



Reviving the rangelands: Silvopasture approaches for profitable land restoration

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Abstract

Rangelands cover more than half of the world's land area, providing vital support for around 500 million pastoralists and playing a key role in global livestock production and the livelihoods of pastoral communities. However, approximately half of these rangelands are degraded, negatively impacting both livestock production and pastoralist well-being. This underscores the urgent need for sustainable interventions to restore these ecosystems and improve global livestock production and pastoralist livelihoods. Transforming rangelands into more productive and climate-resilient systems, such as silvopasture (SPS) offer a promising solution. Research conducted by ICAR-IGFRI, Jhansi, India, in degraded semi-arid rangeland conditions of Bundelkhand converted to SPS via planting with native fodder trees, shrubs, and pasture species revealed significant findings. Under 12-years of evaluation, SPS was found to produce year-round fodder, with grasses yielding approximately 30–40 Mg ha⁻¹ yr⁻¹ green fodder and forage legumes yielding 10–12 Mg ha⁻¹ yr⁻¹ green fodder, supplying high-quality fodder from July to December. Trees produced 12–15 kg/tree of green top feed, and shrubs yielded around 7–8 kg/shrub of green top feed, ensuring supply of green fodder during lean months from December to June. These SPS systems were estimated to maintain 4–5 ACU ha⁻¹ yr⁻¹ and in addition to it sequestered 14.35 to 30.68 Mg C ha⁻¹ in above and below-ground biomass, equivalent to 52.66 to 112.60 Mg ha⁻¹ of atmospheric carbon dioxide equivalent storage. Furthermore, the SPS accumulated 31 to 48 Mg C ha⁻¹ in the soil layer up to 60 cm and released around 38.31 to 81.92 Mg ha⁻¹ of oxygen under various trees, shrubs, and grass/legumes combinations. The eco-restoration efficiency of these SPS systems was also found to be approximately 10 times greater than that of fallow land and also boosted TOC by 2–3 folds in soil over fallow land. The findings clearly demonstrate effectiveness of SPS as a climate-resilient approach for transforming degraded rangelands into profitable land use system ensuring diversified production and income generation to pastoral communities.

Introduction

Over half of the Earth's land area is occupied with the rangelands ecosystem which is very crucial for sustaining global livestock production and livelihoods of more than 500 million pastoralists. However, rangelands are currently facing degradation owing to overgrazing, developmental activities, fire, climate change etc. which is hampering livestock production, livelihood of pastoralists and ecosystem services negatively (UNCCD 2024). Thus, there is an urgent need to restore these ecosystems and sustain livestock production, pastoral livelihoods and

ecosystem services in long run. Restoring degraded rangeland via transforming them to silvopasture systems offers a nature based solution to enhance productivity, carrying capacity, climate-resilience and ecosystem services in rangeland ecosystems. Considering this, a study for 12 years was conducted on silvopasture systems established on semi-arid central India's degraded landscapes with the aim to find out the fodder production potential, carrying capacity, carbon storage and oxygen release potential of SPS.

Methods

The silvopasture systems (SPS) consisting of indigenous high value fodder trees of semiarid zone viz. *Ficus infectoria*, *Morus alba*, *Acacia nilotica*, and a shrub *Leucaena leucocephala*; perennial grass species *Megathyrsus maximus* and *Chrysopogon fulvus* along with the perennial fodder legume *Stylosanthes seabrana* was studied for 12 years. The study receives average rainfall of 867 mm/annum; is prone to drought; and faces high temperature during summer (maximum: 47.4 °C in June); 4.1°C of minimum temperature in December with 60% mean annual relative humidity. Soil of the site is typical inceptisol having shallow depth, poor fertility, poor water holding capacity and low organic matter. Trees were planted at the spacing of 5 × 5 m; shrub at 5 m (row to row) × 2 m (plant to plant) and grasses as well as legumes at the spacing of 50 × 50 cm in rows between two trees/shrub rows.

The system was maintained in 4.32 ha area under rain-fed conditions and each treatment was replicated thrice under randomized complete block design. Green biomass yield of grasses and legume was measured by harvesting 1 × 1 m area at six random places in each plot and then calculated per hectare basis as Mg ha⁻¹ (green fodder). For tree species, canopies were imposed to 30% pruning and shrub was pollarded at 1 m height and green pruned fodder biomass (leaves and soft twigs) per tree/shrub was recorded and was calculated per hectare basis as Mg ha⁻¹.

Total biomass carbon stock of trees, grasses and legume species under silvopasture system was calculated by adding their per hectare above ground biomass carbon (AGBC) and below ground biomass carbon (BGB) content. Above ground biomass carbon (AGBC) stock of trees/shrub, grasses and legume species was calculated by multiplying respective dry above ground biomass with a conversion factor of 0.50 and was expressed as Mg C ha⁻¹ (IPCC 2006). Below ground biomass carbon (BGBC) stock of trees/shrub was calculated by multiplying AGBC with 0.26 (IPCC default value: IPCC 2006) and of grasses/legume by multiplying AGBC with their root: shoot ratio (*C. fulvus*: 0.59; *M. maximus*: 0.51; *S. seabrana*; 0.44). Finally total biomass carbon stock under each SPS was calculated by adding total biomass carbon stock of the respective trees/shrub with total biomass carbon stock of grasses/legume under each combination. This total carbon stock potential was converted to carbon-dioxide mitigation potential or carbon dioxide equivalent storage (CO₂e) (carbon stock × 3.67) as per IPCC (2006). Soil carbon stock in system was calculated as per the methodology of Ghosh et al. (2018) using fallow land as a reference. Total oxygen release in the system was calculated as Mg ha⁻¹ using the formula (total oxygen release = total carbon stock (Mg ha⁻¹) × 32/12) (Nowak et al. 2007, Keerthika and Chavan 2022). Data were analyzed using analyses in online OPSTAT software, a statistical software package for agricultural research workers (Sheoran et al. 1998).

Results

Twelve years of evaluation of SPS revealed that the grass component have green fodder biomass production potential of around 30–40 Mg ha⁻¹ yr⁻¹ and forage legumes component have green fodder biomass production potential ranging between 10–12 Mg ha⁻¹ yr⁻¹. Grasses and legume are capable of ensuring quality green fodder supply from July to December months. The trees have potential to produce 12–15 kg/tree of green top feed, and shrubs have potential to produce around 7–8 kg/shrub of green top feed during lean period from December to June months. These SPS can easily sustain 4–5 ACU (Adult Cattle Unit) ha⁻¹ yr⁻¹ along with ensuring round the year quality green fodder supply for livestock.

Biomass carbon storage studies revealed that these SPS have a huge capacity to store between 14.35 to 30.68 Mg C ha⁻¹ in above and below-ground biomass under various trees/shrub and grasses/legume combinations. This carbon stored in biomass is equivalent to sequestration of 52.66 to 112.60 Mg ha⁻¹ of CO₂e. In addition to this, these SPS can accumulate around 31 to 48 Mg C ha⁻¹ in the 0-60 cm soil layer (Kumar et al. 2022). Further, the oxygen release capacity of these SPS is around 38.31 to 81.92 Mg ha⁻¹ of oxygen under various trees, shrubs, and grass/legumes combinations. Moreover, these SPS have also been reported to have eco-restoration efficiency of approximately 10 times greater than that of fallow land and have capacity to enhance total organic carbon content by 2–3 times in soil over fallow land (Kumar et al. 2022).

Discussion

Thus, twelve years of evaluation of these SPS under semi-arid conditions at Jhansi, India demonstrated that establishing these systems on degraded landscapes including rangelands can sustain round the year quality fodder supply and thereby ensure pastoral livelihoods in the long run. Besides this, silvopasture systems can help in mitigating climate change via carbon storage in biomass, thus helping to offset the green house gases emission from grazing livestock. Huge oxygen release capacity of these SPS makes them viable option to help in oxygen shortage owing to rising pollution. Prioritizing the establishment of SPS on degraded rangelands, underutilized wastelands, permanent grasslands, and pastures across various agro-climatic regions in India as well as across globe can help to address the ongoing need for premium-quality fodder, enhance livestock productivity, bolster pastoral economies, and promote environmental sustainability.

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