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Rhodes Grass *(Chloris gayana)* biomass productivity and its effect on soil health under rain-fed conditions in Pothohar region, Punjab, Pakistan

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SUMMARY

Shortage of quality fodder and soil erosion are the main issues that deteriorate both soil quality and land productivity in the arid area of Potowar. The inclusion of grasses with high productivity can mitigate fodder shortage and restore soil productivity. The present study was conducted to assess the effect of Rhode grass (*Chloris Gayana*) grass on fodder productivity and soil health in the area. The current study was conducted on sloppy terraced lands prone to gully development at the Nawa Garah site, Tehsil Fateh Jang. An area of 110 x 20 sq. ft. was selected and was divided into three equal compartments. Each plot was constructed twenty feet apart from each other. On the contour lines the sapling of *Leucaena leucocephala* (Ipil-Ipil) was planted with one-foot space. In between the two contour lines called an alley, the grass tuft of *Chloris gayana* was planted. After one year of plantation biomass, the productivity of the grass in three consecutive seasons were recorded and at the end of the season, soil characteristics were also determined in the Soil Physics lab, LRRI, NARC. Rhode grass produced 3.4 t ha^{-1} biomass as compared to control (grazed land with local grass species) with 480 kg ha^{-1} and the same trend was observed in the case of carbon pool. Similarly, the animal unit of grass was also observed significantly higher in the summer season than in the other two seasons. Rhode grass significantly decreased soil pH and bulk density. Soil nitrate and phosphorus content were also significantly increased by Rhode grass cultivation. The research study aimed to provide quality fodder on a sustainable basis to ruminants at their doorsteps to resilient farmers. It also restored the soil health and crop productivity of the eroded lands. Furthermore, this data will also help develop policies, strategies and programs for the conservation of eroded lands.

Keywords: Rhode grass, Biomass productivity, carbon stock, soil health.

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INTRODUCTION

Pakistan has a total land area of around 88 million hectares, approximately 60% of which is comprised of rangelands (Ashraf and Akbar, 1989). This resource sustains millions of cattle, which are critical for poor rural people's livelihood, food security, and nutrition. Pothohar is a rain-fed plateau near the top of the Indus Basin with truncated and varied terrain. The Pothohar area runs from the salt range to the foothills of the Himalayas and is located between the Indus and Jhelum rivers. Thus, the Pothohar area encompasses the majority of Attock, Jhelum, Rawalpindi, and Chakwal (Chaudhry et al., 2004).

In addition to local livestock, the region provides grazing options for a huge number of sheep and goats throughout the year, as well as transhumant animals in the northern highlands periodically in winter. This demonstrates the high potential of range regions for providing vegetation to small ruminants (Ahmad et al., 2016). Wheat, maize, barley, bajra, gramme, and ground nut are among the crops farmed in Pothwar. From July to October, around 80% of the rain falls, which mostly benefits crop productivity. The primary reasons of poor productivity include very unpredictable, unevenly distributed rainfall, erosion, water runoff, and widespread plant nutritional deficit. Nutrient loss due to erosion is one of the most significant causes of soil productivity reduction (Moyo, 2003).

Soil erosion is one of the most important kinds of land degradation, with serious consequences for soil fertility, water ecology, crop production, and landscape attractiveness (Saleemullah, 2018). The Pothohar region is prone to soil erosion, with an average yearly soil loss of 19 tonnes ha1 year1, with the greatest erosion (70-208 tonnes ha1 year1) occurring in river channels and steep regions (Ruppenthal et al., 1997). The soils of Pothowar suffer from several nutrient shortages due to the loss of small soil particles (along with nutrients) and centuries of agricultural production without proper fertilisation (Rashid et al., 1997). Mismanagement of water resources, erosion, fertiliser deficits, and overgrazing all harmed the region's rangeland capabilities.

Restoring good vegetation to degraded soil helps to maintain its structure because the roots become strongly anchored, cover the soil to protect from kinetic energy from rainfall, reduce runoff speed and losses, conserve moisture, and generate an organic matter cycle that improves soil fertility and structure (Lal, 2015). Tree planting and other erosion control methods, such as strip cropping, can also help to reduce soil erosion in this area (Saleemullah, 2018). Correcting nutritional imbalances increased grain output while decreasing the influence of yield loss owing to erosion (Izaurralde et al., 2006). Some intrinsic and endogenous variables (Carpenter et al., 2001; Tobias et al., 2001) influence soil fertility restoration. Soil management is a significant external component; for example, nitrogen deficiencies may be remedied by the use of fertilisers. In such soils, a balanced fertilisation programme combined with suitable moisture conservation methods can be implemented.

Surface runoff may be reduced, soil quality improved, and plant water availability and absorption capacity increased by integrating physical and biological soil and water conservation strategies (Erkossa, 2019). It is also critical to select a grass that is easy to establish, can flourish in degraded environments, grows quickly, and can endure cutting and grazing. Rhodes grass (*Chloris Gayana*) is a naturalised plant native to Africa that is commonly grown across the tropical and subtropical world (Ahmad et al., 2016). It has the potential to spread quickly to cover the ground, is resistant to drought and light cold, and may be grown in conjunction with many other plants (Erkossa, 2019).

Rhodes grass is a perennial grass that is high-yielding, fast-growing, tasty, and deeply rooted. The grass may grow up to 1.5 metres tall. Rhodes grass may thrive in a variety of environments. Farmers favoured the grass for a variety of reasons, including its high production, palatability to animals, and drought tolerance. Rhodes grass is a summer-active perennial that becomes dormant in the winter when soil moisture levels are at their highest (Lawes and Robertson, 2008). As a result, Rhode grass was chosen for this study due to its capacity to spread quickly and cover the ground, resilience to drought and light cold, and appropriateness for growing in conjunction with a variety of other plants (Erkossa, 2019). The current study's goal was to analyse the plant nutritional status of water-eroded farmlands in Gujar Khan Target regions, as well as to evaluate their potential for agricultural and animal management. The findings of this study will be beneficial to farmers and agricultural planners.

MATERIAL AND METHODS

EXPERIMENTAL AREA

The research was carried out in the Nawa Gerah location in the tehsil Fateh Jang, which is located at 33.55° N, 72.58° E, and 402 m above sea level on sloppy terraced soils prone to gully development. The research site has a semi-arid environment with annual rainfall ranging from 700 to 1000 mm. Rainfall is mostly concentrated in the summer, with just around 30% of the average annual rainfall falling during the wheat growing season (October-April). The average maximum temperature in May-June can reach 40°C, while the average lowest temperature ranges from 2.2 to 4.7°C in December and January.

EXPERIMENTAL DESIGN

This experiment was conducted in a Completely Randomized Block Design under field conditions without irrigation and fertilizer.

An area of 110 x 20 ft. was selected at both sites and was divided into three equal compartments. Each plot was constructed twenty feet apart from each other. On the contour lines, the saplings of Ipil-ipil (*Leucaena leucocephala*) were planted with one-foot space. In between the two contour lines called alley, the grass tuft of Rhode grass 30 x 40 cm was planted on triangular shape to utilize the maximum water and to stop the soil erosion and alley to alley distance was retained twenty feet. Ipil-ipil with Rhode grass with a tuft (root shoot cutting) was planted in rain-fed condition.

A transect line was drawn on the contour line and after a five-foot interval, five quadrates were taken for biomass production and firewood of ipil ipil. Each quadrate was five meters apart. Similarly, in each alley three samples of Rhode grass each consist of three quadrates one, two and three meters apart from ipil-ipil plants for bio-mass production of grass with quadrate methodology in three growing seasons i.e. winter, summer and spring. The carbon stock of the grass was also recorded at a maximum height up to root collars. Similarly, other parameters of soil i.e. pH, EC, N, P, K, organic and inorganic carbon and soil texture were also estimated.

The traditional Walkely and Black technique (Black, 1965) was used to estimate soil organic carbon, whereas the Colorimetric approach (Black, 1965) was used to assess soil inorganic carbon. Total carbon in plant samples was evaluated by furnace ignition and total nitrogen by the Kjeldahl technique (Black, 1965). The Hydrometer technique was used to determine the soil texture of the obtained samples (Bouyoucos, 1962). The pH of soil extract was assessed using a pH metre, and the electrical conductivity was measured using a conductivity metre after calibrating the instrument at the solution's temperature (Mc Lean, 1980). Soil P and K were extracted with the help of ammonium acetate solution. In ammonium acetate extract, P was determined with the help of a spectrophotometer while K was determined with the help of Flame Photometer (Ryan et al., 2001).

For the phyto-mass carbon pool, both above and below-ground biomass of grass species at both sites was sampled within the $1m^2$ quadrate. For above-ground biomass grass was harvested at ground level then for below-ground biomass, roots were collected by digging the soil at appropriate depth (cm) of 0-20, 20-40 and 40-60 cm within the $1m^2$ quadrate.

Fresh biomass production data was recorded immediately after harvesting and the same samples were oven-dried at 60^{o}C till constant weight. Roots were sieved to separate roots from soil, stone, and other debris materials. Root biomass was immediately recorded and then oven-dried at 60 C^0 till constant weight for dry below-ground biomass determination. A coefficient of 0.50 or 0.47 was used for the conversion of biomass to carbon stock (Brown and Lugo, 1982; Mohammad, 2018).

STATISTICAL ANALYSIS

The collected data was subjected to variance analysis using a Randomized Complete Block Design. The means of the data were compared by LSD test using statistical software, Minitab 20.

RESULTS

Before the start of experiment, the existing potential of experimental site for forage production and animal carrying capacity was assessed. Plant biomass at four various topographies i.e. flat areas, sloping areas, nullahs/beds/channels and exposed sandstones was harvested in three growing seasons. Data in table 1 showed that the highest forage production was observed during summer season followed by spring and winter in all four areas. During summer season, highest production of forage was found in nullah beds (530.3 kg/ha) followed by flat areas (480.4 kg/ha). Whereas in other two seasons (spring and winter), highest forage production was found in Flat areas followed by sloppy lands and the lowest was found on exposed sandstone areas. Total seasonal productivity of flat areas was highest as compared to other areas.

Table 1: Forage production and Carrying Capacity of different grazed rangeland at varying topography of Nawa Gerah, Tehsil Fateh jang.

Seasons	Flat Areas		Sloping Areas		Nullah Beds/Channels		Exposed Sandstone		Av (kg/ha)	CC (AU/ha/)
Seasons	Forage (Kg/ha)	C C (AU/ ha)	Forage (kg/ ha)	C C (AU/ ha)	Forage (kg/ha)	C C (AU/ha)	Forage (kg/ha)	C C (AU/ha)		
Winter 2020	42.50[c]	0.08[c]	35.10[c]	0.64[b]	35.0[c]	0.06[c]	35.2[c]	0.06[c]	147.80[c]	0.84[c]
Spring 2021	200.10[b]	0.36[b]	140.6[b]	0.26[c]	120.4[b]	0.22[b]	55.0[b]	0.10[b]	516.10[b]	0.94[b]
Summer 2021	480.40[a]	0.88[a]	470.1[a]	0.87[a]	530.3[a]	0.97[a]	64.3[a]	0.11[a]	545.1[a]	2.83[a]

During the second year of experiment, the data on dry biomass, phyto mass carbon and animal unit of Rhode grass during three different seasons. A significantly higher biomass productivity in summer was achieved than the other two seasons i.e. spring and winter. Biomass productivity was increased from 2.47 t/ha in winter to 3.90 t/ha in summer season. Similarly, the carbon stocks data also indicated that carbon storage in grass also increased with time. During the winter season a carbon stock of 1.23 t/ha was observed which increased to 1.95 t/ha in the summer season. The animal unit of the grass also revealed the same significant trend as those observed for biomass productivity and carbon storage in soil (Figure 1).

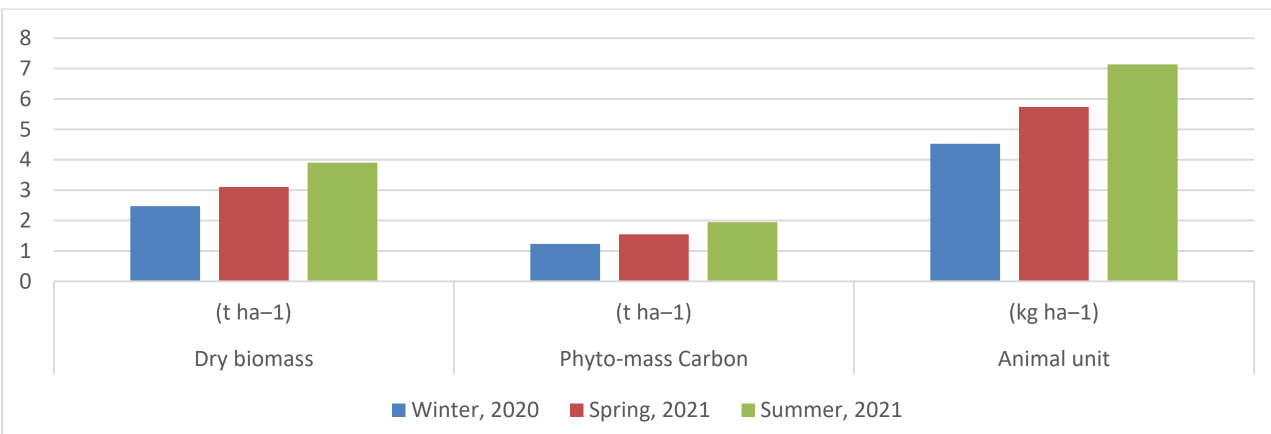

Figure 1: Rhode grass (*Chloris gayana*) biomass productivity, Phyto mass carbon and animal unit during three seasons at Nawa Gerah, Fateh jang.

Both soil organic carbon (SOC) and soil inorganic carbon (SIC) pools increased with time at all three soil depths (Table 3). SOC pool was 4.31 kg/ha in winter 2020 which was increased to 4.50 kg/ha in the summer season at the 0–20 cm. SIC pool was also increased with time from 16.08 to 17.23 kg/ha at the surface soil depth. Similar trends were observed in both SOC and SIC pools at the other two lower soil depths. Both SOC and SIC pools decreased with an increase in soil depth (Figure 2).

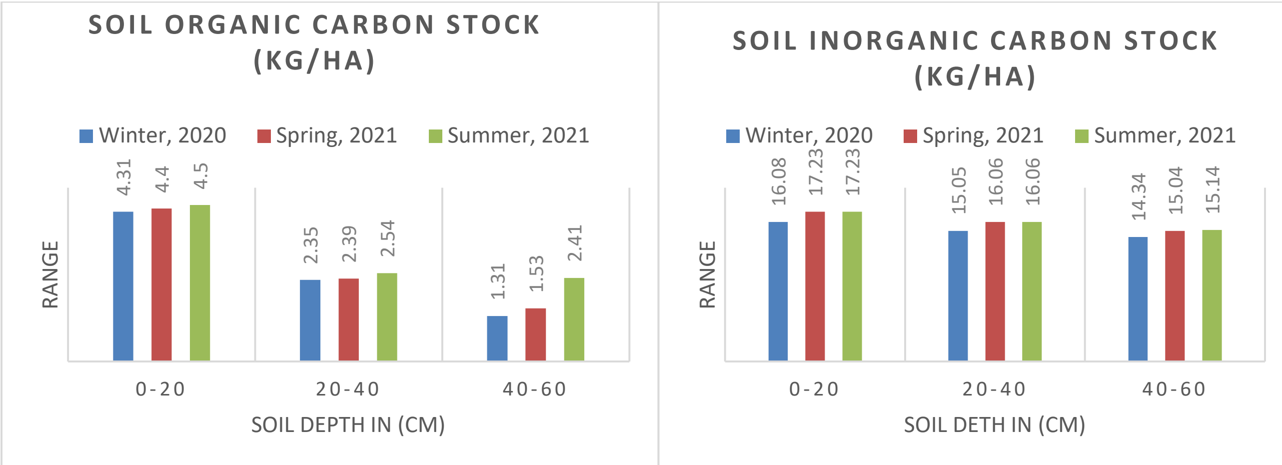

Figure 2: Soil organic and inorganic carbon at three soil depths under Rhode grass (*Chloris gayana*) during three seasons were recorded at Nawa Gerah in tehsil Fateh Jang.

The data shown in Figure 3 showed that the bulk density of soil was significantly lower at the surface soil as compared to lower soil depths in grazed as well as in un-grazed land. After two years of converting grazed land to un-grazed land, soil bulk densities at all three soil depths were decreased with significant differences. At 0–20 cm soil depth, soil bulk density was 1.5 g cm^{-3} in grazed land, which decreased to 1.45 g cm^{-3} in un-grazed land (Rhode grass) after two years. At 20–40 soil depth, bulk density also significantly decreased but at the lowest soil depth (40–60 cm) the difference was non-significant.

The results also indicated that the Rhode grass gave a significant increase in soil organic carbon (SOC) in un-grazed land as compared to grazed land area. The increase in SOC was significant at the upper soil depths (0–20 cm; 20–40 cm) and was non-significant at the lowest soil depth (40–60 cm). SOC under Rhode grass increased from 2.23 to 3.41 g kg^{-1} at 0–20 cm soil depth while at 20–40 cm soil depth, it increased from 1.64 to 1.94 g kg^{-1}.

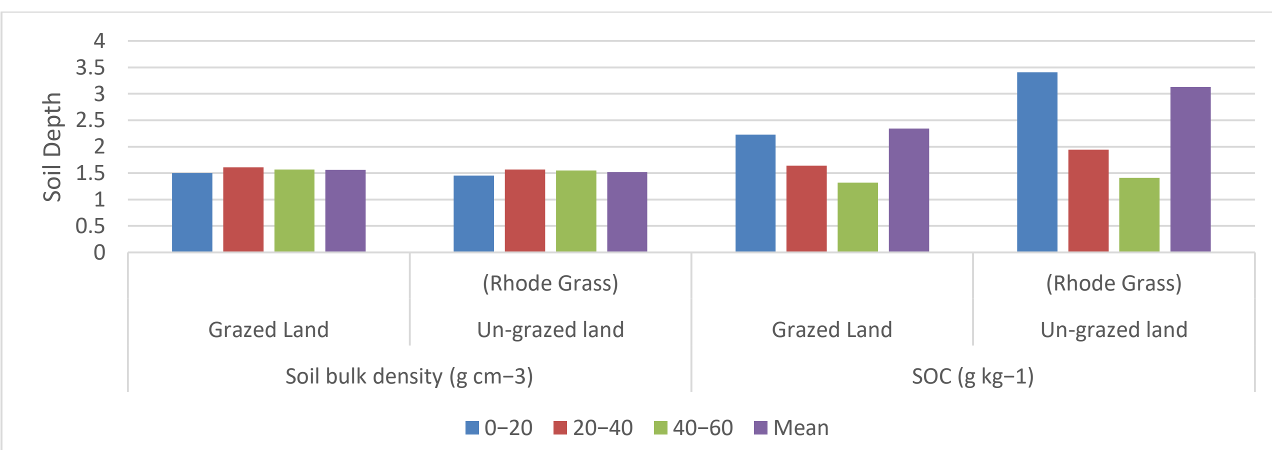

Figure 3: Soil bulk density (g cm^{-3}) and pH was collected during under different grasses at various soil depths at Nawa Gerah in tehsil Fateh Jang.

Data on soil pH revealed that the soil of both grazed and un-grazed land was moderately alkaline (Figure 4). Under grazed land soil pH ranged from 8.17 to 8.28 while under un-grazed land it ranged from 8.10 to 8.15. Soil pH was slightly higher in the surface depth under both grazed and un-grazed land. Rhode grass significantly decreased soil pH at all soil depths. When the grazed land was converted to un-grazed land, soil pH in the surface soil was decreased from 8.28 to 8.15. Soil EC ranged from 0.15 to 0.16 dS m^{-1}. So, there were no significant differences in soil EC.

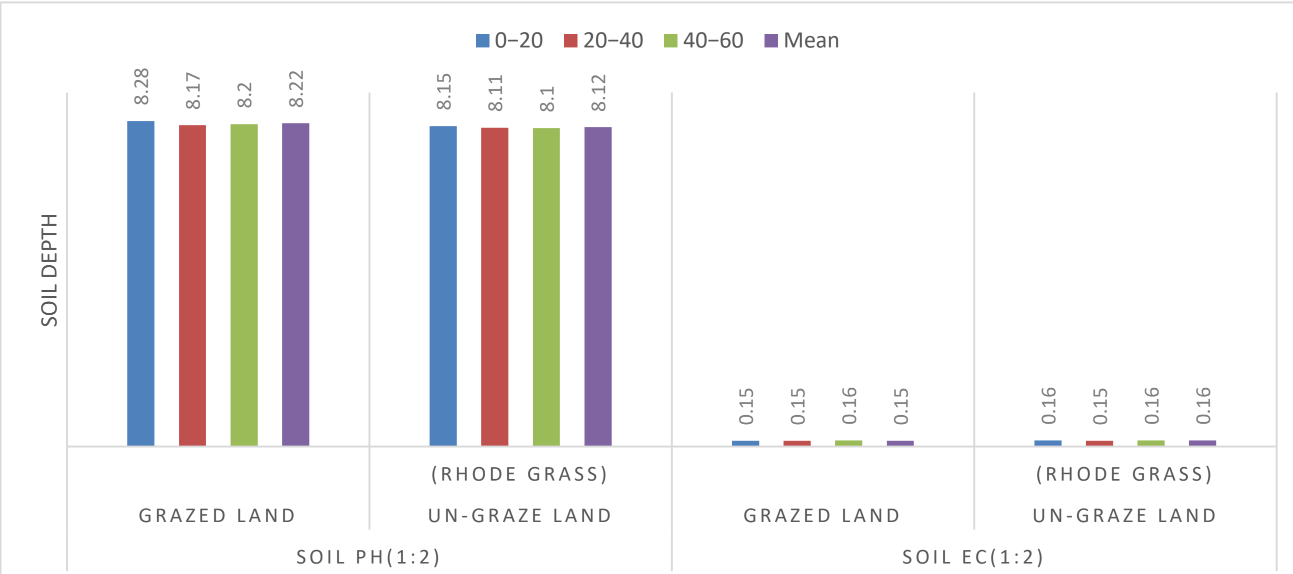

Figure 4: Soil pH and Soil electrical conductivity (dS m^{-1}) after one year under different grasses at various soil depths at Nawa Gerah in tehsil Fateh Jang.

Data on AB-DTPA extractable Soil NO_3–N, P_2O_5 and K_2O. All three nutrients were deficient in the region. Soil NO_3–N and P_2O_5 were significantly higher in the surface soil depth (0–20 cm). When the grazed land was converted to un-grazed land with Rhode grass, both soil and phosphorus contents were significantly increased in surface soil from 5.97 to 8.15 mg kg^{-1} and 4.00 to 6.18 mg kg^{-1}. At the lower two depths, both nutrient contents were increased with non-significant differences. No differences were observed in the potash content of soil (Table 2).

Table 2: Soil NO_3-N, Soil P_2O_5 and Soil K_2O content under different grasses at various soil depths at Nawa Gerah in tehsil Fateh jang.

Soil depths (cm)	NO_3–N (mg kg^{-1})		Soil P_2O_5 (mg kg^{-1})		Soil K_2O (mg kg^{-1})	
	Grazed Land	Un-grazed land (Rhode grass)	Grazed Land	Un-grazed land (Rhode grass)	Grazed Land	Un-grazed land (Rhode grass)
0−20	5.97^b	8.15^a	4.00^b	6.18^a	40	40
20−40	5.8^{bc}	6.10^b	3.83^c	4.13^b	37	41
40−60	5.58^c	5.64^c	3.61^c	3.67^c	41	41
Mean	5.78^B	6.68^A	3.81^B	4.66^A	41	40

DISCUSSION

The Potowar region is home to diverse ecosystems, habitats and species. There are diverse factors, over grazing, degradation of the soil cover and frequent droughts, the ecosystem and habitat of the wildlife of the arid regions are badly affected. The palatable species of grasses are vanishing rapidly and being replaced by plant species not preferred by grazing livestock, most of the rangelands are overstocked, overgrazed and over harvested suppressing the natural ability of palatable plants to regrow. Persistent over grazing naturally reduces the quality of pasture. The number of livestock is far in excess than the carrying capacity of the rangeland.

Fast growing, drought tolerant and palatable Rhode grass was sown. The data was collected during the second year of Rhode grass establishment in three seasons i.e. winter, spring and summer. Rhode grass in un-grazed land produced highest dry biomass (3.90 t ha^{-1}) in summer which was significantly higher than that produced in winter and spring seasons. In the grazed land the total dry biomass productivity per year was 723 kg ha^{-1} per year which was significantly increased to 9.47 t ha^{-1} per year by establishing Rhode grass under controlled grazing conditions. Thus our results were also in line with (Erkossa, 2019 and Robertson, 2008) who observed the Rhode grass to grow and spread fast to cover the ground, tolerance to drought, light frost and its suitability for growing in association with many other plants.

Farmers preferred the grass due to its several useful characteristics including its high yield, palatable by livestock and drought tolerance (Robertson, 2008). So, enhancing forage productivity by Rhode grass also enhanced animal unit of the region as it depends on forage productivity. Increase in biomass productivity also increased the phyto-mass carbon stock of the area.

The result indicated that the Rhode grass gave a significant increase in soil organic carbon (SOC) in un-grazed land as compared to grazed land area at Nawa Gerah. Similar results were observed by Erkossa (2019). More soil organic carbon in un-grazed land was due to more biomass productivity of Rhode grass litter inputs, which is a major factor influencing the organic C accumulation in soils (Klumpp et al., 2009). Similarly higher biomass productivity in summer seasons also resulted in higher soil organic carbon in summer as compared to other seasons. This is because of more humidity and rainfall in the summer. Higher carbon contents at lower depths in un-grazed land were also due to the deep root system of the grass (Piñeiro et al., 2006).

The bulk density plays a very vital role in plant growth. In the grazed land it ranged from 1.5 g cm^{-3} at the surface soil to 1.61 g cm^{-3} in lower depths. This range of bulk density is suitable for plant growth as the soil is porous enough to proliferate roots in soil. When Rhode grass was sown for two years and grazed land was converted to un-grazed, the soil bulk density was significantly decreased. Grasses have extensive root systems that can penetrate deep into the soil. These roots help stabilize the soil structure and promote the formation of aggregates, which create pore spaces for water infiltration and air circulation and consequently reduces soil bulk density. The decomposition of these roots also adds organic matter to the soil, further increasing soil carbon content (Allard et al., 2005).

The soil of the region is alkaline in nature having pH of 8.17 to 8.28 in the 60 cm soil profile. Which was significantly decreased by growing Rhode grass. Similar results were observed by (Erkossa, 2019). Grassland plants contribute to the accumulation of organic matter in the soil through root exudates, litter, and root turnover (Allard et al., 2005). Grasses enhances microbial activity, which play a crucial role in soil nutrient cycling and organic matter decomposition therefore organic matter decomposition release organic acids (carbonic acid) which decreases soil pH (Fujii, 2014; Rukshana et al., 2011).

Rhode grass sowing and its controlled grazing also increased soil nitrate and phosphorus content. As the grazing reduced standing biomass relative to the enclosure by almost 65%, reducing the total above-ground nutrient stocks in grazed grassland to half or less of those in un-grazed grassland, whereas the exclusion of grazing led to greater nutrient partitioning into above-ground dead matter. Study of (Seidel et al.,2009) also observed a significant increment of 82 mg kg^{-1} in soil NO_3–N under grassland while (Wang et al., 2021) revelated that soil P content under grassland area increased up to 5.6 mg kg^{-1} while in control (no grassland area) P content was only 4.1 mg kg–1.

Grasses increase soil nitrogen and phosphorus cycling by enhancing soil microbial due to more biomass productivity of Rhode grass litter inputs, which is a major factor influencing release of more C to the rhizosphere by plants, which stimulates extracellular enzyme activities and enhances microbial activities, thus promoting soil phosphorus availability (Zhu et al., 2021; Cade-Menun et al., 2017). Moreover, grasslands also enhance soil P by mineralization of originally bound P in the soil which ensure the P availability for plant uptake and their growth (Wang et al., 2021). Grasses have deep and extensive root systems that can reach deep into the soil therefore these extensive longer roots can also improve soil nitrogen and phosphorus content even in the lower soil layers (Skinner and Comas, 2010).

CONCLUSION

This research findings suggest that cultivating Rhode grass through controlled grazing can boost the region's forage production capabilities. Additionally, it has the potential to enhance soil quality by reducing soil bulk density and pH levels, while increasing soil organic matter and nutrient content. Implementing controlled grazing alongside Rhode grass cultivation can lead to improved livestock conditions in the area and aid in carbon sequestration efforts. Rhode grass, due to its extensive coverage of the soil surface, will unquestionably contribute to a significant reduction in soil erosion within the region.

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