Improving the productivity of degraded pasture land through demonstration of legume forage over sowing: The case of Ayba pasture land, South Tigray, Ethiopia

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Improving the productivity of degraded pasture land through demonstration of legume forage over sowing: The case of Ayba pasture land, South Tigray, Ethiopia

Tesfay Atsbha¹, Solomon Wayu², Hagos Kidane³, Kiflom Degf² and Girmay Abreha²

Abstract: The study was undertaken in Northern Ethiopia, at Emba Aloje District, to assess forage yield of the natural pasture over sown with adapted legume forage. The design was a single plot design and the treatments were farmers’ practice and Vicia sativa over sown. A total of 60 quadrats of 1 by 1 m² size were used for herbaceous species composition, above ground biomass and dry matter yield and analyzed by t-test equal variances using R-software. Over sowing legume forage increased dry matter yield significantly as compared with the farmers’ practice pasture land. The higher dry matter yield was recorded for pasture land over sown with Vicia sativa (3.43 ton/ha). Vicia sativa over sown also increased the basal cover of herbaceous (2.28) compared to farmers’ practice (1.47). Similarly, the Vicia sativa over sown pasture land had significantly (p < 0.001) higher forage biomass than the farmers’ practice area. Results from the comparative analysis also indicated that Vicia sativa over sown on the degraded grazing land had a higher cost effective than the existing farmers’ practice as the calculated net return was found to be

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Tesfay Atsbha, MSc in Range Ecology and Biodiversity from Haramaya University and BSc degree in Animal and Range Sciences from Hawassa University, Ethiopia. My research interests and areas of expertise include species diversity monitoring, assessment of carbon sequestration, restoration/rehabilitation of range land and pasture land. Together with colleagues, he has more than 20 publications in peer-reviewed journal mainly related to species biodiversity (ecological rehabilitation, restoration and carbon sequestration with climate change). The research reported in this paper is part of a project that mainly promotes the enhancement of pasture land through legume over sowing. Hence, this paper has its own contribution in achieving the aim of the project which is stated as to enhance pasture land productivity for improved livestock feed scarcity. Now, he is engaged in researches related to range ecology and biodiversity at Tigray Agricultural Research Institute, Tigray, Ethiopia.

PUBLIC INTEREST STATEMENT

Over sowing adapted legume species for rehabilitation of degraded pasture land is one of the best solutions to improve the quality and quantity of natural pasture. The objective of this study is then to demonstrate adapted legume species for over sowing and investigate their role in improving the productivity of degraded natural pasture land. The study was conducted at the highland of Northern Ethiopia, Southern Zone of Tigray, Emba Aloje district. The result showed that pasture land over sown with Vicia sativa has a higher annual dry matter yield, forage biomass, dry matter percentage and basal cover than adjacent farmer’s practice pasture land. In general, the community had an interest to rehabilitate their pasture land through Vicia sativa over sowing after they had seen the pasture land productivity. Over sowing of Vicia sativa pasture had higher biomass yield and it is economical to use it for improving degraded pasture lands.
positive. It is, therefore, concluded that over sowing degraded grazing land with Vicia sativa improves biomass yield, and it is also cost-effective as compared with farmers' practice. Therefore, based on the finding of the study it is highly recommended that the concerned governmental and nongovernmental organization should give emphasis to promote Vicia sativa over sown for the rehabilitation of degraded pasture land.

Subjects: Agriculture & Environmental Sciences; Conservation - Environment Studies; Biodiversity & Conservation; Ecology - Environment Studies

Keywords: over sowing; pasture land; South Tigray; Vicia sativa; management

1. Introduction

Natural pasture and crop residues are poor in quality and provide inadequate protein, energy, vitamins and minerals (Daniel, 1990). Thus, the existing feed resources do not meet the nutrient requirements for growth and reproduction of animals. It is therefore one of the major constraints to livestock productivity. Pasture management can provide significant benefits including improved forage yields, lower feed costs and improve livestock performance (Abadi et al., 2017). In order to increase the availability of feed resources, pasture land management practice needs to be improved. More sustainable management of the land can be achieved through improved agricultural management, such as over sowing with Nitrogen-fixing legumes (Nebi, 2018). Grass-legume mixtures offer many benefits compared with grass monocultures (Peyraud et al., 2009): they provide nitrogen to the plant-soil-system and thus reduce fertiliser costs, increase forage intake, and make it possible to extend the harvesting period without compromising forage quality.

Legumes provide many benefits to as pasture system and do not need any nitrogen fertilization. They improve the seasonal distribution of forage dry matter by boosting summer production and they improve protein levels and overall digestibility of the forage. If a pasture mainly composes of unproductive native grasses, there may be a benefit of introducing improved legume species and varieties (Alemayehu, 2002). Over sowing is the simplest among forage development strategies and can be undertaken at a very low cost. It involves broadcasting or sowing improved forage species into common grazing lands, native pastures and degraded areas without any cultivation or other inputs (Alemayehu, 2002).

Over sowing natural pastures with adapted exotic legume species improved the dry matter yield and species composition than untreated natural pasture land. Over sowing adapted legume species for rehabilitation of degraded pasture land is one of the best solutions to the grazing lands in the high lands of Ethiopia to improve the quality and quantity of natural pasture. Over sowing of Vicia sativa pasture had higher biomass yield and it is economical to use it for improving degraded pasture lands (Tesfay et al., 2017). Studies show that the average dry matter yield for pasture land over sown with Vicia sativa (3.96 t/ha) and Vicia dasycarpa (3.12 t/ha) in the South Tigray (Tesfay et al., 2017). However, there was no demonstration of legume over sowing on degraded pasture land before this study in the study area. Therefore, the objective of this study was to demonstrate adapted legume species for over sowing and investigate their role in improving the productivity of degraded natural pasture land. The specific objective of this study was to demonstrate adapted legume species for over sowing and investigate their role in improving the productivity of degraded natural pasture land and to assess the perception of farmers’ on legume species for over sowing technology on the natural pasture land enhancements.
2. Materials and methods

2.1. Study area

The study was conducted at the highland of Northern Ethiopia, Southern Zone of Tigray, Emba Alaje District, Ayba “Kebele”, which represent the lowest administrative unit (Figure 1). The elevation of the area is 2350 m with an annual average rainfall of 912 mm and a mean daily temperature ranging between 9°C and 23°C. The rainfall pattern is bi-modal with the “Belg” rain (short rains) occurring March to May and the “Meher”, which is the main season, rain lasting from June to September. Major crops such as sorghum (Sorghum bicolor), teff (Eragrostis teff), maize (Zea mays), wheat (Triticum spp.), barley (Hordeum vulgare L.), faba bean (Vicia faba), field pea (Pisum sativum), linseed (Linum usitatissimum), onion (Allium cepa L.), pepper (Piper nigrum), cabbage (Brassica oleracea), fruits are grown in the study area (Girmay et al., 2014). Natural pasture is the major animal feed source in the area where farmers’ practice intensive pasture land grazing with higher rate of stocking, which leads to poor natural pastureland management.

2.1.1. Implementation of legume over sowing demonstration

After selecting the interested farmers, practical and theoretical training was provided to district experts, development agents and landless youth which enabled them to develop skills on the general management practice of pasture land. A total of 100 landless youth were participated and a total of 0.5 ha were covered by Vicia sativa over sown. Participant farmers had prepared their own pasture lands, which are used as inputs for the demonstration of the over sowing and the Agricultural Growth Program (AGP) project was provided the raw materials like vetch seed.

2.1.1.1. Study design and measurements. The study design was a single plot design. The treatments for the study were farmer’s practice and vetch over sowing. Farmers’ practice is a method of grazing livestock on a specific unit of land, where the animals have continuous, unrestricted access to the rangeland for a period of the year (referred to as growing season continuous grazing) (Vallentine, 2001; Verdoordt et al., 2010). An area was closed to livestock and protected by guards and bylaws against grazing and cutting during the wet season and grazed by livestock. The treatment variety was selected based on previous adaptability to the area and the potential to enrich the quality of the forage herbage. The amount of vetch seed rate that is used in the

![Figure 1. Map of study area (Ayba “Kebele”).](image)
Figure 2. Before over sowing (left side) and after over sowing (right side).

Figure 3. Pasture land with sativa over sown (left side) and farmers’ practice (right side).

Figure 4. Over sowing legume species (*Vicia sativa*).

Figure 5. Farmers’ practice (left side) and pasture land with sativa over sown (right side).
experiment was 30 kg/ha. The size of experimental plot was 100 m² (10 m × 10 m). Over sowing was performed on the onset of the main season rain. After sowing the plots were left to grow naturally without any intervention except protection from external disturbances such as human and animal interference. Data collected included biomass yield, perception data, pasture botanical composition (percentage) and dry matter yield. For the determination of dry matter yield, forage samples were harvested at the end of the day (90 days).

2.2. Sampling procedure

2.2.1. Forage sampling procedures
A sixty 1 m by 1 m quadrat were placed randomly in every plot. Botanical composition percentages and total dry matter yield were determined by harvesting from three times laid quadrates of size 1 m × 1 m from each plot randomly at its 50% flowering stage, at a height of 5 cm near the ground. After harvesting, the total fresh weight of the forage sample from each quadrat was measured immediately for biomass yield determination using a sensitive balance. Sub-samples representing 10% of the whole forage samples harvested from the treatments were taken for determination of dry matter yield.

2.2.2. Dry matter yield
The dry matter yield of each quadrat was determined by drying a representative sample in an air dry for partial dry matter determination. The dry matter yield of each quadrat was converted to tons per hectare after drying. Dry matter production was calculated through the values of green production and dry weight percentage. Dry matter percentage = dry weight/fresh weight ×100. The dry matter production (ton/ha) was calculated as (10 × TotFW × (DWss/HA × FWss)) (Tarawali, 1995). Where TotFW = Total fresh weight, DWss = reweight subsample, FWss = Fresh weight subsamples and HA = Harvesting area.

2.2.3. Basal cover
In each quadrat, the basal cover or area (the area occupied at the intersections of the plant-soil interface) of the living plant parts was estimated. Basal estimation has done by clipping for clear observation, accordingly plants basal covers in the quadrats were cut, to facilitate visual estimation of the basal cover of living plant parts. The basal cover rating of the quadrats was considered “excellent” when completely filled (>75%), “good” when partially filled (60–74%), “poor” when 50–69% filled, “very poor” when <50% filled.

2.2.3.1. Farmers’ perception. Farmer’s perceptions were collected from randomly selected 45 participant farmers through participatory rural appraisal approach using group discussion to compare the improved technology (legumes over sowing) and farmers’ practice.

2.3. Comparative analysis
The comparative analysis included the variable costs and benefits for the calculation. Net return was calculated to determine the profitability of Vicia sativa over sowing following Upton formula (Upton, 1979). The gross field benefit per day was calculated by dividing the final sell of the biomass. Net Return or net benefit was calculated as the amount of money left when total variable costs are subtracted from total returns or gross field benefit. The cost was calculated based on cost needed for the different activities and inputs used for the application. However, the cost of harvesting and transporting ripe hay from pasture was not calculated.

2.4. Statistical analyses
Data collected from herbaceous vegetation composition, aboveground biomass, dry matter yield, basal cover and dry matter percentage were analyzed by t-test with equal variances to determine if there were significant differences between means of the various herbaceous characteristics with respect to different land management practice using R-software version 3.3.3 (The R Core Team, 2017). Significant differences were declared at p ≤ 0.05. Farmer’s perception data were analyzed
using SPSS version 20 and means comparison was tested using the t-test of Independent Samples Test with Levene’s Test for Equality of Variances.

3. Result and discussion

3.1. Botanical composition

Natural pastures are composed of grasses, legumes, sedges and other heterogeneous plants in various families, which could be herbaceous or woody forms (McIlroy, 1972). Pasture component species, grasses, existing legumes and others were significantly different (p < 0.001) among all the treatments and higher results of grass composition were obtained for untreated pasture (69.4%), followed by Vicia sativa sown pasture (53.27%). The composition of treatments in the demonstration site for Vicia sativa was 20.4% (Table 1). These findings suggest that grass-legume mixtures offer a great potential for increased production (Finn et al., 2013; Lüscher et al., 2014; Nyfeler et al., 2009). The composition of Vicia sativa and Vicia dyscarpa in the pasture land sown with Vicia sativa and Vicia dyscarpa was 39.3% and 33.3%, respectively (Tesfay et al., 2017). Grass-legume mixtures (over sowing) have the potential to increase productivity, herbage nutritive value and resource efficiency (Peyraud et al., 2009). Over seeding forage legumes into existing pasture may help to reduce forage deficit on small and resource-limited small farms (Bartholomew, 2005; Bartholomew & Williams, 2010). Forage legumes generally have higher nutritive value than grass species, and therefore, growing grasses and legumes in mixtures can improve herbage nutritive value compared with grass monocultures (Zemenchik et al., 2002). The resulting benefits include reduced dependence on fossil energy and industrial N-fertilizer, lower production costs, higher productivity and increased protein self-sufficiency (Lüscher et al., 2014).

3.2. Dry matter yield

The annual dry matter yield of the natural pasture was significantly affected by legume over sowing (Table 2). The higher yield was recorded on pasture land over sown with Vicia sativa (3.43 ton/ha) and 17.06% higher than that of the adjacent farmer’s practice. The result was similar with Tesfay et al. (2017), in Southern Tigray, who observed increased dry matter production of a natural pasture over sown with Vicia sativa (3.96 ton/ha). Other authors have reported increase in pasture production when suitable pasture legumes were successfully incorporated (Walker, 1969; Stobbs, 1969; Lwoga, 1983). There were significant variations in total fresh biomass yield of the natural pasture with the over sowing and farmers’ practice (P < 0.001) (Table 2). Aboveground biomass of herbaceous species was higher in the over sowing area than farmers’ practice (19.03 and 10.29 ton/ha, respectively). The mean aboveground biomass yield measured in over sowing was 84.94% higher than that of the adjacent farmer’s practice. The results indicated that over sowing legume species like Vicia sativa for pasture plots resulted in increased biomass production in comparison with non over sowing (farmer’s practice). Cropping mixtures/Over sowing could be a promising strategy for sustainable increase (Loreau & Hector, 2001; Loreau et al., 2001). Cardinale et al. (2007) found that over sowing, on average, achieved a yield benefit of +77% compared with the average monoculture. The yield advantage of the average mixture (over sowing) was 18%, when compared with the mean yielding monoculture (Finn et al., 2013). Over sowing had a highly significant effect on the pasture land yield (Finn et al., 2013; Kirwan et al.,

| Treatments        | Species composition (%) |
|-------------------|-------------------------|
|                   | Grass | Natural legume | Vicia sativa | Forbs    |
| Farmers’ practice | 69.4  | 9.33           | *            | 21.6     |
| Vicia sativa      | 53.27 | 18.62          | 20.4         | 7.72     |
| P value           | <0.001| <0.001         | <0.001       | <0.001   |

*Absence.
These findings suggest that grass–legume mixtures offer a great potential for increased production (Connolly et al., 2013; Lüscher et al., 2014; Suter et al., 2010). There was a highly significant difference (p < 0.001) in the dry matter percentage of herbaceous plants between legume over sowing plot and farmers’ practice plot. The over sown plot had a higher dry matter percentage than the farmers’ practice plot (Table 2). The basal cover was significantly increased by treatment application (P < 0.001) relative to the farmers’ practice plot (Table 2). The highest mean basal cover (2.28) was recorded in plots treated with over sowing legume, while the lower (1.47) was observed under farmers’ practice plot. Therefore, the present study confirmed that over sowing legume species would promote the re-vegetation of various herbaceous species that might lead to higher basal cover.

### 3.3. Farmers’ perception

Farmer’s selection criteria on pasture land for pasture land rehabilitation purpose are shown in Table 4. Based on farmers’ selection criteria, over sown pasture had significantly (P = 0.05) mean score over farmers’ pasture land on production performance (Table 3). However, the farmers perceived negatively on the cost effective and simplicity of the technology when compared with their practice (farmers’ practice). Besides this, farmers were perceived positively on Vicia sativa over sowing in terms of the amount of hay yield increment, forage quality enhancement, species composition increment and basal cover.

| Parameters                  | Farmers’ practice | Vicia sativa over sown | P-value | t-value |
|-----------------------------|-------------------|-------------------------|---------|---------|
| Amount of hay yield increased | 1                 | 5                       |         |         |
| Forage quality enhanced     | 1                 | 5                       |         |         |
| Soil fertility improved      | 1                 | 5                       |         |         |
| Cost effectiveness          | 4                 | 1                       |         |         |
| Simplicity to apply         | 4                 | 1                       |         |         |
| Species compositions increased | 1               | 5                       |         |         |
| Basal cover enhanced        | 1                 | 5                       |         |         |
| Total score                 | 13                | 27                      | 0.05    | −2.17   |
| Mean                        | 1.86              | 3.86                    |         |         |

NB: score (1–5); 1 = low and 5 = very high.
cover enhancement (Table 3). Generally, the community had an interest to rehabilitate their pasture land through *Vicia sativa* over sowing after they had seen the pasture land productivity. Hence, it is quite an evidence that farmers in the Ayba kebelle clearly show the effect of *Vicia sativa* over sowing on pasture land to boost production and productivity of the degraded pasture land. Therefore, this positive observation of farmers on the application of *Vicia sativa* over sowing on pasture land has an implication for further scaling up of the practice in the whole pasture land Ayba kebelle and beyond in other kebelles in the district.

### 3.4. Comparative analysis

*Vicia sativa* over sowing to pasture land costs about ETB 1900 per hectare while the conventional practice had no cost of production as indicated below (Table 4). Although legume over sown forage production has cost implication, it yielded a higher dry mass harvested from this production method which also resulted in higher net benefit (ETB 24010). Legume over sown pasture land had shown about 50.92% additional net benefits over the conventional practice. Over sowing of the natural pasture with legume species increased biomass production, it is economical to apply these as degraded land improving legume species (Tesfay et al., 2017).

### 4. Conclusions

Over sown natural pasture has significantly higher dry matter yield and dry matter percentage than the untreated natural pasture land. This showed that over sowing adapted legume species has a positive impact on pasture land enhancement. Over sown natural pasture have also significantly higher basal cover and forage biomass than farmers’ practice. Generally, over sowing adapted legume species for rehabilitation of degraded pasture land is one of the best solutions to the pasture lands in the high lands of Ethiopia to improve the quality and quantity of natural pasture. Hence, over sowing of *Vicia sativa* pasture had higher biomass yield and it is economical to use it for improving degraded pasture lands.

### Table 4. Partial cost-benefit analysis

| Variable costs                      | Legume over sowing | Conventional practice |
|-------------------------------------|--------------------|-----------------------|
| Cost of seed (ETB/Qt)               | 900                | 0                     |
| Cost of labour (ETB)                | 1000               | 0                     |
| Total variable cost (ETB)           | 1900               | 0                     |
| Yield of dry mass or hay (ton/ha)   | 3.43               | 2.93                  |
| Price of hay (ETB/ton)              | 7000               | 5000                  |
| Total return from sale of hay (ETB) | 24,010             | 14,650                |
| Net return obtained (ETB)           | 22,110             | 14,650                |
| ΔTVC                               | 1900               |                       |
| ΔNR                                | 7460               |                       |
| Advantage over the technology in %  | 50.92              |                       |

ΔNR = change in net return; ΔTVC = change in total variable cost, Qt = quintal, ETB = Ethiopian Birr.

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### Competing interests

We declare that we do not have competing interests.

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Authors’ contributions
TA and SW planned the study, collected data, and prepared the first manuscript. HK, KD and GA, commented on the study plan, data analysis and commented and revised the draft manuscript.

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