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Evaluating Restoration Methods A Cross A Range of Plant Communities Dominated by Invasive Annual Grasses to Native Perennial Grasses

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Abstract
The objectives of the study were to determine whether there are differences in plant community response to restoration methods & to create awareness among the pastoralists/ agro-pastoralists on how to restore degraded rangeland. Six treatments were established: (1) ripping, mulching and seeding (2) ripping, manuling and seeding (3) ripping, mulching, manuling and seeding (4) control. The treatments were arranged in a randomized complete block design with factorial and replicated three times in each plant community. Each treatment plot was 3m by 6m, and depending on the treatment assigned to the plot, measurements for the vegetations were taken from those plots. Seeds of perennials, large tufted and palatable grass species were selected for reseeding purpose i.e., Andropogon canaliculatus, Tetrapogon cenchriformis, Panicum coloratum and Chrysopogon plumolosus. The study was carried out over the last three rainy seasons from 2015/16 and 2017/ 2018. Data were collected from germination to dry matter yield within three years of the experimental years. Accordingly, the result showed as variation clearly observed among the restoration treatments to different plant community. There is a significant difference at ($P<0.05$) rangeland parameters collected in all Restoration methods in each seasons. A total of 18 species of grasses were identified in the study district. Of the grass species 11(61.1%) species were perennials and 7 (38.9%) species were annuals. In Perennial plant community with Restoration Methods of Ri+Ma+Mu+Se was significant difference at ($P<0.05$) in the three consecutive seasons in Biomass production. The highest Biomass production was observed in the third season of implementation time which was 2.37 ton/ha while the lowest biomass production was observed in the first season of implementation period in control one which was 1 ton/ha. In Mixed plant community with Restoration Methods of Ri+Ma+Mu+Se was significant difference at ($P<0.05$) in the three consecutive seasons in Biomass production. The highest Biomass production was observed in the third season of implementation time which was 1.75 ton/ha while the lowest biomass production was observed in the first season of implementation period in control one which was 0.83 ton/ha.
Therefore, we conclude that from this finding, perennial plant community with Restoration methods of Ri+Ma+Mu+Se is more effective method to rehabilitate denuded rangeland areas in semi-arid areas and also Annual plant community with Restoration methods of Ri+Ma+Mu+Se has shown dramatic result to improved range resources within short period of time. However, continuous onsite training & practical demonstration was very crucial to enhance the adoption rate of those Restoration methods.
Keywords: Restoration Methods, plant community, Germination, Basal cover & Biomass Yield
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1. Introduction

The Afar Region is located in the North Eastern lowlands of Ethiopia, with the area of about 100,860 km^2 (IB-ANRS, 2000) and the topography of the region varies from hilly escarpment in the western and southern edges with an altitude of 1000-1500 m.a.s.l to lowland plains that fall in the altitude of 0-100 m.a.s.l. Around 95 percent of the region has a flat landscape with altitude decreasing towards North eastern parts. More than 95% of the rural population is pure pastoralists, typically transhumant, although there are few parts of the people, which are sedentary in some pocket areas (Philpott *et al*., 2005).

The Region has a total number of 2,546,790 cattle, 2,541,920 sheep, 4,398,590 goats, 884,290 camels, 189,330 donkeys, 900 horses and 3,340 mules (CSA, 2004). The Afar pastoral communities depend on multi-species livestock production. However, camels, sheep, goats, cattle, and donkeys constitute the main productive assets of the local community. The primary feed sources for this large number of livestock are rangelands composed of indigenous species of grasses, shrubs and fodder trees. Most of these grass species however, are subjected to continuous threat of genetic erosion and extinction due to over grazing, rangeland degradation, undesirable plant encroachment (like *Prosopis juliflora, Parthenium hysterophorus, Calotropis procera, Tribulis terrestris, Sida ovata, Cryptostegia grandiflora* etc.) (APARI, 2005) and also *Acacia nubica* dominantly invaded the rangeland areas in Chifra district (Mohammed, 2009).

Overgrazing is the main antropic factors leading to the deterioration of the perennial plant cover. Its negative effect is excessive removal of the living parts of the high range value species, which may lead to their extinction. This factor is being more harmful when coupled with the climate aridity effect (drought). Most of the

grazing areas of Afar region are exposed to overgrazing because of this the availability of animal feed decline both in quality and quantity, due to this, the community always moved from one area to the other areas inorder to search animal feed and water but through journey the pastoralists were faced different problems with the neighboring region community and also emaciated animals were always never come back to the original place because they will die on the way before reach into temporary settlement area, even after rainy season the grazing areas of the region covered by annual grasses which stayed only for two to three months after that the vegetation become diminished. As result of this, productivity of the livestock is very low there by affecting the livelihood of the people.

So implementation of different traditional and modern rangeland management system is crucial inorder to rehabilitate the degraded and encroached grazing areas of Afar region. Research and development in rangeland improvement schemes is therefore an important investment in order to reverse the negative impacts of different rangeland degradations caused by biotic and/or biotic factors. Furthermore, improvement impacts enhance livestock performances with higher values for local and export markets and enable the contribution of the sub sector in boosting income generation by pastoralists.

2. Specific Objectives

- ✓ To determine whether there are differences in plant community response to restoration treatments as measured by species composition, vegetation cover and density across treatments
- ✓ To know the species diversity of the above ground vegetation
- ✓ To identify best restoration technique or techniques would be more appropriate for a given plant community
- ✓ To create awareness within the community on how to restore degraded rangeland

3. Materials and Methods

3.1 Description of the Study area

The study was undertaken in Chifra district of zone one (Awsi Rasu) of the Afar Regional State. It is located south west of Semera on the main road of Mile to Woldiya, which is about 162 km from the regional capital city (Semera). Chifra is climatically characterized as arid and semi-arid agro-ecological area, where livestock production is the main occupation of the community. The average temperature of the area is about 29ºC, and the rainfall is bimodal with erratic distribution, with the long rainy season (Kerma) is between Mid-June to Mid-September and the short rainy season (Sugum) that occurs between March and April. The average annual rainfall is recorded to be between 400 and 600 mm (APARDB, 2006).

3.2 Experimental Procedure

Each study site was visually evaluated and identified three plant communities dominated by annual grasses, perennial grasses, and mixed annual and perennial grasses using the protocols described in Johnson and Simon (1987). Predominately annual communities were described as areas containing less than 10% native perennial grass. Mixed communities was described as areas containing between 15 and 25% native perennial grass, whereas predominately perennial communities were described as area containing more than 25% native perennial grass.

Six treatments were established: (1) ripping, mulching and seeding (2) ripping, manuling and seeding (3) ripping, mulching, manuling and seeding (4) control. The treatments were arranged in a randomized complete block design with factorial and replicated three times in each plant community. Each treatment plot was 3m by 6m, and depending on the treatment assigned to the plot, measurements for the vegetations were taken from those plots. Seeds of perennials, large tufted and palatable grass species were selected for reseeding purpose i.e., *Andropogon canaliculatus, Tetrapogon cenchriformis, Panicum coloratum and Chryspogon plumolosus.* The above grass species were mixed in order to sown in two plant communities which are annual communities and mixed communities. The reseeding was taken at a rate of 120g/spp/100m^2. Samples of each seeds were taken to the laboratory to assess the purity percentage. Immediately following seeding, compressed pellets uneaten leaf mulch were broadcasted on the seeded plots at a rate of 1,953 kg per ha.

Treatment Combination

No	Plant community	Restoration methods
1	Annual communities	Control
		Ripping, Mulching and Seeding
		Ripping, Manuling and Seeding
		Ripping, Mulching, Manuling and Seeding
2	Mixed communities	Control
		Ripping, Mulching and Seeding
		Ripping, Manuling and Seeding
		Ripping, Mulching, Manuling and Seeding
3	Perennial communities	Control
		Ripping and Mulching
		Ripping and Manuling
		Ripping, Mulching and Manuling

3.3 Materials used and data collected

3.3.1 Germination Scores

The germination of grasses assessed by randomly placing three quadrants (visual within structures) by giving the scores of (3.5 - 4= poor germination; 3-3.5= fair germination; 2= good germination; 1= excellent germination) for each plot/structure. A score was considered germinated when the radicle length was 2mm or above.

3.3.2 Basal cover

Cover assessed using quadrate (0.5m x 0.5m) by randomly placing in the structures. An area of 0.25 m^2 was selected for detailed assessment, and divided into halves. One of these was further divided into quarters, one of which divided into eighths. All grasses in the selected 0.25m2 per plot was cut, transferred while kept together, and drawn in the eighth part to facilitate visual estimations of basal covers of living parts. The rating of basal cover was considered 'excellent' when the eighth was completely filled (12.5%) or 'very poor' when the cover was less than 3% (Baars et al. 1997). Then, each percentage multiplied by four to convert to out of 100%.

3.3.3 Herbaceous species composition

The grass species were clustered into 3-groups based on the desirability following indigenous knowledge and ecological status supported by information from literature survey. The desirability rating was based on their long-term response to grazing and palatability. Ecological status, as used here, indicates species composition classified as decreasers, increasers and invaders or pioneers as defined in Tainton (1999). Accordingly, highly desirable species included species that are decreasers and perennials with a high palatability based upon the pastoralists perceptions. The intermediate desirable species are those that increase in abundance with moderate over-utilization, and perennials, which are average or high in terms of their palatability. The less desirable species include those species that increase in abundance with severe or extremely severe over-utilization of rangelands. This group includes perennial and annual species that are less palatable (Tainton, 1999).

3.3.4. Dry matter determination

The dry matter production was taken by using quadrant (0.5m X 0.5m) from each plot/structures. Four quadrants were taken from each sample plot and the herbaceous species were divided into grasses and non-grasses by hand separation. The grass species were sorted by species while the non-grass herbaceous was combined as forbs. The samples were oven-dried at 105^0C for 24 hours and weighed in order to determine the dry matter content.

3.4. Statistical Analysis and Interpretation

The data obtained from the vegetation was subjected to ANOVA using the GLM procedure of Statistical Analytical System (SAS) (2001) computer software. A significant difference was detected through ANOVA with $P \leq 0.05$ and Means were separated by Duncan's Multiple Range Test (DMRT).

4. Result & Discussion

4.1 Herbaceous Species Composition, Use Values & Relative Abundance

4.1.1 First Implementation Year

Annual Plant Community

In first year trial, total grass species recorded in Annual plant community was 12 (6 annuals and 6 perennials) but the frequency or the occurrence of annuals grasses greater than perennial grasses in each plots. In restoration techniques (R+M+S & R+ Ma+ S), less desirable grass specie like *Aristida adoenesis* were commonly found and also undesirable grass species like *Tragus beteronianus* & *Brachiaria eruciformis* were dominantly found in each experimental plots while in restoration techniques (R+ M+ Ma+ S), desirable grass like *Dactyloctenium*

aegypticum & Digitaria milanjana were presented in each experimental plots.

Mixed Plant Community

In first year trial, total grass species recorded in Annual plant community was 11 (4 annuals and 7 perennials) but the frequency or the occurrence of annuals grasses greater than perennial grasses in each plots.

Perennial Plant Community

In first year trial, total grass species recorded in Annual plant community was 10 (2 annuals and 8 perennials) but the frequency or the occurrence of annuals grasses greater than perennial grasses in each plots.

Table 1:- Herbaceous Species Composition, Use Values and Relative Abundance in Different Plant Communities in the 1st Implementation Year

Species Names	Cg	Year I								
		Annual			Mixed			Perennial		
		Ri+Mu+Se	Ri+ Ma+ Se	Ri+ Mu+ Ma+ Se	Ri+Mu+Se	Ri+ Ma+ Se	Ri+ Mu+ Ma+ Se	Ri+ Mu	Ri+ Ma	Ri+ Mu+ Ma
Eleusine multifolia	LD	C	C	P	P	P	P	-	-	-
Dactyloctenium aegypticum	D	P	P	P	P	C	C	C	C	C
Eragrostis teniufolia	LD	D	D	P	-	-	-	-	-	-
Panicum coloratum	HD	P	P	C	C	C	C	C	C	C
Chrysopogon plumolosus	D	P	P	C	C	C	C	C	C	C
Aristida adoenesis	LD	C	C	C	-	-	-	P	P	P
Cynodon dactylon	HD	-	-	-	P	P	C	P	C	C
Tragus beteronianus	UD	D	D	C	P	P	P	-	-	-
Digitaria milanjana	D	P	P	P	P	P	C	P	C	C
Andropogon canaliculatus	D	P	P	C	C	C	D	C	C	C
Tetrapogon cenchriformis	D	P	P	C	C	C	D	C	C	C
Brachiaria eruciformis	UD	C	C	P	P	P	-	-	-	-
Chloris prieurii	LD	C	P	P	P	P	p	P	P	P
Cenchrus ciliaris	HD	-	-	-	-	-	-	P	P	P

Remark: Cg = Categories; HD = highly desirable; D = Desirable; LD = Less desirable; UD = Undesirable; D = Dominant (>20%); C = Common (10-20%); P = Present (<10% of the total herbaceous plant) and - = absent

4.1.2 Second Implementation Year

Annual Plant Community

In second year trial, total grass species recorded in Annual plant community was 12 (5 annuals and 7 perennials) but the frequency or the occurrence of annuals grasses grater than perennial grasses in each plots. In restoration techniques (R+M+S & R+ Ma+ S), less desirable grass species like Eleusine multifolia & Aristida adoenesis were commonly found and also undesirable grass specie like Brachiaria eruciformis were commonly found in each experimental plots while in restoration techniques (R+ M+ Ma+ S), desirable grass like Digitaria milanjana were present ed in each experimental plots.

Mixed Plant Community

In second year trial, total grass species recorded in Annual plant community was 13 (3 annuals and 10 perennials) but the frequency or the occurrence of annuals grasses grater than perennial grasses in each plots.

Perennial Plant Community

In second year trial, total grass species recorded in Annual plant community was 12 (2 annuals and 10 perennials).

Table 2:- Herbaceous Species Composition, Use Values and Relative Abundance in Different Plant Communities in the 2nd Implementation Year

Species Names	Cg	Year II								
		Annual			Mixed			Perennial		
		Ri+Mu+Se	Ri+ Ma+ Se	Ri+ Mu+ Ma+ Se	Ri+Mu+Se	Ri+ Ma+ Se	Ri+ Mu+ Ma+ Se	Ri+ Mu	Ri+ Ma	Ri+ Mu+ Ma
Bothriochloa insculpta	D	-	-	-	P	P	P	P	P	P
Dactyloctenium aegypticum	D	P	P	P	P	C	C	C	C	C
Eragrostis teniufolia	LD	D	D	P	-	-	-	-	-	-
Panicum coloratum	HD	P	P	C	C	C	D	D	D	C
Chrysopogon plumolosus	D	P	P	C	C	C	D	C	D	C
Aristida adoenesis	LD	C	C	C	-	-	-	P	P	P
Cynodon dactylon	HD	-	-	-	P	P	C	P	C	C
Tragus beteronianus	UD	D	D	C	P	P	P	-	-	-
Digitaria milanjana	D	P	P	P	P	P	C	P	C	C
Andropogon canaliculatus	D	P	P	C	C	C	D	C	C	C
Tetrapogon cenchriformis	D	P	P	C	C	C	D	C	C	C
Brachiaria eruciformis	UD	C	C	P	P	P	-	-	-	-
Cenchrus pennisetiformis	HD	-	-	-	p	p	p	P	P	P
Cenchrus ciliaris	HD	C	P	P	P	P	p	P	P	P
Chloris prieurii	LD	-	-	-	-	-	-	P	P	P
Eleusine multifolia	LD	C	C	P	P	P	P	-	-	-

Remark: Cg = Categories; HD = Highly desirable; D = Desirable; LD = Less desirable; UD = Undesirable; D = Dominant (>20%); C = Common (10-20%); P = Present (<10% of the total herbaceous plant) and - = Absent

4.1.2 Third Implementation Year

Annual Plant Community

In third year trial, total grass species recorded in Annual plant community was 13 (5 annuals and 8 perennials) but the frequency or the occurrence of annuals grasses greater than perennial grasses in each plots.

Mixed Plant Community

In third year trial, total grass species recorded in Annual plant community was 13 (3 annuals and 10 perennials) but the frequency or the occurrence of annuals grasses greater than perennial grasses in each plots.

Perennial Plant Community

In third year trial, total grass species recorded in Annual plant community was 14 (3 annuals and 11 perennials).

Table 3:- Herbaceous Species Composition, Use Values and Relative Abundance in Different Plant Communities in the 3rd Implementation Year

Species Names	Cg	Year III								
		Annual			Mixed			Perennial		
		Ri+Mu+Se	Ri+ Ma+ Se	Ri+ Mu+ Ma+ Se	Ri+Mu+Se	Ri+ Ma+ Se	Ri+ Mu+ Ma+ Se	Ri+ Mu	Ri+ Ma	Ri+ Mu+ Ma
Bothriochloa insculpta	D	-	-	-	P	P	P	P	P	P
Dactyloctenium aegypticum	D	P	P	P	P	C	C	C	C	C
Eragrostis teniufolia	LD	D	D	P	-	-	-	-	-	-
Panicum coloratum	HD	P	P	C	C	C	D	D	D	C
Chrysopogon plumolosus	D	P	P	C	C	C	D	C	D	C

Species Names	Cg	Year III								
		Annual			Mixed			Perennial		
		Ri+Mu+Se	Ri+ Ma+ Se	Ri+ Mu+ Ma+ Se	Ri+Mu+Se	Ri+ Ma+ Se	Ri+ Mu+ Ma+ Se	Ri+ Mu	Ri+ Ma	Ri+ Mu+ Ma
Aristida adoenesis	LD	C	C	C	-	-	-	P	P	P
Cynodon dactylon	HD	-	-	-	P	P	C	P	C	C
Tragus beteronianus	UD	D	D	C	P	P	P	-	-	-
Digitaria milanjana	D	P	P	P	P	P	C	P	C	C
Andropogon canaliculatus	D	P	P	C	C	C	D	C	C	C
Tetrapogon cenchriformis	D	P	P	C	C	C	D	C	C	C
Brachiaria eruciformis	UD	C	C	P	P	P	-	-	-	-
Cenchrus pennisetiformis	HD	-	-	-	p	p	p	P	P	P
Cenchrus ciliaris	HD	C	P	P	P	P	p	P	P	P
Chloris prieurii	LD	-	-	-	-	-	-	P	P	P
Eleusine multifolia	LD	C	C	P	P	P	P	-	-	-
Cymbopogon giganteus	HD	-	-	-	-	P	P	P	P	P
Teterapogon vilosus	D	-	-	-	-	-	-	P	P	P

Remark: Cg = Categories; HD = Highly desirable; D = Desirable; LD = Less desirable; UD = Undesirable; D = Dominant (>20%); C = Common (10-20%); P = Present (<10% of the total herbaceous plant) and - = Absent

4.2 Effect of Restoration Methods in Different Plant Community on Germination (scores), Basal cover (%), Species Composition & Dry matter yield (ton/ha) during the first Implementation Year

Variations of Germination, basal cover, species composition and dry matter yield were observed among treatments during the first implementation year. High germination score was observed in two different treatments which were Annual and Mixed plant community with Restoration method of Ri+Ma+Mu+Se significantly difference at ($P<0.05$) than the other treatments. In case of Basal cover, Perennial plant community with Restoration method of Ri+Ma+Mu+Se was significantly difference at ($P<0.01$) than other treatments while in species composition, Annual plant community with Restoration method of Ri+Ma+Mu+Se was significantly difference at ($P<0.05$) than other treatments. In case of biomass yield, Perennial plant community with Restoration method of Ri+Ma+Mu+Se was significantly difference at ($P<0.05$) than other treatments.

Table 4: ANOVA (LSM and SE) of Rangeland Parameters in Different Plant Community in First Implementation Year

Parameter	TRT	Year I		
		Annual	Mixed	Perennial
Germination (score)	Control	$3.72+0.023^{d}$	$3.53+0.02^{c}$	$3.72+0.024^{c}$
	Ri+Mu+Se	$3.36+0.02^{c}$	$2.99+0.023^{b}$	$3.61+0.2^{c}$
	Ri+Ma+Se	$3.11+0.02^{b}$	$2.79+0.024^{b}$	$3.32+0.0.23^{b}$
	Ri+Ma+Mu+Se	$2.83+0.023^{a}$	$2.22+0.02^{a}$	$3.12+0.2^{a}$
Basal cover (%)	Control	$25.56 + 2.25^{d}$	$29.7+2.99^{c}$	$35.2+3.148^{c}$
	Ri+Mu+Se	$28.6 + 1.55^{c}$	$32.9+2.65^{c}$	$43.6+2.48^{b}$
	Ri+Ma+Se	$30.33 + 2.80^{b}$	$36.1+2.26^{b}$	$49.4+3.36^{a}$
	Ri+Ma+Mu+Se	$31.26 + 2.71^{a}$	$42.2+3.05^{a}$	$51.0+4.08^{a}$
Species composition	Control	$8.0 + 2.0^{d}$	$6.33+1.52^{c}$	$7.0+2.0^{c}$
	Ri+Mu+Se	$12.0+ 2.0^{c}$	$7.33+2.08^{c}$	$8.33+2.51^{b}$
	Ri+Ma+Se	$13.0+ 2.0^{b}$	$10.0+2.0^{b}$	$8.66+1.52^{b}$
	Ri+Ma+Mu+Se	$14.0 + 2.0^{a}$	$12.3+2.51^{a}$	$10.0+2.0^{a}$

Parameter	TRT	Year I		
		Annual	Mixed	Perennial
Biomass	Control	0.226 + 0.125 [d]	0.83+0.07 [c]	1.00+0.19 [d]
	Ri+Mu+Se	0.34 + 0.14 [c]	0.95+0.2 [b]	1.16+0.17 [c]
	Ri+Ma+Se	0.63+ 0.18 [b]	1.14+0.13 [a]	1.56+0.16 [b]
	Ri+Ma+Mu+Se	0.83+ 0.18 [a]	1.16+0.16 [a]	1.79+0.14 [a]

- ✓ [a-d] means with different superscripts letters along row differ significantly ($p<0.05$)
- ✓ [*]Germination (3.5-4= poor; 3-3.5= fair;2= good; 1= excellent)

4.3 Effect of Restoration Methods in Different Plant Community on Germination (scores), Basal cover (%), Species Composition & Dry matter yield (ton/ha) during the Second Implementation Year

Germination score, basal cover, species composition and dry matter yield were significantly difference among treatments during the second season. High germination score was observed Perennial plant community with Restoration method of Ri+Ma+Mu+Se significantly difference at ($P<0.05$) than the other treatments. In Perennial plant community with Restoration method of Ri+Ma+Mu+Se, the basal cover and biomass yield were significantly difference at ($P<0.05$) than the remaining treatment combination. In case of species composition, Annual plant community with Restoration method of Ri+Ma+Mu+Se was highest number compare to other treatments which was 14.66.

Table 5: ANOVA (LSM and SE) of Rangeland Parameters in Different Plant Community in Second Implementation Year

Parameter	TRT	Year II		
		Annual	Mixed	Perennial
Germination (score)	Control	3.59+0.79 [d]	3.41+0.12 [d]	3.2+0.1 [d]
	Ri+Mu+Se	3.126+0.11 [c]	2.91+0.06 [c]	2.79+0.75 [c]
	Ri+Ma+Se	2.90+0.083 [b]	2.64+0.09 [b]	2.32+0.04 [b]
	Ri+Ma+Mu+Se	2.33+0.07 [a]	2.21+0.09 [a]	1.98+0.077 [a]
Basal cover (%)	Control	28.7+2.32 [d]	33.2+2.58 [d]	42.9+3.14 [c]
	Ri+Mu+Se	31.13+3.88 [c]	36.5+1.87 [c]	47.23+2.45 [b]
	Ri+Ma+Se	33.0+3.17 [b]	43.1+2.88 [b]	47.4+3.38 [b]
	Ri+Ma+Mu+Se	34.9+2.20 [a]	47.8+2.15 [a]	53.0+2.4 [a]
Species composition	Control	10.0+2.0 [d]	8.0+2.0 [d]	8.0+0.0 [c]
	Ri+Mu+Se	12.3+1.154 [c]	9.0+1.73 [c]	8.66+1.52 [c]
	Ri+Ma+Se	13.66+1.52 [b]	12.0+2.0 [b]	9.6+0.57 [b]
	Ri+Ma+Mu+Se	14.66+1.52 [a]	13.0+2.0 [a]	11.0+1.0 [a]
Biomass	Control	0.86+0.13 [d]	1.15+0.16 [d]	1.05+0.19 [d]
	Ri+Mu+Se	0.99+0.20 [c]	1.3+0.08 [c]	1.34+0.19 [c]
	Ri+Ma+Se	1.36+0.06 [b]	1.55+0.17b	1.83+0.12 [b]
	Ri+Ma+Mu+Se	1.54+0.17 [a]	1.9+0.08 [a]	2.043+0.09 [a]

- ✓ [a-d] means with different superscripts letters along row differ significantly ($p<0.05$)
- ✓ [*]Germination (3.5-4= poor; 3-3.5= fair;2= good; 1= excellent)

4.6 Effect of Restoration Methods in Different Plant Community on Germination (scores), Basal cover (%), Species Composition & Dry matter yield (ton/ha) during the third Implementation Year

High germination score was observed in Mixed plant community with Restoration Methods of Ri+Ma+Mu+Se, significantly difference at ($P<0.05$) than the remaining treatment combination. In Basal cover & biomass yield, Perennial plant community with Restoration Methods of Ri+Ma+Mu+Se was significantly difference at ($P<0.05$) than other treatment combination. In Perennial plant community with Restoration Methods of Ri+Ma+Mu+Se, the basal cover & species composition were highest number compare to other treatments which were 74.1% & 2.37 respectively. In case of species composition, Annual plant community with Restoration method of Ri +Ma+Mu+Se was highest number compare to other treatments which was 17.3.

Table 6: ANOVA (LSM and SE) of Rangeland Parameters in Different Plant Community in Third Implementation Year

Parameter	TRT	Year III		
		Annual	Mixed	Perennial
Germination (score)	Control	3.72+0.1 ^{c}	3.55+0.176 ^{c}	3.46+0.27 ^{c}
	Ri+Mu+Se	3.6+0.1 ^{c}	3.4+0.21 ^{c}	3.39+0.24 ^{c}
	Ri+Ma+Se	3.33+1.377 ^{b}	2.91+0.77 ^{b}	3.2+0.304 ^{b}
	Ri+Ma+Mu+Se	3.15+0.13 ^{a}	1.33+0.17 ^{a}	2.97+0.25 ^{a}
Basal cover (%)	Control	31.0 + 2.21 ^{d}	36.1+3.31 ^{d}	48.33+5.95 ^{c}
	Ri+Mu+Se	31.96+2.55 ^{c}	40.53+3.23 ^{c}	61.26+2.83 ^{b}
	Ri+Ma+Se	34.23+3.16 ^{b}	49.26+3.49 ^{b}	65.93+4.10 ^{b}
	Ri+Ma+Mu+Se	40.96+1.98 ^{a}	56.93+2.90 ^{a}	74.1+4.01 ^{a}
Species composition	Control	11.66+ 1.52c	9.33+0.57 ^{c}	8.66+0.57 ^{c}
	Ri+Mu+Se	14.6+0.57b	13.6+0.57 ^{b}	11.33+0.57 ^{b}
	Ri+Ma+Se	15.0+1.73b	13.0+1.73 ^{b}	11.3+1.15 ^{b}
	Ri+Ma+Mu+Se	17.3+1.15 a	16.0+1.0 ^{a}	13.0+1.0 ^{a}
Biomass	Control	1.26+ 0.47 ^{b}	1.42+0.17 ^{c}	1.28+0.23 ^{d}
	Ri+Mu+Se	1.13+0.09 ^{b}	1.63+0.21 ^{b}	1.6+0.16 ^{c}
	Ri+Ma+Se	1.56+0.19 ^{a}	1.68+0.15 ^{b}	2.2+0.13 ^{b}
	Ri+Ma+Mu+Se	1.81+0.16 ^{a}	1.75+0.39 ^{a}	2.37+0.11 ^{a}

- ✓ $^{a-d}$ means with different superscripts letters along row differ significantly ($p<0.05$)
- ✓ *Germination (3.5-4= poor; 3-3.5= fair;2= good; 1= excellent)

4.7 Effect of Restoration methods in Different Plant Community on Biomass Production during the whole implementation years

In Perennial plant community with Restoration Methods of Ri+Ma+Mu+Se was significant difference at ($P<0.05$) in the three consecutive seasons in Biomass production. The highest Biomass production was observed in the third season of implementation time which was 2.37 ton/ha while the lowest biomass production was observed in the first season of implementation period in control one which was 1 ton/ha. In Mixed plant community with Restoration Methods of Ri+Ma+Mu+Se was significant difference at ($P<0.05$) in the three consecutive seasons in Biomass production. The highest Biomass production was observed in the third season of implementation time which was 1.75 ton/ha while the lowest biomass production was observed in the first season of implementation period in control one which was 0.83 ton/ha.

In Annual plant community with Restoration Methods of Ri+Ma+Mu+Se was significant difference at ($P<0.05$) in the three consecutive seasons in Biomass production. The highest Biomass production was observed in the third season of implementation time which was 1.81 ton/ha while the lowest biomass production was observed in the first season of implementation period in control one which was 0.22 ton/ha.

Table 7: ANOVA (LSM and SE) of Biomass production(ton/ha) in Different Restoration methods within the Consecutive Implementation Years

Treatment Combinations		Biomass Production		
		Year 1	Year 2	Year 3
Annual	**Control**	0.22 +0.12 ^{c}	0.86+0.13 ^{b}	1.26+ 0.47 ^{a}
	Ri+Mu+Se	0.34 + 0.14 ^{c}	0.99+0.20 ^{b}	1.13+0.09 ^{a}
	Ri+Ma+Se	0.63+ 0.18 ^{c}	1.36+0.06 ^{b}	1.56+0.19 ^{a}
	Ri+Ma+Mu+Se	0.83+ 0.18 ^{c}	1.54+0.17 ^{b}	1.81+0.16 ^{a}
Mixed	**Control**	0.83+0.07 ^{c}	1.15+0.16 ^{b}	1.42+0.17 ^{a}
	Ri+Mu+Se	0.95+0.2 ^{c}	1.3+0.08 ^{b}	1.63+0.21 ^{a}
	Ri+Ma+Se	1.14+0.13 ^{b}	1.55+0.17 ^{a}	1.68+0.15 ^{a}
	Ri+Ma+Mu+Se	1.16+0.16 ^{c}	1.58+0.08 ^{b}	1.75+0.39 ^{a}

Treatment Combinations		Biomass Production		
		Year 1	Year 2	Year 3
Perennial	Control	1.00+0.19[b]	1.05+0.19[b]	1.28+0.23[a]
	Ri+Mu+Se	1.16+0.17[c]	1.34+0.19[b]	1.6+0.16[a]
	Ri+Ma+Se	1.56+0.16[b]	1.83+0.12[b]	2.2+0.13[a]
	Ri+Ma+Mu+Se	1.79+0.14[c]	2.043+0.09[b]	2.37+0.11[a]

✓ a-c means with different superscripts letters along column differ significantly (p<0.05)

4.8 Effect of Restoration methods in Different Plant Community on Basal Cover during the whole implementation years

In Perennial plant community with Restoration Methods of Ri+Ma+Mu+Se was significant difference at (P<0.05) in the three consecutive seasons in Basal cover. The highest percentage of basal cover was observed in the third season of implementation time which was 74.1 while the lowest percentage of basal cover was observed in the first season of implementation period which was 51.0. In Mixed plant community with Restoration Methods of Ri+Ma+Mu+Se was significant difference at (P<0.05) in the three consecutive seasons in Basal cover. The highest percentage of basal cover was observed in the third season of implementation time which was 56.93 while the lowest percentage of basal cover was observed in the first season of implementation period which was 42.2.

In Annual plant community with Restoration Methods of Ri+Ma+Mu+Se was significant difference at (P<0.05) in the three consecutive seasons in Basal cover. The highest percentage of basal cover was observed in the third season of implementation time which was 40.96 while the lowest biomass production was observed in the first season of implementation period which was 31.26.

Table 8: ANOVA (LSM and SE) of Basal Cover in Different Restoration methods within the Consecutive Implementation Years

Treatment Combinations		Basal Cover		
		Year 1	Year 2	Year 3
Annual	Control	25.56 + 2.25[c]	28.7+2.32[b]	31.0 + 2.21[a]
	Ri+Mu+Se	28.6 + 1.55[b]	31.13+3.88[a]	31.96+2.55[a]
	Ri+Ma+Se	30.33 + 2.80[b]	33.0+3.17[a]	34.23+3.16[a]
	Ri+Ma+Mu+Se	31.26 + 2.71[c]	34.9+2.20[b]	40.96+1.98[a]
Mixed	Control	29.7+2.99[c]	33.2+2.58[b]	36.1+3.31[a]
	Ri+Mu+Se	32.9+2.65[c]	36.5+1.87[b]	40.53+3.23[a]
	Ri+Ma+Se	36.1+2.26[c]	43.1+2.88[b]	49.26+3.49[a]
	Ri+Ma+Mu+Se	42.2+3.05[c]	47.8+2.15[b]	56.93+2.90[a]
Perennial	Control	35.2+3.148[c]	42.9+3.14[b]	48.33+5.95[a]
	Ri+Mu+Se	43.6+2.48[b]	47.23+2.45[b]	61.26+2.83[a]
	Ri+Ma+Se	49.4+3.36[b]	47.4+3.38[b]	65.93+4.10[a]
	Ri+Ma+Mu+Se	51.0+4.08[b]	53.0+2.4[b]	74.1+4.01[a]

✓ a-c means with different superscripts letters along column differ significantly (p<0.05)

5. Conclusion & Recommendation

5.1 Conclusion

Generally from this finding we concluded that, implementation of different Restoration methods within three categories of plant communities has been improved range species composition, basal cover & biomass production compared with the control one. In Annual plant community with Restoration Methods of Ri + Ma+Mu+Se showed good performance in biomass production than the other treatment combinations. The higher biomass production was harvested from the treatment combination of annual plant community with Restoration Methods of Ri+Ma+Mu+Se in the 3rd season which was 1.81 tone/ha and the lowest result was the treatment combination of annual plant community with control one in the 1st season which was 0.22 tone/ha. In Mixed plant community with Restoration Methods of Ri + Ma+Mu+Se showed good performance in biomass production than the other treatment combinations. The higher biomass production was harvested from the

treatment combination of mixed plant community with Restoration Methods of Ri+Ma+Mu+Se in the 3rd season which was 1.75 tone/ha and the lowest result was the treatment combination of mixed plant community with control one in the 1st season which was 0.83tone/ha

Therefore, we conclude that from this finding, perennial plant community with Restoration methods of Ri+Ma+Mu+Se is more effective method to rehabilitate denuded rangeland areas in semi-arid areas and also Annual plant community with Restoration methods of Ri+Ma+Mu+Se has shown dramatic result to improved range resources within short period of time. However, continuous onsite training & practical demonstration was very crucial to enhance the adoption rate of those Restoration methods.

5.2 Recommendation

The following recommendations were derived from the data of the study and the observations during experimentation period

- ✓ Verification of the best suitable Restoration methods in order to promote at wide scale
- ✓ Continues awareness rising to the community about the best suit Restoration methods

6. References

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