Integrated agricultural production systems in lowlands

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ABSTRACT

Integrated agricultural production systems (SIPA's) are systems where crop crops are carried out in an integrated manner, with grain and forage cultivation in the same area, in rotation, succession or intercropping, in addition to the presence of grazing animals. These systems, in addition to diversifying agricultural production, benefiting crops and livestock, are more sustainable, economically viable agricultural practices aimed at preserving soils. Integrated crop-livestock systems are based on the idea that livestock activity can contribute to the generation of organic waste, improvement of the physical and chemical characteristics of the soil, crop alternation, interruption of the cycle of plant diseases and reduction of losses caused by climate variability. In addition, although the benefits of the adoption of LPIS in lowlands are known, they are still incipient and need more research to produce more consistent technical recommendations.

Keywords: Rice, Ryegrass, Production, Integrated Systems, Sustainability.

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INTRODUCTION

In the Western Border of Rio Grande do Sul, the main activities developed are extensive cattle ranching and the cultivation of irrigated rice. However, for both activities, profit margins have become smaller, challenging producers to adopt more sustainable production strategies (Carmona *et al*., 2018).

In addition, the activities have isolated challenges such as the scarcity of forage for cattle in the winter period, and soil degradation due to turnover, irrigation and intense use of inputs in rice farming. As integrated systems allow the association between agricultural and livestock activities with benefits to both, they would be an alternative to mitigate the proposed challenges (Carvalho *et al*., 2018). As it is a summer crop, rice is grown only in spring/summer, opening a gap for winter forage cultivation. These, especially ryegrass, could supply the forage shortage that occurs in this period and also provide quality food for beef cattle herds (Mantai *et al*., 2015).

The cultivation of pastures and the introduction of cattle in agricultural areas under integrated systems and with adequate management provides benefits to soil structure and summer crops. Forage grasses have a root system that contributes to the improvement of soil structure. The presence of animals, on the other hand, accentuates the production of forage roots through defoliation, while promoting nutrient cycling through feces and urine (Reis; Silva, 2011). The benefits mentioned above have been measured and are consolidated for integration systems implemented in tropical and subtropical areas in Brazil. However, for lowlands, information is still scarce, lacking other indicators to support technical recommendations (Bohn *et al*., 2020).

Also, although the environmental and social gains have already been measured in research with integrated systems, economic evaluations are still incipient or incomplete. However, they are as relevant as the others to validate the proposed systems and subsidize their dissemination on properties (Mantai *et al*., 2015). Thus, the objective of this review was to list the main issues related to the implementation and conduction of PIS systems in lowlands.

LITERATURE REVIEW

INTEGRATED AGRICULTURAL PRODUCTION SYSTEMS

Integrated agricultural production systems (SIPA's) consist of growing grain-producing crops with forage crops in the same area, in rotation, succession, or intercropping (Barbosa *et al*., 2022a). These systems, in addition to diversifying agricultural production, benefiting crops and livestock, are more sustainable, economically viable agricultural practices aimed at soil conservation (Coser *et al*., 2018).

Due to its ability to provide economic and environmental benefits, according to Barbosa *et al*. (2022b) LPIS has received special attention from researchers and has been adopted by farmers in

Brazil (Bonetti *et al*., 2015). Thus, Brazil leads the research in LPIS in relation to the rest of the countries in the world, according to Moraes *et al*. (2017), with approximately 11.5 million hectares are occupied by different arrangements of LPIS's. Of these, the subtropical region accounts for 44% of this area (Skorupa; Manzatto, 2019). However, its adoption in crops intended for the cultivation of irrigated rice is still incipient, especially with regard to the availability of data to support management recommendations. In these areas, called lowlands, the cultivation of irrigated rice in spring/summer and ryegrass in autumn and winter is predominant. In Rio Grande do Sul, about 1.1 million hectares are cultivated with flood-irrigated rice, according to (CONAB, 2019) due to the characteristics of the soil in these regions. These have a low water infiltration rate, low macro porosity and high compaction close to the surface, which makes it difficult for other crops to be inserted, according to Denardin *et al*. (2019) to achieve positive results in LPIS.

Therefore, it becomes a challenge to deploy and conduct systems in LPIS and lowlands. Countering this challenge, as rice cultivation is costly and expensive in terms of labor, water, energy, and as these resources are becoming increasingly scarce, this activity is becoming less profitable (Kumar; Ladha, 2011). Therefore, the implementation of LPIS in current agricultural production models can help generate income in the off-season of summer crops, and/or increase productivity in rice crops.

This increase would be possible because the SIPA's advocate the adoption of no-tillage as a cropping system, thus, the absence or minimal disturbance of the soil minimizes its degradation (Coser *et al*., 2018). In the same way, the constant maintenance of living or dead cover in the soil contributes to the increase in the production of dry matter per unit area, according to Mazzuchelli *et al*. (2020) that can be used as a ground cover (Skorupa; Manzatto, 2019). This also contributes to the increase of soil carbon (C) stocks, according to Guesmi *et al*. (2019) that act as a subsidy for the supply of nutrients, according to Soares *et al*. (2019) with a consequent increase in crop productivity (Sousa *et al*., 2020).

How can LPIS be to have their time-culture-space arrangements adjusted according to the needs of each reality, according to Barbosa *et al*. (2022a), research contemplating lowland environments can be conducted under the principles of SIPA's. Furthermore, although the benefits of adopting LPIS are known, in lowlands they are still incipient, and require further studies to generate more consistent technical recommendations (Carmona *et al*., 2018).

It is also worth noting that the conventional agricultural system model is in evidence, because over the years the loss of forage diversity and environmental pollution by excess nutrients and pesticide residues, according to Anghinoni *et al*. (2013), has made society currently demand that specialized production models commit to producing food in the most connected way possible with nature (Carmona *et al*., 2018)element.

FORAGE COMPONENTS IN SIPA's

As in the rest of Brazil, in the southern region the activity is based on the use of pastures as the main food resource. Also, as the well-defined cold season, characterized by the reduction of the photoperiod, low temperatures and the occurrence of frost, limits the production and quality of tropical forages, according to Peretti *et al*. (2017), forage strategies should be adopted to fill this food gap.

LPIS in Brazil comprise a great diversity of forage species due to the diversity of our edaphoclimatic conditions. However, of the pastures cultivated in winter, the most used species is ryegrass (*Lolium multiflorum* Lam.), according to Bohn *et al*. (2020) due to its productive potential and good adaptation to the environmental conditions of the region (Dotto *et al*., 2022). In addition to being a good alternative to compose subtropical systems of crop-livestock integration, according to Moraes *et al*. (2014), because it has a high potential for dry matter production, according to Peterson *et al*. (2019), can be used for both grazing and ground cover (Bohn *et al*., 2020). As SIPA's aim at social, environmental, and economic sustainability, among the challenges, the adoption of pasture management strategies that aim to maximize plant and animal production are extremely important (Dotto *et al*., 2022). Thus, in addition to the choice of forage species, the grazing method and the fertilization strategy must be defined in order to meet the principles mentioned.

In continuous stocking, the animals have unlimited and uninterrupted access to the entire area to be grazed throughout the grazing period and in rotational stocking there is alternation between defoliation and rest (Dotto *et al*., 2022). Due to the interspersion of rest and grazing periods, in the rotating stocking, the regrowth process occurs in isolation from the grazing process (Ongaratto *et al*., 2020). On the other hand, continuous stocking is characterized by milder changes in pasture condition over the period (Dotto *et al*., 2022). This is the most suitable option for adoption in SIPA systems, as the constant soil cover maintained by the higher residual grazing height provides the sponge effect, minimizing soil compaction (Coser *et al*., 2018).

In ryegrass, when used for grazing, in its management it is recommended the entry of animals into the area when the ryegrass is approximately 30 cm tall, for a better use of the pasture (Flores *et al*., 2008). However, grazing management should prioritize a pasture height always higher than 10-15 cm to stimulate regrowth (Peretti *et al*., 2017). The period of use of ryegrass pastures can last up to 80 days, subject to the climate, soil fertilization and especially area management (Pelegrini *et al*., 2010). Although it is a forage species extensively studied in the southern region of Brazil, its dynamics in LPIS in lowlands is not yet fully elucidated. Thus, studies contemplating the performance of ryegrass inserted in alternative LPIS systems in lowlands will support technical recommendations for the management of this pasture.

ANIMAL COMPONENT IN SIPA's

The livestock phase of LPIS in the subtropical regions of Brazil is commonly adopted in the winter period and the main plant species used are winter forage grasses (Bertol *et al*., 2022). Of these, ryegrass is the predominant one in lowlands, with dry matter productions that can reach 10 tons/ha and total digestible nutrient concentrations that can reach more than 80%, providing excellent animal performance (Fontaneli *et al*., 2016).

However, this is dependent on the management of grazing intensity in the livestock phase, which determines the amount of forage available to the animal: higher grazing intensities will provide lower forage availability and vice versa (Bertol *et al*., 2022). This is directly linked to the animal load used, which is one of the main challenges for increasing the area of LPIS in Southern Brazil. There are paradigms linked to the consumption of forage material that would cover the soil and the potential compaction of the soil by animal trampling, according to Carvalho *et al*. (2021), that is, both are linked to the grazing intensity of the livestock phase (Bertol *et al*., 2022).

Although grazing should be moderate to minimize soil compaction and maximize forage production, it should be present, as it is responsible for plant root growth. In other words, the animal component is fundamental for the sustainability of the system, because in addition to promoting defoliation with root growth of forage plants, it also provides the cycling of nutrients through feces and urine. Integrated crop-livestock systems are based on the premise that livestock activity can contribute to the generation of organic waste, improvement of the physical and chemical characteristics of the soil, crop rotation, interruption of the cycle of plant diseases and reduction of losses resulting from climate variability. Additionally, these systems can provide fresh and highly nutritious forages for livestock, including in winter, while in other systems forage can be scarce (Vinholis *et al*., 2021). For this reason, the adoption of animals with genetic potential can enhance the SIPA's, providing greater animal gain and greater efficiency in the use of the forages offered.

AGRICULTURAL COMPONENT IN SIPA's

In the subtropical regions of Brazil, the agricultural cultivation phase of SIPA's is commonly adopted in the summer period, and includes irrigated rice (*Oryza sativa*), soybean (*Glycine max*) and/or corn (*Zea mays) crops*. In lowlands, corn is rarely cultivated, except when used to produce silage for animal feed. Rice cultivated in the irrigated form is the predominant crop in lowlands in the agricultural phase. However, the sustainability of its cultivation has been declining season after season, with increased production costs and reduced water availability.

Soybeans are the most important economic commodity in Brazil and widely used around the world. In recent years, new areas have been used for soybean production, mainly in the lowlands of agricultural fields in southern Brazil historically managed by cattle ranching (Maranhão *et al*., 2019).

However, most areas presented limiting factors for production, such as low soil fertility and reduced water retention, reducing the potential for grain yield.

However, the gains related to soybean cultivation would not be directly economic. As it is a leguminous crop, it has the capacity for biological nitrogen fixation. Also, its pivoting root system could contribute to the decompaction of the superficial layers of the soil, contributing in the long term to the improvement of its structure. Combined, these characteristics could contribute to a more favorable soil condition for ryegrass, providing higher DM productivity and higher animal load (Silva *et al*., 2019).

ECONOMIC COMPONENT IN SIPA's

The adoption of technologies enables productivity gains and/or lower production costs through the use of new inputs and new combinations of resources (Vinholis; Souza Filho; Carrer, 2023). These gains have been observed in Brazilian agriculture. In recent decades, the generation and adaptation of agricultural technologies to tropical conditions has enabled the country to sustain a consistent increase in food production. In 2020, agribusiness GDP reached 26.6% of share in the national GDP (Center for Advanced Studies in Applied Economics, 2020).

Monoculture crop production and conventional livestock farming not integrated with crops were designed for a rapid increase in productivity and food supply (Vinholis *et al*., 2021). Thus, monoculture is the predominant plant and animal production system in Brazil, based on the intense use of natural resources, chemical formulas, and non-renewable energy (Mendonça *et al*., 2020).

However, some of these production systems have shown signs of saturation and negative environmental impacts (Vinholis *et al*., 2021). However, in the face of an imminent scarcity of natural resources, production systems need to be rethought (Mendonça *et al*., 2020). Crop-livestock integration systems have been developed as an alternative that offers increased productivity and greater environmental sustainability (Vinholis *et al*., 2021). These systems enable the economic exploitation of production areas throughout the year, allowing greater production of grains, milk and meat, at lower costs due to the interaction between crops and pasture.

In economic theory, any economic gains obtained from the diversification of production systems are justified by the so-called "scope economy", which occurs when the cost of producing two items in a given production system is lower than when the same items are produced separately (Mendonça *et al*., 2020).

However, measuring and demonstrating the economy of scope in production systems is not so simple, according to Gameiro *et al*. (2016), probably due to the difficulty in calculating the cost of production of an integrated system, especially for farmers (Mendonça *et al*., 2020). This can be explained because there is no "protocol" for estimating the cost of an integrated system, which means that there are multiple ways to conceptualize costs in nature-related production systems. The different possibilities of CLI system configurations in relation to the crops implanted and the management carried out are challenged to demonstrate the economic advantages of this system (Mendonça *et al*., 2020).

CONCLUSION

Integrated agricultural production systems (SIPA's) provide an alternative to increase productivity and reduce the effects of environmental impact, standing out for being a sustainable and competitive technology to boost the agricultural sector. However, information on lowlands is still scarce, and other indicators are lacking to support more consistent technical recommendations.

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