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Sustainable Use of Grassland Resources for Improved Livelihoods

Liana Jank
EMBRAPA, Brazil

Cacilda Borges do Valle
EMBRAPA, Brazil

Rosangela Maria Simeão
EMBRAPA, Brazil

Roberto Giolo de Almeida
EMBRAPA, Brazil

Mateus Figueiredo Santos
EMBRAPA, Brazil

See next page for additional authors

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Liana Jank, Cacilda Borges do Valle, Rosangela Maria Simeão, Roberto Giolo de Almeida, Mateus Figueiredo Santos, and Sanzio Carvalho Barrios

Sustainable use of Grassland Resources for Improved Livelihoods

Liana Jank[1], Cacilda Borges do Valle[1], Rosangela Maria Simeão[1], Roberto Giolo de Almeida[1], Mateus Figueiredo Santos[1], Sanzio Carvalho Barrios[1]

[1]Embrapa Beef Cattle, Rua Radio Maia, 830, Campo Grande, MS, Brazil

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Introduction

Grasslands occupy about 80% of global agricultural land and represent a wide range of ecosystems (Bosi et al., 2020). Pastureland represents approximately 889 million ha in Africa, followed by China (~506 million ha), Oceania (~345 million ha), Asia (~307 million ha, excluding China and India), United States (~252 million ha) and Brazil (~149 million ha) (Goldewijk et al. 2017; Bosi et al. 2020; Landau et al., 2020). Rangelands alone are the world largest land surface, and in 28 countries they represent more than 60 percent of total land area (FAO, 2009). The livelihoods of almost one billion people depend on grassland, thus improved management of grasslands is key to food production and sustainable development in many countries (FAO, 2009).

In general, animal production based on pastures is less geographically constrained than crop production and may occur in more diverse types of environmental conditions (Roser and Ritchie, 2019). However, in the face of world human population growing expectancies in the next few decades, the pressure for more animal products, such as milk and beef, will increase. Production will have to increase 57% for beef and 48% for milk by 2050 compared to that in 2005, as projected by FAO (Alexandratos and Bruinsma, 2012), while other estimates indicate that the global demand for livestock products will double by 2050 (Bajželj et al., 2014; Rao et al., 2015). This higher production needs to consider scenarios where land for pastures may have to be reduced in response to a number of reasons, as has been happening in Brazil (Martha Jr. et al., 2012; Landau et al., 2020), which, in turn will demand greater productivity per area.

In recent years, global agricultural activities have been required to adopt environmentally friendly production strategies to reduce the opening of new unexplored areas and thus reduce the impact of climate change (Schultze-Kraft et al., 2018). Therefore, the challenge faced by both agriculture and animal production nowadays is to produce more in order to meet the increase in domestic demand and exports, but without expanding the cultivated area already in use complying with sustainability.

The strategies to accomplish sustainable pastures globally tend to be vast and heterogeneous. The most frequent and important challenge cited in the literature is the prevention of loss of perennial grass productivity through the years; followed by soil degradation and decrease in animal weight gains. Looking ahead, these stresses are projected to intensify due to heat waves, frequent droughts and less water availability and their competition for crop and human use. It is predicted that all climate changes will affect ecosystems and economics through diminished rangeland carrying capacities, increased site vulnerability to soil degradation, compromised regional feed and pasture forage production, and intensified animal heat stress (Havstad et al., 2018; Spiegal et al., 2020). In addition, new biotic stresses caused by insects and diseases have also been observed as never before in cultivated pastures.

The environmental impact of the animal industry has received increased public attention due to its perceived effects on climate change (Thompson and Rowntree, 2020). However, it is impossible to socially address hunger eradication and ensure human food security without addressing animal production and its importance in the survival and livelihood of more than half of the world's population (FAO, 2018a). Livestock production allows food production on 57% of the earth's land that cannot be used for crop production (Mottet et al., 2017); and livestock production supplied 25% of protein and 18% of calories consumed globally in 2016, both of which are required for nutritional security (Mottet et al., 2017).

This paper presents and discusses some strategies being adopted to improve sustainability of grasslands, with emphasis on tropical regions and cultivated pastures.

Main body text

Sustainability strategies

Nowadays, and more than ever, after the release of the latest 2021 IPCC Report, sustainability must be sought. Sustainability involves the needs of the present generation without compromising the ability of future generations to meet their own needs to fulfill their aspirations for a better life (Report of the World... 1987). In agriculture, sustainability is directed to satisfying human food and fiber needs; enhancing environmental quality and natural resources; making the most efficient use of nonrenewable resources and on-farm resources and integrating, where appropriate, natural biological cycles and controls; sustaining the economic viability of farm operations; and enhancing the quality of life for farmers and society as a whole (USDA, 2007).

Pasture sustainability is a must, and many possibilities and strategies are available. In general, well managed high quality improved forages are more efficient than native pastures, by their increased production and quality, despite the existence of very productive nutritious native pastures. The higher production may contribute to release land for other uses and the higher quality and better pasture management may contribute to reduce methane emission from animals (Souza Filho et al., 2019). Thus, breeding to improve forage quality and production is a large contribution, not only for the animal production chains, but also to the environment and to alleviate climate change. An even better proposal is the use of integration with crops which may increase crop production (Szymczak et al., 2020), improve soil quality with consequent increase in animal performance. The use of integration with trees, may increase C sequestration and thus neutralize GHG emission from animals (Alves et al., 2017).

The main available strategies for increased sustainability are intensification due to the adequate use and management of the pastures and animals, correct use of soil conservation practices and recovery, integrated systems with crops and integrated systems with trees and a forest component. The practice of using trees is very common in Asia in small-scale farms, which, at the same time as animals are reared, trees are exploited, as coconut tree, as an example (Salendu et al., 2018; Deepthi et al., 2021).

According to Rao et al. (2015), sustainable intensification improves the productivity of tropical forage-based systems, decreases the ecological footprint of livestock production and generates ecosystem services, as improved soil quality and erosion reduction. These authors developed “The LivestockPlus concept” (Figure 1) that shows how properly managed improved forages may result in sustainable intensification of mixed crop-forage-livestock systems in the tropics, respecting social, economic and environmental objectives. For this, there must be a synergism between soils, plants, animals, people and the environment. Four principles are involved in producing more meat and milk. These are the use of sown pastures; sown pastures in combination with crop residues; sown pastures integrated with crops and trees; and actions that are essential for the adoption and widespread use of improved forage-based systems, including genetic improvement of livestock, changes to regional and national policies and increases in human and social capital. Thus, the benefits for improved livelihoods include more milk, meat, eggs, manure use, adaptation to climate change, food security, income generation, poverty alleviation and improved family nutrition (Figure 1).

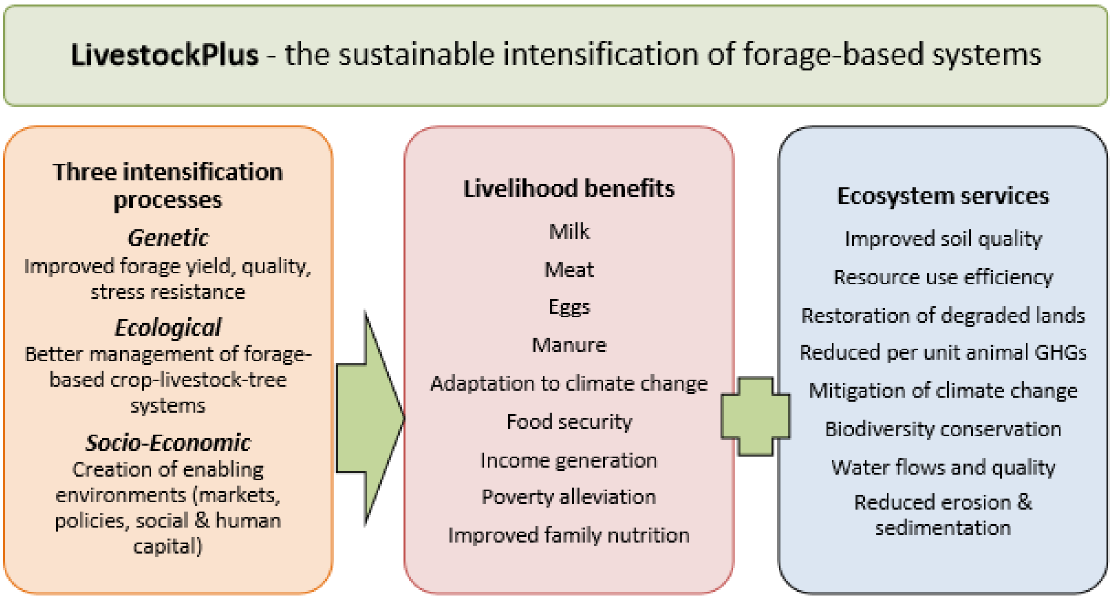

Figure 1. LivestockPlus: A concept to improve livelihoods and ecosystem services via the sustainable intensification of forage-based crop-livestock-tree systems (Rao et al., 2015).

Livestock manure provides organic fertilizer for over 50% most of the world's croplands, converting waste products into inputs for production of high-value food (Bruinsma, 2003; FAO, 2018b). The manure plays an important role in replenishing soil organic matter, which is critical for maintaining soil health and quality and hence sustaining crop productivity and restoring degraded soils (FAO, 2018b). Animal based food production contributes meaningfully to goals for a sustainable food system, by converting millions of tons of agroindustrial by-products that cannot be consumed by humans into livestock feeds, concomitantly reducing waste and environmental pollution and increasing human-consumable food. It is critical to note also that globally, only about 14% of the feed dry matter ingested by livestock is edible to humans, based on recent FAO data (Figure 2, Mottet et al., 2017), and probably even lower in several developing countries where ruminant livestock subsist mainly on pastures or crop residues.

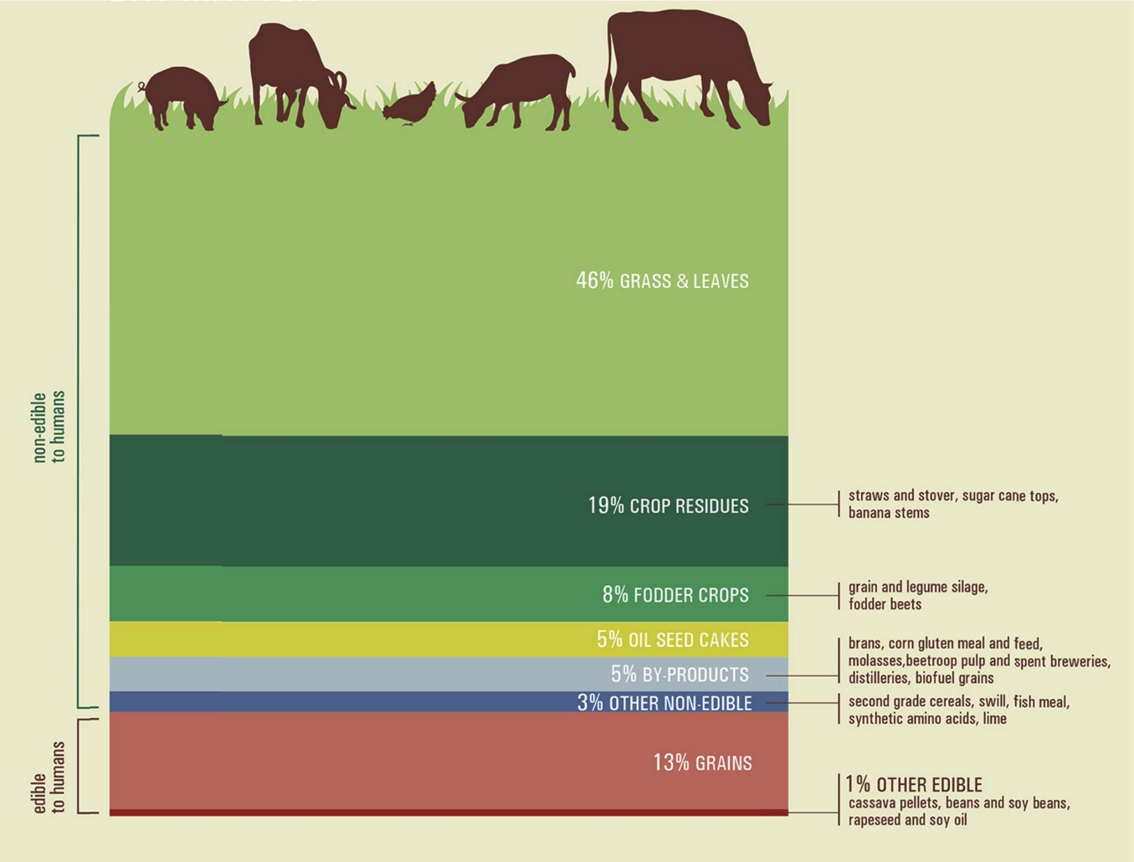

Figure 2. Global livestock feed dry matter intake. (FAO, 2017, adapted from Mottet et al., 2017).

Examples from Brazil

Brazil with its 118 Mha of cultivated pastures is the country with the largest extent of planted tropical pastures in the world. For this reason, many of the examples used in this paper will be from Brazil. Many initiatives have also been previously discussed and reported by Euclides et al. (2010) and Almeida et al. (2013).

Several programs have been and are being developed and implemented in Brazil to meet the goals of decreasing greenhouse gas emissions by 37% by 2025 and 43% by 2030 (Government of Brazil, 2021). The ABC plan was created by the Brazilian Government in 2010 and is one of the main political policies for a Low Carbon Emission Agriculture and is strongly based on technology transfer involving soil conservation, direct planting system, and crop-livestock-forest integration to mitigate GHG emissions from agriculture. It was structured into seven Programs: 1) Recovery of Degraded Pastures; 2) Integration of Crop-Livestock-Forestry (ICLF) and Agroforestry Systems; 3) Direct Planting System; 4) Biological Nitrogen Fixation; 5) Planted Forests; 6) Animal Waste Treatment; and 7) Adaptation to Climate Change. Direct planting system is largely used in the country to avoid tilling and soil disturbance and thus loss. The official plan ensures credit for projects adopting this technology (BRASIL, 2012, cited by Alves et al., 2017). Until 2018, 52 million hectares had been benefitted by this plan and 115% of the goal was accomplished. Also, 170 million Mg CO_2 eq. were mitigated (Manzatto et al., 2020).

In April 2021, the Brazilian Government launched another program called Plan ABC+ from now on called “Brazilian Agricultural Policy for Climate Adaptation and Low Carbon Emission

(ABC+)” (Mapa, 2021). This is an amplified wider strategy than the ABC plan. The government estimates that by 2030, low carbon emission agricultural practices will have been adopted by 52 million hectares.

Another approach is a seal that was developed called the “regenerative livestock production seal” which is a set of sustainable practices as a production model which revitalizes the system producing an environmental surplus instead of an ecological deficit (O Agro pode mais, 2021). Thus, to obtain this seal, the cattleman has to observe the recommendations of the soil specialist in order to fix carbon instead of emitting it.

Another government program in Brazil is the technological concept brand called "Carbon Neutral Brazilian Beef" (Carne Carbono Neutro - CCN, in Portuguese) developed by Embrapa in 2015. The concept is represented by a label referring to beef cattle produced under integrated systems with mandatory presence of a forestry component. This concept aims to support implementation of more sustainable cattle systems, especially regarding environment, through introduction of trees that are able to neutralize emissions of methane by cattle. It ensures added value for beef produced under such systems. In short, to receive and use the “Carbon Neutral Beef” seal, the final product (beef and its derivatives) must comply with all the prerequisites and parameters inherent to the general concept established (Alves et al., 2017).

Following the line of mitigation of GHG emissions, in 2020 Embrapa launched the Low Carbon Brazilian Beef concept brand, to value beef produced in livestock systems based on good agricultural practices and sustainable intensification, however, without the presence of the forestry component in the productive area (Almeida and Alves, 2020). At the same time, many beef processing industries in Brazil are rejecting cattle from farms with pending issues such as from deforestation areas, indigenous land, areas embargoed by the government, environment conservation areas or that contain a history of slave work

According to Rao et al. (2015), sustainability also implies on lifestyle choices involving changes to the production and consumption systems, thus, sustainable intensification involves social transformation. A very good example of social transformation resulting from technology adoption is the case study in Brazil, of a program called ‘Balde Cheio’ (translation Full Bucket).

The ‘Balde Cheio’ Program (Full Bucket) in Brazil was selected as one of Embrapa's technological solutions aligned to the Sustainable Development Goals referring to poverty eradication, decent employment and economic growth (O agro pode mais, 2021). The program is a technology transfer methodology that aims to train technical assistants, rural extensionists and cattlemen to expand milk production and create an alternative income for small and medium-sized rural producers (Embrapa, 2021). The program was initially based on well-managed and fertilized Mombaça pastures (guineagrass cultivar Mombaça released by Embrapa in 1993 - Jank, 1995), and on existing pastures in good conditions with the indications the project team furnishes.

By this program, one property per county (must be over 0.5 ha area, be a family enterprise and focused on dairy) is selected by the trained technician to serve as a reference for other producers in that region. After approval by the project team, the owner must answer a questionnaire that will identify the production system, the socioeconomic situation of the family, and environmental issues. The property receives the technical assistance of the trained technician for four years and theoretical classes. For the property to be used as a classroom and a reference to that county and to continue receiving the benefits of the program, the producer has to execute everything exactly according to the guidelines and to what was agreed upon (Sebrae, 2021).

The case study involved 1,609 properties in 468 counties in 19 Brazilian states assisted by the program (O Agro pode mais, 2021). The results showed that the program generated an increase in the producers' revenue by 2.3 times, in addition to raising the quality of life of the rural and urban populations. Milk production increased 43%, while occupied area decreased 7% and workforce performance improved 37%, resulting in an almost double average gross margin per hectare.

However, one of the main positive effects, not perceivable in the statistics, was the rescue of the self-esteem of small-scale milk producers, and rural extension technicians, who now have decent incomes and better living conditions for the whole family. Also, more jobs were created and more people were fixed in the country, especially the young generation.

Due to the success of this program, this methodology is now being adapted to other specific conditions, as milk production from goats, buffaloes, and for beef cattle (O agro pode mais, 2021).

Another successful initiative for improvement of the efficiency of the productive system due to technology is the Young Steer Program (Programa Novilho Precoce) (Bungenstab, 2012). This program, together with the Protocol of ‘Good Agricultural Practices: Beef Cattle’ (Valle, 2011) established a set of standards and procedures that must be adopted by the participating properties in order to receive the tax incentives offered by the Government of the State of Mato Grosso do Sul. This, not only allowed farmers to achieve increased productivity and sustainability of the activity, addressing social, labor, productive and environmental aspects, but also became an important and relevant management tool to meet the growing demand for safe food and consolidate Brazil as the world's largest producer of beef from sustainable production systems,

Forage Germplasm

In temperate climates, there is a continuous release of forage cultivars based on solid, well established breeding programs and there are many programs based on the same species in different countries. Also, the number of different species studied and Young Steer Program bred is small. In tropical countries, however, there are very few and recent programs and in only a few countries, because breeding is only at its infancy. But the number of species of forage worth breeding is very large. Maass and Pengelly (2019) reported that around 160 worthy species were included in the Tropical Forages database of CIAT (https://www.tropicalforages.info/text/intro/index.html), and even if 50% are of limited forage value, the numbers are still very large.

Almost 182,000 accessions of more than 1000 species of grasses, legumes and fodder trees have been collected worldwide both from tropical and temperate regions (Figure 3). These are maintained in 80 national and international genebanks registered in Genesys (www.genesys-pgr.org (Hanson and Ellis (2020). Despite the large genetic diversity, both within species as well as in terms of species numbers with forage potential, the germplasm conserved in these banks are underutilized and unexplored in the forage breeding programs.

On the other hand, Maass and Pengelly (2019) expressed concerns that around 60% of the conserved accessions in the two International Centres (CIAT and ILRI) have limited forage value. Thus, efforts dispended in the conservation of these accessions are constantly being reviewed and discussed, since conservation is very costly especially if these resources and not being explored.

Nevertheless, efforts in germplasm conservation are important, especially if the breeding programs use the germplasm and if new accessions are constantly being incorporated into the program. To deal with this and since seed storage is still the most cost-effective and efficient method for forage conservation (Hanson and Ellis, 2020), Pengelly and Maass (2019) presented many suggestions on how the use and conservation of these forage accessions should be dealt with based on improved efficiency, effectiveness, awareness and collaboration that should be adopted urgently. Efficiency could be attained by implementing taxa priorities and losing the lowest priority germplasm; by developing core collections and eliminating duplicates, triplicates etc. More efficacy could be attained by fitting the best existing genotype into targeted agro-ecological niches and production systems. This requires the expertise of conventional breeders and former germplasm specialists, which invest in field observations and descriptive assessment, and not only about applying the latest technologies by younger generation of researchers. Increase seed supply is also suggested to supply greater quantities of well-adapted elite material, for increased evaluation and utilization. And last, increased awareness and knowledge of other forage evaluation and utilization elsewhere. To help with this issue The Tropical Forages Database is available (https://cgspace.cgiar.org/handle/10568/49072), as well as the excellent newsletters produced by Maass and Pengelly (2016-2019).

Figure 3. Worldwide forage collection sites. Source: Hanson and Ellis (2020).

Forage Breeding

Through breeding, many characteristics can be improved which result in higher sustainability for improved livelihoods. The first characteristic is yield, which based on large germplasm resources is the easiest to be improved. Through time, improved yields have been obtained in most forages. In temperate climates, 4% to 5% increases in yield have been reported per decade in perennial ryegrass (*Lolium perenne* L.) breeding (Wilkins and Humphreys, (2003) cited by Kingston-Smith et al. (2013)). However, yield of cultivars of smooth bromegrass (*Bromus inermis* Leyss.) developed between 1942 and 1995 did not change (Casler et al., 2000).

In tropical forages, however, breeding is still a very recent activity, thus large gains in yield may still be observed. Based on the germplasm collected in the Centre of Origin of *Megathyrsus maximus* (syn. *Panicum maximum*) and transferred to Brazil in the early 1980s (Savidan et al., 1987), leaf dry matter yields of the first two cultivars released, Tanzânia-1 in 1990 and Mombaça in 1993, were respectively 86% and 136% greater than cultivar Colonião in use at the time (Jank, 1995). Further large increases in yield, as these presented, either through selection within the germplasm or through breeding may hardly be expected, however new challenges to the breeder are constantly forthcoming such as resistance to pests and diseases, tolerance to waterlogging and dry spells among others, as mitigation and adaptation strategies in a climate change scenario.

Other characteristics include nutritive value, with increased protein and digestibility, which will have a direct effect on decreasing GHG emissions by the cattle. Thus, increased quality of the forage will contribute to mitigate climate changes (Euclides et al., 2010; Eugène et al., 2021). New cultivars bred for increased tolerances/resistances to both biotic and abiotic stresses will also contribute to an increased sustainability. Table 1 shows the main characteristic improved in some of the released forage cultivars in Brazil which contribute to an increased sustainability. Accessions found in germplasm banks may be excellent sources of tolerance and resistance to many sources of diseases and pests, as well as to increased quality and yield in tropical forages.

Table 1. Improved forage species in Brazil and the main characteristics improved.

Species	**Cultivar**	**Cultivar compared**	**Main Characteristic improved ***	**Reference**
M. maximus	Tanzânia	Colonião	24% > ADG	Euclides et al., 1999
M. maximus	Mombaça	Colonião	136% > LDMY	Jank, 1995
M. maximus	BRS Tamani	Massai	49% > ADG	Braga et al., 2019
M. maximus	BRS Quênia	Tanzânia	32% > ADG	Andrade et al., 2013
M. maximus	Massai	Colonião	53% < seasonality of production	Embrapa Gado de Corte, 2001
Brachiaria brizantha	BRS Xaraés	Marandu	20% > Animal Production	Valle et al., 2004
B. brizantha	BRS Piatã	Marandu	7% > Live weight gain	Valle et al., 2007
B. brizantha	BRS Paiaguás	Piatã	8% > ADG in the dry season	Euclides et al., 2016
Brachiaria hybrid	BRS Ipyporã	All others	> Resistance to spittle-bugs	Valle et al., 2017
Pennisetum purpureum	BRS Capiaçu	Cameroon	66% > TDMY	Pereira et al., 2017
P. purpureum	BRS Kurumi	Mott	56% > LDMY	Pereira et al., 2017
Andropogon gayanus	BRS Sarandi	Planaltina	14% > LDMY 21% < STMY	Carvalho et al., 2021
Stylosanthes spp.	BRS Campo Grande	Mineirão	Seed production	Embrapa Gado de Corte, 2007
Stylosanthes guianensis	BRS Bela	Mineirão	Seed production and clay soils adaptation	Embrapa Gado de Corte, 2019

*LDMY = Leaf dry matter yield; SDMY = Stem dry matter yield; TDMY = Total dry matter yield; ADG = Average daily gain per animal

Hanson and Ellis (2020) presented a very nice synthesis of the climate zone suitability for cultivation of the most common tropical and sub-tropical forage species. They classified the species in terms of suitability for arid, semi-arid, sub-humid, humid and highland zones. Breeding within these species, respecting their cultivation suitability will definitely improve sustainability, by increasing yield and persistence of the pastures and avoiding pasture degradation. Breeding for disease and pest resistances, and abiotic stresses, as drought and water logging tolerances are also excellent alternatives to improve sustainability for the same reasons above.

Discussion/Conclusion

Since Grasslands occupy about 80% of global agricultural land and as we head to more intensive climate changes, pasture sustainability is absolutely imperative. Considering the different climates, soils, herds, cattle and pasture management and both forage and financial resources available worldwide, every step taken towards a more sustainable reality is very positive and necessary. Every activity which improves pasture productivity, quality, persistence, intensification, carbon sequestration, resilience, adaptation, GHG mitigation, whilst decreasing soil degradation and demands for water use, fertilizers, insecticides, pesticides and herbicides contribute to pasture sustainability and result in positive social, environmental and economic impacts. Thus, forage selection from natural germplasm conserved in genebanks and forage breeding to obtain new improved more efficient and adaptive cultivars, as well as management strategies to improve pasture use, and public policies all help pasture sustainability.

Different countries are creating their own policies, frequently injecting governmental resources in order to more effectively stimulate the adoption of these policies by farmers, in order to mitigate deleterious effects of animal production on pastures and probably this is the most effective way to attain sustainability. There is a worldwide discussion on consumption of red meat but the demand for this excellent source of protein in the near future will undoubtedly continue to be high or even increase. Therefore, despite the differences in consciousness levels in the different countries it is indeed imperious to improve forages and pasture management to continue to make the world a better and more sustainable place to live.

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