S1	50	50	45	45	48	17	17	15	20	17	1,2,3,4,5,9,12,1 3,20	1,2,3,4,5,14,22	1,2,3,4,5,6,9,12,17	1,2,3,4,5,6,9,12
	S2-2 tonda^{-1}	S2	50	55	45	50	50	17	18	17	18	18	1,3,4,5,6,10,11, 13	1,2,3,4,5,6,9,1 2	1,2,3,4,5,20	1,2,3,4,5,7,9,11,12,20
	S4-4 tonda^{-1}	S4	55	60	55	55	56	20	22	20	20	21	1,2,4,5,12,13,17 ,20	1,2,4,5,7,9,11, 12,14,17	1,2,3,4,5,6,12,16	1,3,4,5,9,12,15
	S8-8 tonda^{-1}	S8	60	70	55	60	61	20	24	20	26	23	1,2,3,4,6,9,11,1 2,13,16,18,20	1,2,3,4,5,7,9,1 1,20	1,2,3,4,5,9,12,13,15	1,2,3,4,5,9,11,13,14,20
Cumulative			Average vegetated area of the parcels -%				52	Average plant height of the parcels - cm				18				
***The plant species in the table are listed below in numbers.																
1	*Salvia absconditiflora*							12	*Eremopyrum bonaepartis var. sinaicum*							

2	*Acantho limonulicinum* var. *ulicinum*	13	*Stipa ehrenbergiana*
3	*Astragalus onobrychis*	14	*Nigella arvensis* var. *glauca*
4	*Noaeamucronata*	15	*Papaver hybridum*
5	*Alyssum linifolium* var.*teheranicum*	16	*Onopor dumacanthium*
6	*Alhagi maurorum subsp. Maurorum*	17	*Thymus leucostomus*, endemic
7	*Alopecurus arundinaceus*	18	*Bromus erectus*
8	*Agropyron elongatum*	19	*Centaurea carduiformis subsp*. var.
9	*Bromus tectorum*	20	*Scabiosa argentea* L.
10	*Cynodon dactylon* var. *Villosus*	21	*Xeranthemum annuum*
11	*Descurainia sophia subsp. sophia*	22	*Phlomis armeniaca*

Table 11. Areal distribution of plants in 2017

Average % of areal distribution of plant species in cumulative parcel doses in the Quatrat method in 2017.

Plant Types in Different Dosing Applications	Application of mixing sewage sludge into 0-5 cm soil D dosage issues					Application of scattering sewage sludge on the soil surface S dosage issues				
	D0	D1	D2	D4	D8	S0	S1	S2	S4	S8
Salvia absconditiflora	49,25	29,25	21,25	13,75	6,25	43	27,5	32,5	17,5	9,38
*Acantho limonulicinum*var. *ulicinum*	6,25	12,5	7,5	10	5	11,25	12,5	8,75	6,25	8,75
Astragalus onobrychis	12	6,25	3,75	10	5	7,5	10	10	5,5	6,25
Noaea mucronata	16,25	22	21,75	14,5	16,25	16,25	15	13,75	18,75	14,38
Alyssum linifolium var. *teheranicum*	1,75	5,5	16,25	18,75	16,25		7,25	12,5	13,75	9,5
Alhagi maurorumsubsp. Maurorum	2,5	4,25	3,75		1,25	1,25	5	3,75	2,5	1,25
Alopecurus arundinaceus			0,75	1				0,75	2,5	0,75
Agropyron elongatum		3								
Bromus tectorum	1,75	2	9,25	6,25	21,25		6,25	6,25	11,25	16,13
Cynodon dactylon var.*Villosus*			2,5					1,25		
Descurainia sophia subsp. sophia				1,25	8,25			3,75	1,25	6,88
Eremopyrum bonaepartis var. *sinaicum*	1,5	1,25	6,25	11,25	8,75	1,25	2,75	2,5	7	6,38
Stipa ehrenbergiana	5	9		5	7,5	3,75	2,5	1,25	2,5	8,75
Nigella arvensis var. *glauca*			1,25		1,25	1,75	2,5		1,25	1,75
Papaver hybridum			0,75	0,75					1,25	0,5
Onopordu macanthium					0,5				1,25	1,25
Thymus leucostomus, endemic	1,25	3,75		1,25		7,5	5		5	
Bromus erectus	2,5			1,25		2				1,25
Centaurea carduiformis subsp. var.						1,25				
Scabiosa argentea L.		1,25	5	5	2,5	2,5	1,25	3	2,5	6,88
Xeranthemum annuum						0,75				
Phlomis armeniaca							2,5			
Cumulative-% one hundred	100	100	100	100	100	100	100	100	100	100,00

Conclusion

Unlike soil texture, soil structure can be changed by appropriate agricultural regulations. Stable forms of soil organic carbon, such as humus, within the soil aggregate can retain up to seven times its own weight in water. Efficient management of water and nutrients is achieved by adding organic matter to sandy soils (Corsi, 2018). Benefits of organic matter to the soil and plants in the pasture; It helps retain moisture, provides a good environment for young plants, space and food for microorganisms, and helps loosen and enrich the soil. Organic fertilizer also plays an important role in the establishment of new pastures in poor, erosion-prone areas (Thompson, 1950). Degradation of pastures is a faster process in arid and semi-arid regions. Here, it is not possible to rehabilitate the vegetation without first stabilizing the soil, that is, keeping the soil in place and correcting the deteriorated physical and chemical properties of the soil (Bakır, 1987).

Considering the evaluations in the final report of this project, in regions with a rainfall regime where rainfall is at least 250-300 mm, in marginal, eroded, weak pasture lands, human health can be used in our country, if it complies with all the criteria of the "Regulation on the Use of Sewage Sludge in Soil". Provided that the necessary precautions are taken, it turns out that the D application has a feasible result of 1 ton/da (DM) in the method of mixing into the soil to a depth of 0-5 cm, once every 3 years. This recommended dose is valid for the ecological conditions in this region where the research was conducted, and similar studies are needed to recommend it in different ecological regions of Turkey (Mücevher *et al.,* 2020). As stated by different researchers and the results of this research show, Sustainable Pasture in Our Country In management (SPM), it is expected to improve the eroded, degraded and weak pasture areas with the optimum dose of stabilized, suitable domestic treatment sludge specified in this study, in accordance with the criteria specified in the regulation on the use of sewage sludge in soil, and the data obtained will contribute to the relevant institutions and organizations at the point of implementation is considered.

***Acknowledgments**: Author O. Mücevher thanks for supporting "Evaluation of the use possibilities of sewage sludge in eroded pasture areas", numbered TAGEM/TSKAD/14/A13/P05/04, supported by TAGEM (Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies). to Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies, Turkey" study was compiled from the scope of the project.*

***Funding:** Republic of Türkiye Ministry of Agriculture and Forestry, funding was received by the authors.*

***Conflict of Interest:** The authors declare that they do not have any conflict of interest.*

***Change of Authorship:** The author has read, understood, and complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors and is aware that with minor exceptions, no changes can be made to authorship once the paper is submitted.*

References

Akköz C, Bayram AF, (2012) Meke Gölü tabii varlıklarının korunumunun planlanması (TR52-11-TD01168). T.C. Mevlana Kalkınma Ajansı yayını. Konya. https://www.mevka.org.tr/assets/upload/dosyalar/DsybicgnY1028201994730AM.pdf

Akman Y, Ketenoğlu O, Kurt L, Vural M, (2014) İç Anadolu Step Vejetasyonu. Palme Yayıcılık. Ankara https://www.surelikitap.com/tr/kitap/ic-anadolu-step-vejetasyonu-9786053552475

Akman Y, Ekim T, Büyükburç U, Ketenoğlu O, Karagüllü N, (1990) Polatlı Acıkır alanındaki doğal meraların bitki sosyolojisi yönünden araştırılması. Tarla Bitkileri Merkez Araştırma Enstitüsü, Yayın no: 3. Ankarahttps://dspace.ankara.edu.tr/xmlui/bitstream/handle/20.500.12575/4875/Ankara%20%C3%9Cniversitesi%27nde%20%C3%87evre%20Konusunda%20Kim%20Kimdir.pdf?sequence=1&isAllowed=y

Akyürek İ, (1986) Türkiye'de aşınım sorunları ve çözüm seçenekleri. TMMOB Ziraat Mühendisleri Odası Yayını, Çağlar Matbaası. Ankara. https://kutuphane.tarimorman.gov.tr/vufind/Record/15427/Description

Altın M, Gökkuş A, Koç A, (2005) Çayır Mera Islahı. T.C. Tarım ve Köyişleri Bakanlığı Yayını. Ankara

Arvas Ö, Keskin B, Yılmaz İH, (2007) Effect of sewage sludge on metal content of grassland soil and herbage in semi-arid lans, TÜBİTAK projesi. https://journals.tubitak.gov.tr/cgi/viewcontent.cgi?article=1652&context=agriculture

Avcıoğlu R, (1983) Çayır-Mera Bitki Topluluklarının Özellikleri ve İncelenmesi. Ege Üniversitesi Ziraat Fakültesi Yayınları No: 466, İzmir https://www.nadirkitap.com/cayir-mera-bitki-topluluklarinin-ozellikleri-ve-incelenmesi-riza-avcioglu-kitap10558404.html

Bakır Ö, (1985) ÇayırMeraIslahıPrensipveUygulamaları. Ankara Ünv. Ziraat Fak. Yayınno: 947. Ankara. http://bilgipaketi.uludag.edu.tr/Ders/Index/816303

Bakır Ö, (1987) Çayır Mera Amenajmanı. Ankara Ünv. Ziraat Fak. Yayınno: 992. Ankara. https://kutuphane.tarimorman.gov.tr/vufind/Record/11297

Bot A, Benıtes J, (2005) The importance of soil organic matter. Key to drought-resistant soil and sustained food and production. In: FAO Soils Bulletin (FAO), no. 80 / FAO, Rome (Italy). Land and Water Development Div. 78 p. https://www.scirp.org/reference/ReferencesPapers?ReferenceID=2134978

Corsi S, (2018) Koruyucu Tarım Klavuzu. FAO Türkiye pub. Ankara. https://www.fao.org/3/i7154tr/I7154TR.pdf

Çepel N, (2008) Ekolojik Sorunlar ve Çözümleri. TÜBİTAK Popüler Bilim Kitapları yayın no: 180. https://www.nadirkitap.com/ekolojik-sorunlar-ve-cozumleri-necmettin-cepel-kitap11608701.html

Çetik, AR. 1985. Türkiye Vejetasyonu: 1, İçAnadolu'nunVejetasyonu ve Ekolojisi. Selçuk Ünv. Fen Edebiyat Fak. Yayın no:1. Konya http://web.harran.edu.tr/assets/uploads/sites/67/files/vejetasyon-31072018.pdf

Eyce B, (1995) Bitki Ekolojisi.Selçuk Ünv. Fen-Edebiyat Fak. Biyoloji Bölümü Yayını. Konya.

Ignatieff V, Page HJ, (1965) Gübrelerin Tesirli Bir Şekilde Kullanılmaları (Çev. N. Özbek). Ankara Ünv. Ziraat Fak. Yayın no: 238. Ankara. http://www.agri.ankara.edu.tr/

Johnson I, Alexander S, Dudley N, (2017) Global Land Outlook(First Edition). UNCCD. Bonn, Germany. https://portals.iucn.org/library/node/47008

MGM, 2018. T.C. Orman ve Su İşleri Bakanlığı, Meteroloji Genel Müdürlüğü iklim verileri, Ankara. https://www.mgm.gov.tr/FILES/iklim/yayinlar/2017/Klimatolojik-Makaleler-2017.pdf

Mücevher O, Bitgi S, Ulutaş S, Acar R, Akay A, Dursun Ş, Koyuncu S, Öztekin M, (2020) .Erozyona uğramış mera alanlarında arıtma çamurlarının kullanım olanaklarının değerlendirilmesi, TAGEM/TSKAD/14/A13/P05/04 no'lu proje sonuç raporu, Ekim, 2020, Konya. https://www.tarimorman.gov.tr/TAGEM/Belgeler/pdgt/tskad/tutanak.pdf

Özmen AT, (1983) Konya İli Meralarının Bitki Örtüsü Üzerinde Araştırmalar. Çayır Mera Yem Bitkileri Zootekni Araştırmaları. T.C. Tarım ve Orman Bakanlığı yayın no:78. https://kutuphane.tarimorman.gov.tr/vufind/Record/7381

Özyazıcı MA, Özyazıcı G, (2012) Arıtma Çamurlarının Toprağın Bazı Temel Verimlilik Parametreleri Üzerine Etkileri, Anadolu Tarım Bilim Dergisi, 2012, 27 (2): 101-109. https://dergipark.org.tr/tr/pub/omuanajas/issue/20212/214163

Sutie JM., Reynolds, SG., Batello C, (2005) Grassland of The World. FAO Plant Production and Protection Series no: 34. Rome. https://www.fao.org/4/i1880e/i1880e.pdf

Şimşekli N, (2012) Karapınar rüzgâr erozyonunu önleme alanının sürdürülebilir arazi/toprak yönetimi planının geleneksel yapının perspektifinde geliştirilmesi, ÇukurovaÜniversitesi, Fen Bilimleri Enstitüsü Arkeometri Anabilim Dalı, Yüksek Lisans Tezi. Adana. https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=D53Qa_TSzV1p_U0n8wud6A&no=OGjSLEZs3hwin8q2yVwQww

Tan A, (1989) Meraların Gübrelenmesi. Hayvancılık Çayır MeraYemBitkileri, EğiticiYayınlar no:1. Tarla Bitkileri Merkez Araştırma Enstitüsü. Ankara. https://arastirma.tarimorman.gov.tr/tarlabitkileri/Belgeler/cesit_katalogu.pdf

Thompson WR, (1950) The Pasture Book. Printer in Decatur, G.A. Alabama Engraving Company

Yılmaz T, (1977) Konya İli Sorunlu Alanlarında Oluşan Meraların Bitki Örtüsü Üzerine Araştırmalar. Köyişleri ve Kooperatifler Bakanlığı Toprak Su Genel Müdürlüğü yayın no: 46. https://kutuphane.tarimorman.gov.tr/vufind/Record/5789