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Silvopastoral system: A prototype of livestock agroforestry

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Abstract
Traditional livestock production systems based on grass monoculture tend to exhaust natural resources in a process of continuous degradation. Alternatively, silvopastoral systems are a prototype of agroforestry with a livestock component and are characterized as cleaner production that provides four major environmental benefits: carbon sequestration and reduction in greenhouse gas emissions, biodiversity conservation, soil enrichment and improved air and water quality. Incorporation of a silvopastoral system increases the quantity and quality of wildlife habitat, provides wide range of versatility in potential outputs from the land base and yields economic returns that are comparable to other land uses. The strategies for promoting productivity growth will require concerted research and development on improved use of less fed areas, technology delivery, initial investments, a policy framework and improved farmer-researcher-extension linkages. Despite of the above discussed facts, silvopastoral systems are underestimated and underutilized throughout the developing countries.

Keywords: Agroforestry, carbon sequestration, clean production, economic, silvopastoral, wildlife

1. Introduction
Land, a non-renewable resource, is central to all primary production systems. An ever increasing population places enormous demands on land resources. These pressures on land are compounded by the fact that over 69 per cent of our geographical area falls within dry zone as per the Thornthwaite classification. They are in urgent need of attention and have to be accorded the highest priority for best utilization of these wastelands through proven silvopastoral systems (SPS). On a global scale, the livestock sector accounts for 9 per cent of anthropogenic carbon dioxide (CO_2) emissions, mostly derived from land use changes, especially deforestation and expansion of pastures and arable land for feed crops. Livestock are also responsible for emissions of other gases with higher potential to warm the atmosphere: the sector emits 37 per cent of anthropogenic methane, which has 23 times the global warming potential (GWP) of CO_2, and it also emits 65 per cent of anthropogenic nitrous oxide (N_2O) which has 296 times the GWP of CO_2. In tropical regions about 40 per cent of GHG emissions from cattle (mainly CH_4) are from enteric fermentation [39]. Cattle production systems need to balance trade-offs among resource use and GHG emission. SPS can help mitigate climate change. As climate change takes effect, the land available for crop production contracts and this will place much stress on food production systems. The decreased availability of arable land in the future can increase the vulnerability of the poor who live by the land, which is of great concern and likely to be a major issue for discussion. Further biodiversity of species has been reduced to a few key productive economic species and regeneration of woody species has been suppressed. This allows energy and nutrient flows to be channelled into a narrow range of plant and animal products. Increasing the biodiversity of grassland ecosystems through introduction of SPS is likely to have many benefits to the farming system, i.e. stabilizing soil, providing shelter and shade to animals [17], diversification of income through tree products, enhancing soil fertility [16] and increases water and carbon retention in the soil.

2. What is Silvopastoral system (SPS)?
The term ‘silvo’ means ‘tree’ and ‘pasture’ means ‘grasses’ or ‘grass + legume’ mixtures. SPS are agroforestry arrangements that intentionally combine livestock production with rotational grazing using ideal combination of grasses, legumes and trees as a three dimensional feed source, for producing highly nutritious top fodder and forage, fuel wood, timber and optimising land productivity, conserving plants, soil and nutrients etc. on sustainable basis on

the same unit of land. This involves replantation, substitution or intervention in the existing vegetation by desirable species [10]. SPS makes all components mutually beneficial. They provide nutrient recycling; connectivity among ecosystems; and scenic beauty. Thus, these systems benefit society on the local/producer level as well as on the regional/landscape and global levels as compared to conventional pastures dominated by monocultures. This is a prototype of livestock agroforestry for cleaner production. This system is characterized by a low level of technological development, little use of external inputs, diversified resource use, and a management calendar adapted to the variable local environmental conditions. The multifunctional role of agro ecosystems has also been emphasized by both the [26, 21]. There is also a great deal of interest in providing financial benefits to landowners and farmers for land-use practices that maintain environmental services of value to the wider society [12]. There are three basic components in SPS *viz*., Agriculture, Forestry and Livestock where they form two important systems with livestock:

a) Silvipastoral system (Forestry + Livestock)
b) Agrisilvipastoral system (Agriculture + Forestry + Livestock)

3. Factors affecting SPS

The main factors affecting pasture in a SPS are light i.e. photosynthesis and supply of carbon and nutrients and transformations. Nutrient flow is influenced by the timing, quantity, quality and decomposition rate of litter, all of which are determined by the functional tree type. Quantity of litter entering the system varies throughout the year depending on the tree species. High quality litter (high N, low lignin) will decay and release nutrients quickly whereas that of low quality (low N, high lignin) will decay slowly [42]. Microbial activity will also assist in comparing rates of decomposition from the different functional tree types [44]. A mixture of litter types with different release patterns in terms of evergreen and deciduous trees ensures minimal leaching from the system. Therefore planting mixtures of trees or having different pruning managements would be beneficial for manipulating the timing of nutrient release so as to benefit pasture growth.

4. Types of SPS

Based on different arrangements of the natural elements (grasses, shrubs and trees), as well as specific cropping management options, SPS is grouped into the following types: a) live fences, b) dispersed trees, c) pastures under forest plantations, d) protein banks, e) intensive silvopastoral systems [36].

a) Live fences consist of on-line plantings of trees and/or shrubs in order to fence off crops, pastures or boundaries between properties. Such fences do not only contribute to the existing vegetation and wild animal conservation; they offer wood, firewood, fruit and livestock fodder, too.
b) Dispersed trees is a type of SPS that has only few trees (individual or grouped) not exceeding 10 per cent to 15 per cent of the total area, with the benefits of providing timber, shade and fodder. Due to the consumption of leaves and fruits produced by the trees, there is also an improvement in livestock feeding.
c) Pastures under forest plantations involve the planting of pastures under forest. Livestock production provides additional incomes in addition to the forestry activity, generated before the harvest of the trees. Furthermore, costs for weed control and pasture management are reduced.
d) Protein banks are fodder banks where trees, shrubs and pasture legumes with high protein-containing leaf biomass are combined. Trees are planted as close as 1 m x 1m and cut regularly to induce maximum herbage production.
e) Intensive SPS are a type of SPS that combines high-density cultivation of fodder shrubs (4000 to 40000 plants per ha) with improved tropical grasses and trees species or palms at densities of 100-600 trees per ha. These systems involve rotational grazing with occupation periods of 12 to 24 hours and 40 to 50 days of resting periods, including ad libitum provision of water in each paddock [5].

5. Favourable grasses, legumes, shrubs and tree species for development of SPS in India

Favourable grasses, legumes, shrubs and tree species for the development of SPS in India are represented in Table 1 [35].

Table 1: Favourable grasses, legumes, shrubs and tree species for development of SPS in India

Zones/Soil	Area/State	Grasses	Legumes	Shrubs	Trees
Arid desert and sand dunes	Thar desert	*Lasiurus sindicus, Cenchrus ciliaris* and *C. setigerus*	*Clitoria ternatea, Lablab purpureus* and *Atylosia scarabaeoides*	*Zizyphus numularia*	*Prosopis cineraria, Azadirachta indica* and *Acacia tortilis*
Semi-arid, rocky and gravelly areas		*Heteropogon contortus* and *Sehima nervosum*	*Stylosanthes hamata, Macroptilium lathyroides* and *Lablab purpureus*		*Dalbergia sissoo, Leucaena leucocephala* and *Emblica officinalis,*
Cold desert	North of Great Himalayas	*Cicer, Melilotus* and *Trifolium spp.*			
Ravine soils	Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat	*Cenchrus spp., Pennisetum pedicellatum* and *Dichanthium annulatum*	*Clitoria ternatea, Alysicarpus monilifer* and *Stizolobium deeringianum*	*Dichrostachys* Spp., *Zizyphus numularia* and *Capparia zeylanica*	*Acacia spp., Ficus spp.* and *Bauhinia purpurea*
Saline sodic soils		*Brachiaria mutica, Cynodon dactylon* and *Panicum maximum*	*Clitoria ternatea, Mimosa invisa* and *M. atropurpureum*	*Sesbania, Atriplex* and *Acacia spp.*	
Acidic soils	East India	*Pennisetum polystachyon, P. pedicellatum* and *P. clandestinum*	*Centrosema pubescens, Stylosanthes guianensis* and *Desmodium spp.*		*Ficus numeralis, Albizia chinensis* and *Morus cerrata,*
Swampy and	South and East	*Brachiaria mutica,*	*Sesbania* spp.,		*Salix tetrasperma,*

wet lands	India	*Dichanthium caricosum* and *Brachiaria decumbens*	*Desmanthus virgatus* and *Glycine wightii*		*Eucalyptus robusta* and *Glyricida maculata*
Cho and riverbed affected soils	Sub-mountain regions of the Himalayan	*Chrysopogon fulvus, Dichanthium annulatum* and *Eulallopsis binate*	*Stylosanthes guianensis* and *Calapogonlum mueunoldes*		*Salix spp., Acacia catechu* and *Zizyphus spp.*
Mine's affected areas		*C. fulvus, P. pedicellatum* and *P. maximum*	*S. hamata, A. scarabaeoides* and *M. atropurpureum*		*Acacia species, Albizia species* and *A. indica,*

6. Benefits of SPS

6.1 Silvopasture improves association with wildlife species
In the first five-six years after establishment, the SPS will likely resemble an old-field or pasture and would be utilized by many wildlife species. The grass will attract grazers like deer. Flowering plants along field edges will attract insects that in turn attract perching birds. Loose soil will attract burrowers and rodents such as shrew, mole, rat, and mouse. Other wildlife species such as eastern fence lizard, hog nose snake, cotton tail, garter snake, wild turkey and red tailed hawk will use open grass or pasture land, expose seeds for food, and provide dusting areas for songbirds. The trees in the SPS will attract bark insect feeding birds like woodpecker. SPS, due to their inherent diversity, provide nesting and breeding areas, food, and cover for numerous wildlife species throughout the rotation. The species richness of SPS also makes them very attractive to other wildlife enthusiasts [18].

6.2 Silvopasture improves cattle production per hectare
[34, 9] have shown that the introduction of cattle to SPS has no negative effect on timber growth if introduction occurs after trees reach a height of 18 inches. Cattle will be introduced to the system in year two to allow time for forage and tree establishment [15]. Further, increased efficiency of cattle production per ha (up to 4-fold) with improved animal welfare was also reported by [36, 4].

6.3 Silvopasture improves soil properties
Greater uptake and cycling of nutrients, enhanced availability of nutrients from leaf-litter and enhanced resilience of the soil to degradation, nutrient loss, and climate change was reported by [31, 36]. It is illustrated that some soil quality parameters i.e. soil K (63-75%) and Ca (29-36%) were enhanced by the presence of tree species in SPS.

6.4 Silvopasture improves N-fixation
The protein content of SPS grasses was higher than the average content of tropical grasses which may be due to N-fixation of legumes (Leucaena) [27]. The fixation of nitrogen and the transformation of solar energy into vegetal biomass resulted in higher meat/milk production per hectare. Further, it increased the numbers and the variety of native bird species which enhances environmental services related to pollination, seed dispersion, and biological control of insect pests and reduces water consumption for irrigation. The number of bird species increased by 200 per cent and there were also increases in the numbers of butterflies. The meat production in SPS was 7.9 to 10.7 times higher than in traditional systems and the land productivity, measured in litres of milk per hectare, increases by 52-112 per cent after stabilizing the SPS [36].

6.5 Silvopasture for species richness
Ant richness was 60-62 per cent higher in intensive SPS [38], and dung beetle abundance and diversity were more than two times higher in relation to pasture monocultures [13]. Higher diversity in farm production increases the family incomes after the stabilization period of 5-6 years.

6.6 Silvopasture improves biomass productivity
The biomass production of SPS is higher and is attributed to a better use of vertical space, both aerial and underground, which implies a higher uptake of nutrients and energy [3]. The forage production has increased by 7 times over the initial situation, and by the third year it has doubled. The improved quality of forage is verified in higher digestibility and more energy, protein and other nutrients available. This allowed increasing fivefold the number of animals. The degraded waste lands (shallow red gravelly soils) under semi-arid condition at Jhansi, India producing 1 t/ha/year have been improved to produce upto 10 t/ha/year at a 10 years rotation through SPS [33]. Besides yield improvement by 8 to 10 times, the quality of mixed forage has also improved by 6 to 7 times. There are also possibilities for feeding tree and shrub leaves to pigs, poultry, or farmed fish. Where shrubs and trees are too high for animals to reach, branches can be cut and offered to the animals. Three-level forage production produces more usable plant material than pasture only. Pasture plus *Leucaena* produced 29 per cent more mass and 64 per cent more protein than monoculture herbage-layer only systems. Meanwhile, association of leguminous trees with grasses in pastures has positive effects on yield of grasses, which are nourished with part of the nitrogen biologically fixed by the leguminous trees [29]. In this manner, traditional SPS help reduce environmental contamination while also enhancing production.

6.7 Silvopasture improves animal welfare
After SPS were adopted; the average body condition score was 3.3-3.5 with all animals appearing healthy, alert and with normal behaviour and no aggression. Access to green fodder of high quality, fresh clean water within 150-250m and shade provide an ideal habitat, with no signs of heat stress. Flight distance (a measure of fearfulness of people) was reduced in the SPS, standing at an average of 2-2.5 meters, possibly because of calm regular handling. Animal welfare is also favoured by the fact that cattle are managed in pastures with a high tree density and the trees protect the animals from inclement weather [25, 40]. This leads to improvement of environmental conditions required by the animals to develop their productive and reproductive functions and in general satisfy their physiological needs [29]. Similarly, production of weaned calves per year increased when animals were managed in pastures with a greater tree density. Moreover the beneficial effects of shade are substantial in hot weather with cattle skin temperatures up to 4 °C lower than in pasture only systems. High temperature increases water and energy loss and reduces foraging times in paddocks fully exposed to the sun. Less sun exposure results in less sun-burn, less cancer, and less photosensitisation. Feeding behaviour is improved at high temperature and humidity if the animals are in a SPS [7].

It may be that the improvement in dietary choice contributes to this beneficial effect [24]. More choice of food in SPS results in more control by each individual animal of its environment and thus social behaviour is more normal [1]. The social interactions in shade and social licking have increased by 57 per cent and 65 per cent respectively in semi intensive SPS as compared to monoculture pasture. Further more fights have been observed in monoculture pasture (around 37%) in comparison to semi intensive SPS. The increase in predators lowers the populations of ticks and injurious insects, such as horn flies, and hence reduces the incidence of diseases such as anaplasmosis, which has been shown to drop from 25 to <5 per cent [28, 4, 1]. It is illustrated that goats and sheep grazed on SPS gained (head/day) in their body weight at the rate of 28.6 g, whereas on natural grassland the gain was 10.8 g in goats. Similarly, lambs and kids grazed on silvopasture gained in their body weight at the rate (head/day) of 54.8 and 36.8 g, whereas on natural grassland showed 41.2 and 26.4 g weight gain, respectively.

6.8 Silvopasture improves environmental impact

This increase in biodiversity plays an important role in the biological control of pests. Increased biomass and vegetation cover reduce the effects of soil erosion, while changes in the water cycle - with highest retention and groundwater's use decrease the risks of drought. The cultivation of forage shrubs and their coexistence with pastures increased the amount of organic matter and nutrients in the soil which leads to Chemical and physical soil improvement. At the same time, the presence of nitrogen fixation legumes and the constant rotation of cattle eliminate the need for nitrogen fertilizers. Comparing baseline measurements with SPS already implanted, CO2 emissions were reduced by 9.3-12 per cent [36].

6.9 Silvopasture for increased net returns

There was a 35 per cent increase in costs during the period under review (implementation and maintenance of plant species, fences, technical advice, etc.), but after the 4th year once the SPS stabilizes, the returns increased by 80-130 per cent [36].

6.10 Silvopasture improves carbon sequestration and reduces greenhouse gases

A discussion on SPS is incomplete without a reference to carbon sequestration and greenhouse gases. It is defined as the complex and secure storage of carbon in biomass, leaf litter, roots and soil by preserving or planting trees in pastures, which also leads to increased soil organic matter and forage biomass [2] that would otherwise be emitted or remain in the atmosphere. A variety of studies of tropical zones have demonstrated that the quantity of carbon stored in the soil is much greater than that stored in tree biomass [6, 19]. The tree component alone of a fodder bank and protein bank of *Leucaena leucocephala* may store up to 15.3-19.6 Mg of carbon per hectare [8, 14]. Carbon sequestered in agroforestry systems could be sold in carbon credit markets where such opportunities exist. The largest amount and most permanent form of carbon may be sequestered by increasing the rotation age of trees and/or shrubs. The potential of agroforestry systems to sequester carbon varies depending upon the type of the system, species composition, age of component species, geographic location, environmental factors, and management practices. In a recent review, [30] showed that the carbon sequestration potential of the vegetation component (above and belowground) varied from 0.29 Mg ha^{-1} yr^{-1} in a fodder bank agroforestry system of West African Sahel to 15.21 Mg ha^{-1} yr^{-1} in mixed species stands of Puerto Rico. Soil carbon estimates ranged from 1.25 Mg ha^{-1} in a Canadian alley cropping system to 173 Mg ha^{-1} in an Atlantic Coast SPS in Costa Rica. These authors concluded that, in general, agroforests on arid, semiarid, and degraded sites had a lower carbon sequestration potential than those on fertile humid sites and temperate agroforestry systems had relatively lower rates compared to tropical systems. According to an estimate by [22], improving current management practices (e.g. better management of trees on croplands) in existing agroforestry practices could sequester an additional 17,000 Mg C y^{-1} by 2040. The presence of grazing ruminants will mean emissions of more CH_4 into the atmosphere, and their possible effects. However, in Colombia, in ISPS with leucaena, annual CH_4 emission per animal decreased by 38 per cent [32]. A reduction from 11 to 40 per cent in greenhouse gases emission was also verified in SPS [36]. Further 30 per cent less methane production per kg meat was illustrated in SPS. Mitigation and adaptation are important aspects of ways to cope with climate change [4].

6.11 Silvopasture for cleaner cattle production

The quantity of fixed nitrogen provides a valuable contribution to cleaner cattle production as its presence allows for avoiding use of chemically synthesized fertilizers which, aside from being costly, are produced using energy intensive processes, and they contain nitrogen in a form which may be harmful to soil microorganisms and contaminate soil, plants, and groundwater due to lixiviation [41]. Another advantage is that the efficiency of use of N fixed to the soil by leguminous trees is close to 100 per cent, as compared to 50-60 per cent for soil application of nitrogen fertilizers [39, 43].

6.12 Silvopasture increases Organic Livestock Proximity Index

The rate of the Organic Livestock Proximity Index (OLPI) [29] increases when pastures are managed to have a greater tree density. This index is an indicator of:

1. The level of use of agro-ecological technologies, which are environmentally friendly,
2. The extent to which producers respect the list of permitted, prohibited, and restricted substances stipulated by organic production standards, and
3. The quality of animal products obtained in the cattle raising units. The higher rate of OLPI in the two systems of pastures with trees is principally due to the fact that indicators for sustainable pasture management, animal welfare, and feed management included among OLPI's ten indicators have a high rate of approximation to organic production standards [20].

6.13 Silvopasture provides payment on international level for environmental services

The producers have the possibility of receiving payment on international level for environmental services, due to the fact that these systems allow for:

1. Mitigating effects of climate change through carbon capture and storage, principally by planting trees and increasing organic soil matter.
2. Reducing CO_2 emissions by avoiding slash and burn and deforestation due to reduced pressure on forests and jungles.

3. Reducing nitrous oxide emissions by reducing nitrogen fertilizer use.
4. reducing methane gas emissions by offering animals a variety of fodders with greater nutritional quality, greater digestibility, and a better pattern of ruminal fermentation; and
5. Reducing the impact of rain on the soil, thus increasing the soil's capacity for water infiltration and retention and diminishing surface run off [37].

6.14 Silvopasture improves hydric balance

An important aspect of SPS is that they improve the hydric balance, since, when woody plants and grasses share the same space, the lesser temperature of the herbaceous strata under the tree crown leads to a diminished transpiration rate and less evaporation [45]. This may retard or avoid hydric stress during the dry period. Perennial woody plants affect the water dynamic [37] by:

1. Acting as barriers which reduce runoff.
2. Reducing the impact of rain drops, and
3. Improving the soil by increasing water infiltration and retention. These impacts depend on tree size, principally height and crown cover.

6.15 Silvopasture for soil enrichment

Non N-fixing trees can also enhance soil physical, chemical and biological properties by adding significant amount of above and belowground organic matter and releasing and recycling nutrients in agroforestry systems. Further, higher soil carbon and nitrogen concentrations near the base of trees compared to 2 m away from the base in conventional systems, indicates the importance of shade trees in maintaining and enhancing soil organic matter. It is also suggested that arbuscular mycorrhizal (AM) inoculation may enhance the growth and phosphorus uptake of intercrops under tree shade in agroforestry system and made recommendations for tree canopy management to increase the efficiency of AM inoculants [23].

6.16 Silvopasture enhances biodiversity conservation

In general, silvopasture plays five major roles in conserving biodiversity:

1. Silvopasture provides habitat for species that can tolerate a certain level of disturbance.
2. Silvopasture helps preserve germplasm of sensitive species.
3. Silvopasture helps reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats.
4. Silvopasture provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and
5. Silvopasture helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat. Vegetation complexity might attract beneficial insect eating birds that could reduce insect damage, but complexity was also associated with greater prevalence of fungal leaf symptoms [23].

6.17Silvopasture improves air and water quality

Silvopasture practices such as windbreaks and shelterbelts are touted as having numerous benefits. These benefits include savings in livestock production by reducing wind chills, protecting crops, providing wildlife habitat, removing atmospheric carbon dioxide and producing oxygen, reducing wind velocity and thereby limiting wind erosion and particulate matter in the air, reducing noise pollution, and mitigating odour from concentrated livestock operations.

6.18 Silvopasture improves job satisfaction

Workers on silvopastoral farms reported better job satisfaction [4].

7. Failure in adoption of SPS

For a variety of reasons, the adoption rates of the system and methodologies continue to be very low and it is pertinent to enquire into the reasons for this situation, which are enumerated below [11]:

a. Poor awareness of the potential of integration and the benefits and value addition of SPS.
b. Strong resistance by the crop oriented plantation sector, and are least interested in introducing animals to the system.
c. Crop scientists and plantation managers all have a plant production background without any interest in animals.
d. This perception is also fuelled by high prices for the key commodities e.g. palm oil.
e. Additionally, they are also not interested in making more capital investments e.g. fencing and fodder production.
f. Inadequate technology application and week understanding of systems R and D.
g. Unattractive investment climate.
h. Shortage of estate workers.
i. Less conscious of climate change and their effects on the tree crops.
j. Absence of policies to encourage integrated/mixed farming systems.

8. Policy framework for SPS

The task of stimulating waning agriculture, encouraging growth and promoting SPS to enhance productivity, food security and a clean environment provides major challenge for R and D. These need to be fostered by vigorous policy requirements and are contemplated in the following [11]:

a. Strengthening of official policy to address waning agriculture, its revitalization efficiency in integrated NRM and intensification of production systems.
b. Priority for concerted R and D on rain fed agriculture and small farm systems that are progressive and can intensify.
c. Promotion of ways and means to enhance C sequestration and reduce emissions of GHG in SPS.
d. Integrated tree-crops-ruminant systems are underestimated. Policy interventions are required to stimulate their development.
e. Empowerment of women is central to enhance their effective contribution to the use of productive resources for food and nutritional security, and the stability of farm households.
f. Building systems R and D capacity to deal with complex problems of crop-animal-soil-water interactions and effects of climate change.
g. Micro credits should be made more accessible to small farms and the landless.
h. Improvements are necessary for rural-urban market linkages, collection and processing centres to reduce

transaction costs and in the value chain.

i. Increase investments and promote public-private sector partnerships for greater engagement and agricultural productivity.
j. Choice of trees and their provenance suitable to that locality to be encouraged. Preference should be given to indigenous and fast growing species. Adopt correct spacing recommended to each species with reference to soil and climate.
k. Crop combination in agri-silvopastoral systems should be selected with minimum negative interactions.
l. Ensure supply of quality seedlings/seeds to farmers by the agencies.
m. Imparting training to farmers in crop and animal husbandry for better management of farming.

9. Conclusion

SPS have shown to offer optimal conditions to deliver animal welfare and avoid the current challenges of extensive cattle ranching such as poor body condition and heat stress. SPS provides a better supply of fodder in terms of quantity and quality that meets nutritional needs, as seen in the good body condition for most animals assessed. The problem, fodder scarcity also gradually disappears with the establishment of the SPS on community and wastelands. The animals have freedom of movement and a diverse environment to express a wide range of behaviour. The biomass production has significantly increased, which is one of the key factors for increasing animal production, allowing better stocking rates. Assessing the environmental impact, SPS has proven several advantages over traditional systems. A denser vegetation cover protects the soil from erosion, and there is a better use of groundwater. Trees and fodder shrubs roots contribute to soil fixation, reducing the impact of erosive elements. Improved efficiency of NRM, concerted application of yield inducing technologies, and ways of mitigating and adapting technologies to cope with the effects of climate changes which can significantly enhance the capacity of food production are required. Social and effective development policies are also needed to spur sustainable increased agricultural productivity. Despite the disadvantage of requiring large initial investments, economic results are favourable after a stabilization period ranging from 3 to 6 years, covering in all cases the costs of production.

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