# Synergies in Integrated Systems

Improving Resource Use Efficiency While Mitigating GHG Emissions

Through Well Informed Decisions about Circularity

## D1.2 Technical Briefs – Brazil

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**Project summary**

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|---|---|
| Acronym | SENSE |
| Title | Synergies in integrated systems: Improving resource use efficiency while mitigating GHG emissions through well-informed decisions about circularity |
| Call | 2021 Joint Call ERA-NET Cofund ICT-AGRI-FOOD, FACCE ERA-GAS, SusCrop and SusAn: Circularity in mixed crops and livestock farming systems with emphasis on climate change mitigation and adaptation |
| Duration | 36 months |
| Website | https://sense-eranet.hutton.ac.uk/ |
| Coordinator | The James Hutton Institute (JHI) |
| Partners | Centre for Ecology and Hydrology (CEH)<br>University of Bristol (UOB)<br>Stichting Wageningen Research (WUR)<br>University of Hohenheim (UHOH)<br>Demeter e.V. (Demeter)<br>Consiglio per la ricerca in agricoltura e l'analisi dell'economia agrarian (CREA-AA)<br>Brazilian Agricultural Research Corporation (Embrapa)<br>National Institute of Agropecuarian Technology (INTA)<br>Instituto Nacional de Investigación Agropecuaria (INIA) |

**Deliverable summary**

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|---|---|
| Work package | WP1: Standardized data collection : SENSE centralized database |
| Task | Task 1.2: Preparing the Technical Briefs |
| Deliverable | D1.2: Technical Briefs |
| Responsible partner | WUR/Embrapa |

NZAGRC/MPI

| | |
|---|---|
| Milestone | M02 |
| Deliverable | D07/D06 |
| Responsible partner | Embrapa |

# Contents

# 1 Introduction

Specialization, intensification and spatial separation of crop, livestock and forestry production systems have contributed to climate change and biodiversity loss. Circularity in integrated crop-livestock-forestry production systems may reduce the environmental impact of agricultural production systems by increasing resource-use efficiency while simultaneously mitigating greenhouse gases (GHG) emissions. The SENSE project (2021 Joint Call on Circularity) operates in various case studies involved in integrated crop-livestock-forestry systems in four European countries (Italy, Germany, the Netherlands, and the United Kingdom) and three South American countries (Argentina, Brazil and Uruguay).

The case studies conducted by SENSE can be classified into two categories, namely benchmark and participatory, depending on the availability of historical data and the data generated during the project. These case studies may take place on either an experimental station of a project partner or a commercial farm. In benchmark case studies, sensors will be deployed to enable near real-time monitoring of soil and climate properties (i.e. soil temperature and moisture, air temperature, rainfall, etc), to model GHG emissions and carbon and nutrient cycling (WP3). Circularity and ecological indicators will be assessed (WP2) and short-term circularity measures will be implemented and tested (WP2 and WP3). Case studies will be further co-assessed with farmers/farm managers with a multidimensional sustainability assessment tool (WP4). This will allow us to assess understanding of the current circularity status of these systems. The data we collect will drive models to determine alternate scenarios for improving resource use-efficiency while simultaneously mitigating GHG emissions (WP3), thus identifying best measures that will improve circularity within these integrated systems. To test the viability of GHG mitigation, options will be co-assessed with commercial farmers and their trade-offs with other ecosystem services and their effects on economic and environmental resilience will be further explored with a multidimensional sustainability assessment tool (WP4).

SENSE case studies in Europe and South America cover different climatic and pedological zones and exhibit different levels of integration in crop-livestock-forestry systems and a diverse range of establishment dates and species integration. A particular strength of the SENSE project is the longstanding experience (> 20 years) that South American partners have with the implementation of these integrated systems.

The aim of this Technical Brief is to present the characterization of the case studies in the SENSE project. This report showcases the case studies in Brazil, which are coordinated by our partner Embrapa.

# 2 Task description

In the first year of the project, a data template table has been developed and shared with all case study coordinators to compile the required data for site characterization. Compiled data includes: case study categories (i.e. benchmark, participatory, experimental station, commercial farm); type of integrated system (i.e. Integrated Crop-Livestock (ICL), Integrated Crop-Forestry (ICF), Integrated Livestock-Forestry (ILF), Integrated Crop-Livestock-Forestry (ICFL)); time under integration; area; climate and soil classification; as well as a brief description of the crop, livestock and forestry components. The results are presented in this document.

# 3 Case studies in Brazil

There are three case studies in Brazil (BR1, BR2 and BR3). Table 1 exhibits the general characterization of these case studies.

**Table 1.** General characterization of the case studies in Brazil.

| Case study | Location | Institution | Experimental Station (ES) or Commercial Farm (CF) | Type of Integrated systems | Year of implementation or start of the integration | Total area (ha) | Crop (others) area (ha) | Livestock (grass) area (ha) | Forestry (tree) area (ha) | Climate classification (Köppen) | Mean Precipitation (mm) | Mean Temperature (˚C) | Soil classification (WRB) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR1a | Goiás state | Embrapa Rice and Bean | ES | ICL | 2001 | 7.6 | 7.6 | 0 | 0 | Aw | 1505 | 23 | Rhodic Ferralsol |
| BR1b | Goiás state | Embrapa Rice and Bean | ES | ICL | 2001 | 8.1 | 0 | 8.1 | 0 | Aw | 1505 | 23 | Rhodic Ferralsol |
| BR2 | Mato Grosso state | Embrapa Agrosilvopastoral | ES | ICL, IFL, ICLF | 2012 | 110 | 10 | 22 | 4 | Aw | 1800-2200 | 25 | Ferralsol |
| BR3a | Bahia state | Embrapa Maize and Sorghum | CF | ICL | 2019 | 85 | 0 | 85 | 0 | Aw | 1100-1200 | 24 | Arenosol |
| BR3b | Bahia state | Embrapa Maize and Sorghum | CF | ICLF | 2018 | 15 | 0 | 15 | 15 | Aw | 1100-1200 | 24 | Arenosol |

## 3.1 BR1

The case study BR1 is an experimental station at Embrapa Rice and Bean, which is located in Goiás state (Fig. 1a). The rainfall regime is well defined, with a rainy season from October to April and dry season from May to September (Fig. 1b).

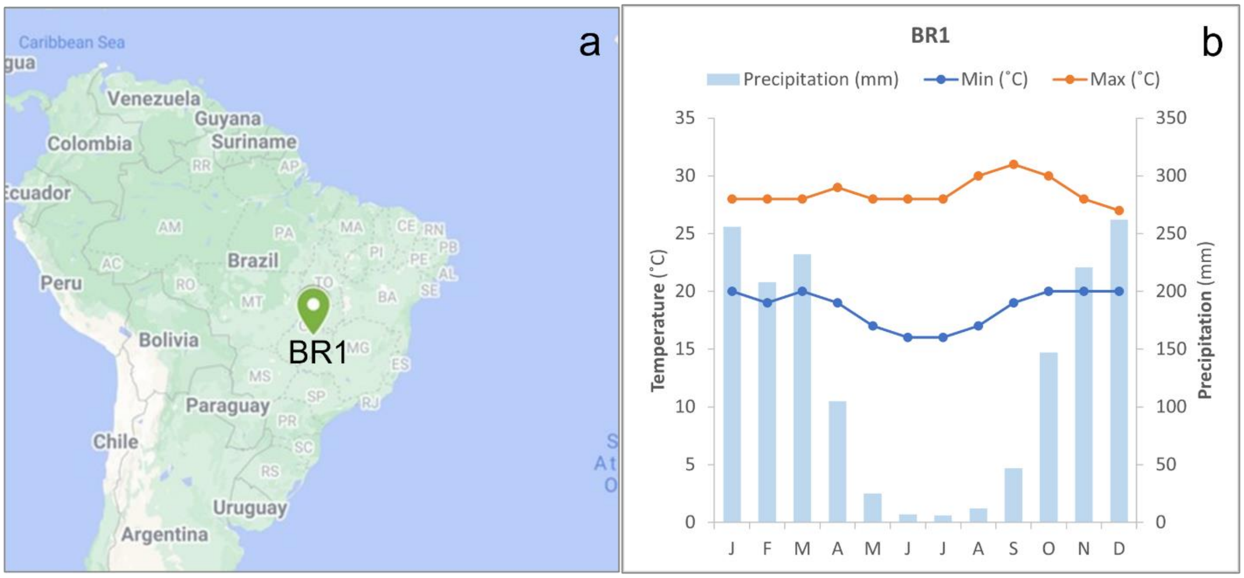


**Fig. 1.** Location of the case study BR1 (Google Maps© image) (a) and the monthly climatic data for the area (b). Climatic data is derived from a 30-year observed data series. Source: climatetempo.com.br.

The soil exhibits clayey texture (58% clay) with kaolinite as the predominant clay mineral and ferrous and aluminum oxides and hydroxides (haematite, magnetite and geothite) and the natural vegetation of the region is a broad-leave evergreen forest. The chemical and physical properties of the BR1 site is shown in Table 2. The BR1 case study is an integrated crop-livestock (ICL) system. The ICL is implemented in two adjacent paddocks (BR1a and BR1b) (

**Fig. 2.** Map and geographical localization of BR1a, BR1b, Forest (native vegetation) and continuous pasture. Source: Oliveira et al. (2022).

). This is a field observational study under near real farm conditions. Two other adjacent areas are used as references to the ICL. One reference is an area under native vegetation, a cerrado forest, and the other is an area under continuous pasture. The management history of BR1 under ICL is presented in **Error! Reference source not found.**. The ICL was implemented in 2001 and is consisted of the rotation between pasture and crop production phases which are revised according to technological development. Both BR1a and BR1b represent the same ICL rotation, but when BR1a is in pasture phase, BR1b is in the crop phase. The ICL rotation is shown in Table 3. The grass species grown over time are *Urochloa brizantha*, the actual variety during this study being cv Paiaguás with occasional mixture with *Panicum maximum*. Livestock was Nelore. Crops produced in the area are: common-bean (*Phaseolus vulgares*), aerobic rice (*Oryza sativa*), maize (*Zea mays*) and soybean (*Glycine max*). There are no trees in BR1 (Fig. 4).

**Table 2.** Mean soil chemical properties and soil particle size distributions for the surface 0-30 cm for two paddocks under integrated crop-livestock systems and an adjacent forest at Santo Antônio de Goiás, Goiás State, Brazil.

| Area | pH | Ca | Mg | Al | H + Al | P | K | Clay | Silt | Sand |
|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | ----- mmol$_c$ dm$^{-3}$ ----- | | | | -- mg dm$^{-3}$ -- | | ----- g kg$^{-1}$ ----- | | |
| BR1a | 5.3 | 25.8 | 10.6 | 1.3 | 16.9 | 8.0 | 90.3 | 642 | 92 | 266 |
| BR1b | 5.7 | 26.3 | 10.1 | 0.8 | 15.3 | 7.4 | 56.2 | 588 | 99 | 313 |
| Continuous pasture | 5.6 | 19.9 | 8.2 | 1.0 | 16.3 | 7.3 | 70.3 | 589 | 97 | 315 |
| Forest | 4.6 | 0.0 | 0.8 | 7.8 | 23.0 | 0.5 | 32.5 | 567 | 95 | 338 |

Sampling was done in October 2022.

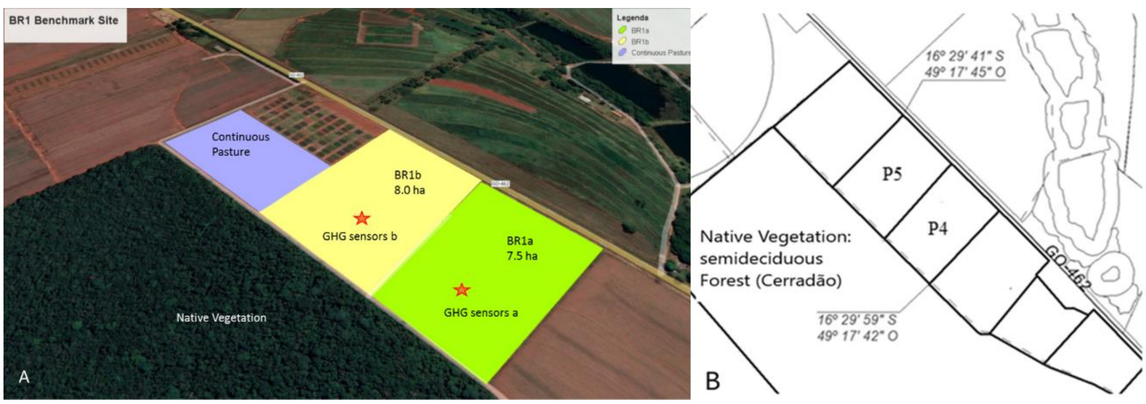


**Fig. 2.** Map and geographical localization of BR1a, BR1b, Forest (native vegetation) and continuous pasture. Source: Oliveira et al. (2022).

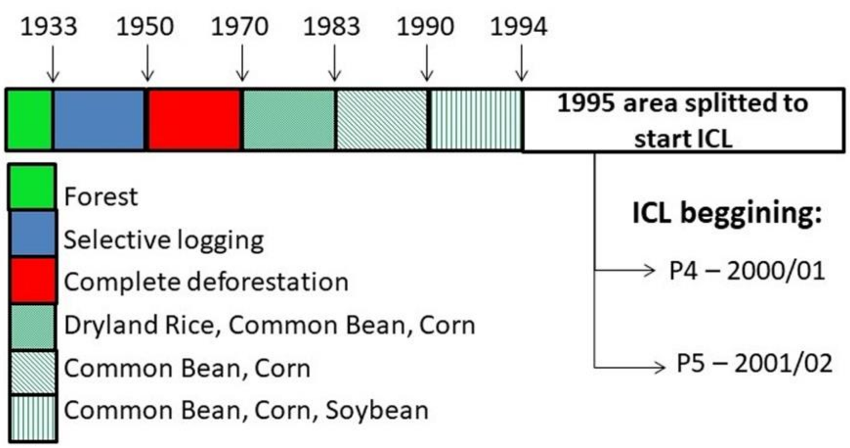


**Fig. 3.** Management history of the BR1 site's integrated crop-livestock (ICL) system. P4=BR1a, P5=BR1b. Source: Oliveira et al. (2022).

**Table 3.** Cropping sequences and tillage history of the two paddocks (BR1a and BR1b) under integrated crop-livestock systems at Santo Antônio de Goiás, Goiás State, Brazil (1990-2022).

| | BR1a | | BR1b | |
|---|---|---|---|---|
| Season Year | Summer | Winter | Summer | Winter |
| 1990/91 | Co. bean† CT‡ | Fallow | Co. bean CT | Fallow |
| 1991/92 | Corn CT | Fallow | Corn CT | Fallow |
| 1992/93 | Corn CT | Fallow | Corn CT | Fallow |
| 1993/94 | Soybean NT | Fallow | Soybean NT | Fallow |
| 1994/95 | Fallow | Co. bean CT | Fallow | Fallow |
| 1995/96 | Corn NT | Fallow | Corn NT | Fallow |
| 1996/97 | Corn NT | Fallow | Corn NT | Fallow |
| 1997/98 | Corn NT | Fallow | Corn NT | Co. bean NT |
| 1998/99 | Soybean NT | Fallow | Rice NT | Fallow |
| 1999/00 | Corn NT | Fallow | Corn NT | Fallow |
| 2000/01 | Corn+U (C)§ NT | U (C)¶ | Soybean NT | Millet NT |
| 2001/02 | Soybean NT | Millet NT | Corn+U(C) NT | U(C) |
| 2002/03 | Corn+U (C) NT | U (C) | Soybean NT | Co. bean NT |
| 2003/04 | Rice CT | Fallow | Corn+U (P) # NT | U (P) †† |
| 2004/05 | Corn+U (P) NT | U (P) | U (P) | U (P) |
| 2005/06 | U (P) | U (P) | U (P) | U (P) |
| 2006/07 | U (P) | U (P) | U (P) | U (P) |
| 2007/08 | U (P) | U (P) | Soybean CT | Co. bean NT |
| 2008/09 | U (P) | U (P) | Rice NT | Fallow |
| 2009/10 | Corn+U (P) NT | U (P) | Soybean NT | U (P) |
| 2010/11 | U (P) | U (P) | U (P) | U (P) |
| 2011/12 | U (P) | U (P) | Corn+U (P) NT | U (P) |
| 2012/13 | U (P) | U (P) | U (P) | U (P) |
| 2013/14 | Soybean NT | Fallow | U (P) | U (P) |
| 2014/15 | Rice NT | Sorgh+U (P)‡‡ NT | U (P) | U (P) |
| 2015/16 | Corn+U (P) NT | U (P) | Soybean (NT) | Fallow |
| 2016/17 | U (P) | U (P) | Rice NT | Millet NT |
| 2017/18 | U (P) | U (P) | Corn+U (P) NT | U (P) |
| 2018/19 | Soybean NT | Fallow | U (P) | U (P) |
| 2019/20 | Co. bean/ Rice+U (P) NT | U (P) | U (P) | U (P) |
| 2020/21 | U (P) | U (P) | U (P) | U (P) |
| 2021/22 | Co. bean/ Rice+U (P) NT | U (P) | U (P) | U (P) |

† Co. Bean, common bean.
‡ CT, conventional tillage; NT, no-till.
§ Corn+U (C), corn with *Urochloa* spp. cultivated as a cover crop.
¶ U(C), *Urochloa* spp. cultivated as a cover crop.
# Corn+U (P), corn with *Urochloa* spp. cultivated as a pasture.
†† U (P), *Urochloa* spp. cultivated as a pasture.
‡‡ Sorgh+U (P), sorghum with *Urochloa* spp. cultivated as a cover crop.
## Rice+U (P), aerobic rice with *Urochloa* spp. cultivated as a cover crop.
Source: Oliveira et al. (2022).

Circularity in BR1 involves reducing the use of mineral fertilizers by biological N fixation in common-bean; application of biological inputs, such as growth promoter bacteria, in aerobic rice; intensification of crop rotation planting two summer crops, one of them in intercropping with *Urochloa sp.*; year-round living cover crop; implementing of leguminous species in the pasture. All areas have been under zero tillage since 1995. Compared to conventional ICL management (historical background of the ICL system) and continuous pasture, the above-described sustainable management practices increase circularity, reduce external inputs; increase system intensity; contribute to reducing cultivated land area or increasing productivity by enhancing productivity, and therefore reduce greenhouse gas emissions, increase resilience and promote adaptation capacity to the effects of climate change.

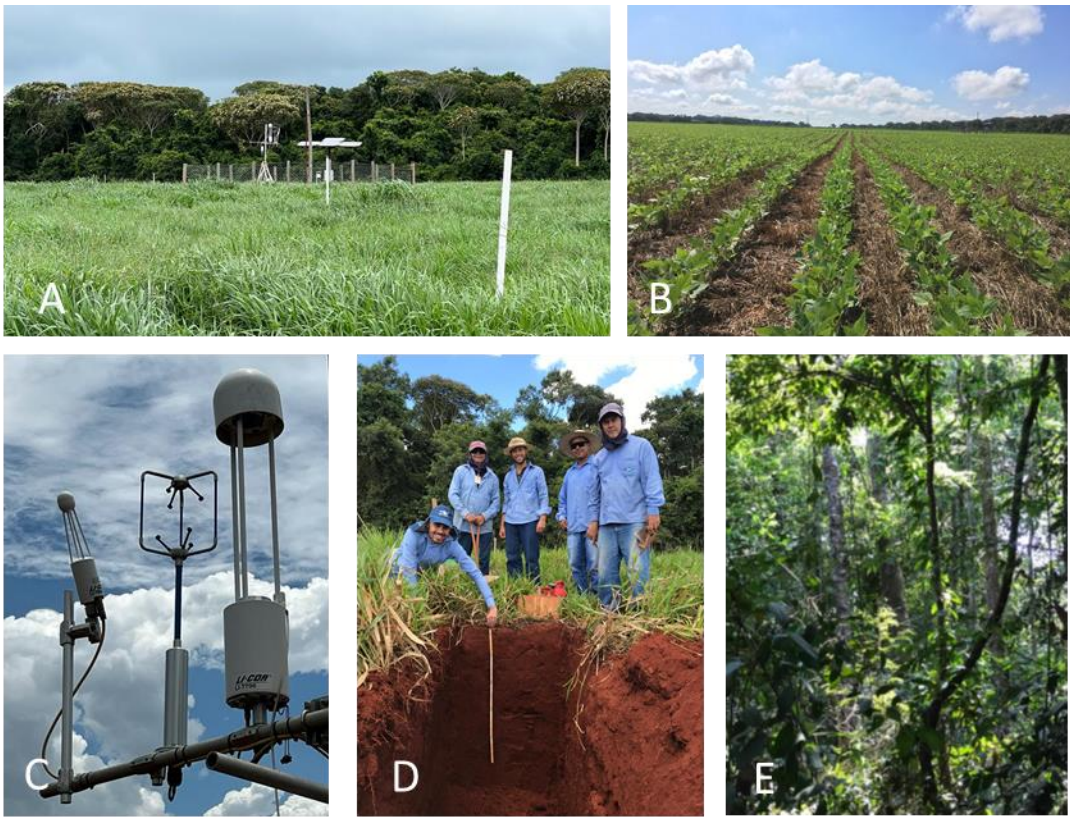


**Fig. 4.** A: Site BR1a with pasture (*Urochloa brizantha* cv Paiaguás) in integrated crop-livestock system; B: Site BR1b with common-bean (*Phaseolus vulgaris* BRS A504) in integrated crop-livestock system; C: CO2/H2O and CH4 sensors (LI-Cor Inc.); D: clayey Rhodic Ferralsol; E: Natural vegetation: semi-deciduos forest (savanna formation - Cerradão). Photos were taken between October and December, 2022.

## 3.2 BR2

The case study BR2 is an experimental station of Embrapa Agrosilvopastoral, which is located in Mato Grosso state (Fig. 5a). The rainfall regime is well defined, with a rainy season from October to April and dry season from May to September (Fig. 5b).The soil is classified as Oxisol and the natural vegetation as Amazon rainforest, sometimes classified as ecotone Forest/Cerrado biome. In the area we have 4 silvopastoral system with different tree densities: 120, 130, 260 e 340 trees/ha. All the systems have the pasture formed by Ipyporã grass (an interspecific Urochloa hybrid - U. brizantha × U. ruziziensis) grazed by dairy (crossbred Holstein x Gyr). The forestry component is composed of Eucalyptus trees (Eucalyptus spp.) for energy production (Fig. 6).

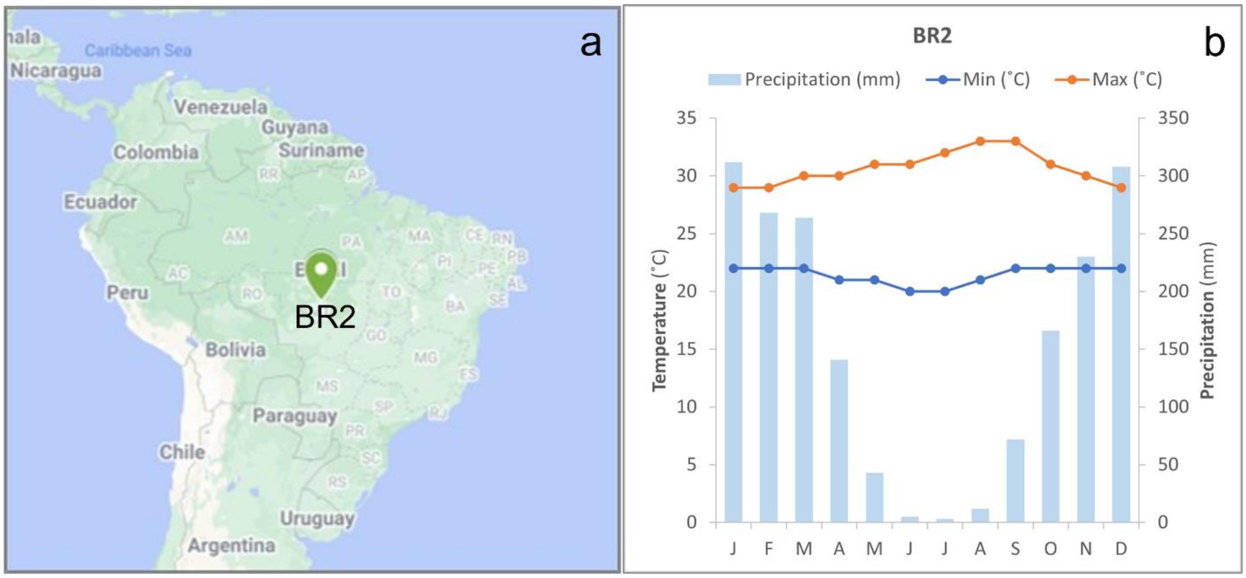


**Fig. 5.** Location of the case study BR2 (Google Maps© image) (a) and the monthly climatic data for the area (b). Climatic data is derived from a 30-year observed data series. Source: climatetempo.com.br.


**Fig. 6.** Aerial view (a) and ground view (b) of the case study BR2.

The evaluated systems, started in 2010 with subsoiling, correction of soil acidity and correction fertilization, and in January 2011, planting Eucalyptus urograndis - clone H13 in rows in an east-west direction with a spacing of 2 m between plants and 3 m between rows. In the first two years after the establishment of the trees, the inter-row area was occupied with planting corn, and then there was intercropping between corn and Urochloa brizantha cv BRS Piatã. When the corn was harvested, the grass remained in the area to standardize the canopy according to the grazing strategies. Subsequently, in 2016 the Piatã grass was desiccated to form a new pasture for Panicum maximum cv Massai, which was also desiccated in 2019 to establish a pasture with Urochloa spp. cv. BRS RB331 Ipyporã, grass that followed until the present configuration. More details follow.

In 2016, corn was sown along with Massai grass in the experimental area. Before sowing, the area was desiccated with glyphosate to remove the corn crop residues (previous single crop). On 12/14/2016, maize (Dekalb 390 variety – VT Pro technology) was sown together with Massai grass, with 45 cm spacing between rows (maize sowing density of 60,000 seeds ha-1) of Massai grass per linear meter (6 kg ha-1 of commercial seeds with 78% cultural value). The planting fertilization used was 200 kg ha-1 of formulated commercial fertilizer (NPK 04-30-16).

In the year of implantation, two covering fertilizations were carried out, the first with 80 kg ha-1 of formulated commercial fertilizer (NPK 20-00-20) in the corn four-leaf stage, and the second with 150 kg ha-1 of urea in the seven-leaf stage of maize.

In April 2017, the corn was ensiled, allowing the development of Massai grass to establish the pasture. Corn silage was used to supplement the animals in the dry season/2018 (beginning on 07/09 and 12/06/2018 for moderate shading, full sun and intense shading systems, respectively, and ending on 10/17/ 2018). Between 10/09 and 11/17/2017, a last fertilization of Massai grass formation was carried out with 100 kg ha-1 of KCl (60% K2O), on 10/13/2017 with 400 kg ha-1 of simple superphosphate ( 18% P2O5) and on 10/23/2017 with 120 kg ha-1 of urea (45% N).

In 2018, the plots received maintenance fertilization in cover under different forms and times. The first was carried out before the beginning of the experiment (01/10/2018) with only urea (100 kg ha-1 of urea), in a single application distributed by broadcast and mechanized. The second was carried out almost a year after the first fertilization, using commercial formulation fertilizer (NPK), equivalent to a total of 100 kg ha-1 of N, applied manually and divided into two applications in each paddock in the area useful cultivation (12 kg of 20-00-20 per paddock, per application), after grazing and animals leaving the paddocks.

In the formation of Ipyporã grass in 2019, the sowing density was 5 kg of pure viable seeds and fertilization of 200 kg ha-1 of 8-28-16 (NPK) was applied in line. Maintenance fertilization on Ipyporã grass was carried out on 03/20/2020, with 200 kg ha-1 of urea; 02/12/2021, with 200 kg ha-1 NPK (20-0-20); 03/30/2021 with 300 kg ha-1 of supersimples; 10/25/2021 1.5 Mg ha1 of dolomitic limestone; 02/24/2022 with 250 kg ha-1 of NPK (20-0-20).

Circularity in BR2 involves reducing the use of external inputs; increase system intensity; contribute to reducing cultivated land area or increasing productivity by enhancing productivity, and therefore reduce greenhouse gas emissions, increase resilience and promote adaptation capacity to the effects of climate change.

## 3.3 BR3

The case study BR3 is a commercial farm located in Bahia state (Fig. 7a). The rainfall regime is well defined, with a rainy season from October to April and dry season from May to September (Fig. 7b). The average annual relative humidity is around 70%, with maximum monthly values occurring from November to May, and minimum monthly values from June to October. The average annual evapotranspiration is about

1,600 mm, with the period of greatest evapotranspiration between June and October, surpassing the precipitation and becoming more critical at the end of the dry period, in the months of August and September, due to the accumulation of losses from previous months. Most of the area around BR3 are under natural vegetation (Cerrado). The predominant relief in the area ranges from flat to slightly undulating and an essentially sandy matrix and the soils in the area are predominantly classified as Arenosols with low cohesion of soil aggregates and fragile structure, implying high erodibility and high drainage capacity. In addition, these soils exhibit low levels of organic matter and natural fertility. However, medium and fine fractions of sand predominate in the profile, which, associated with a characteristic increment of clay in depth, allow greater water retention in the subsurface layers, notably around one meter in depth. In addition, the flat to gently undulating relief, the high permeability and the absence of physical impediments in depth favor the mechanization of agricultural activities in large areas. Therefore, they are potentially arable soils in intensive systems, requiring conservationist management strategies that prioritize soil coverage, deep root growth and the increase of organic matter in the profile, as well as the reduction of surface water runoff while minimizing soil disturbance, which may results in soil compaction.

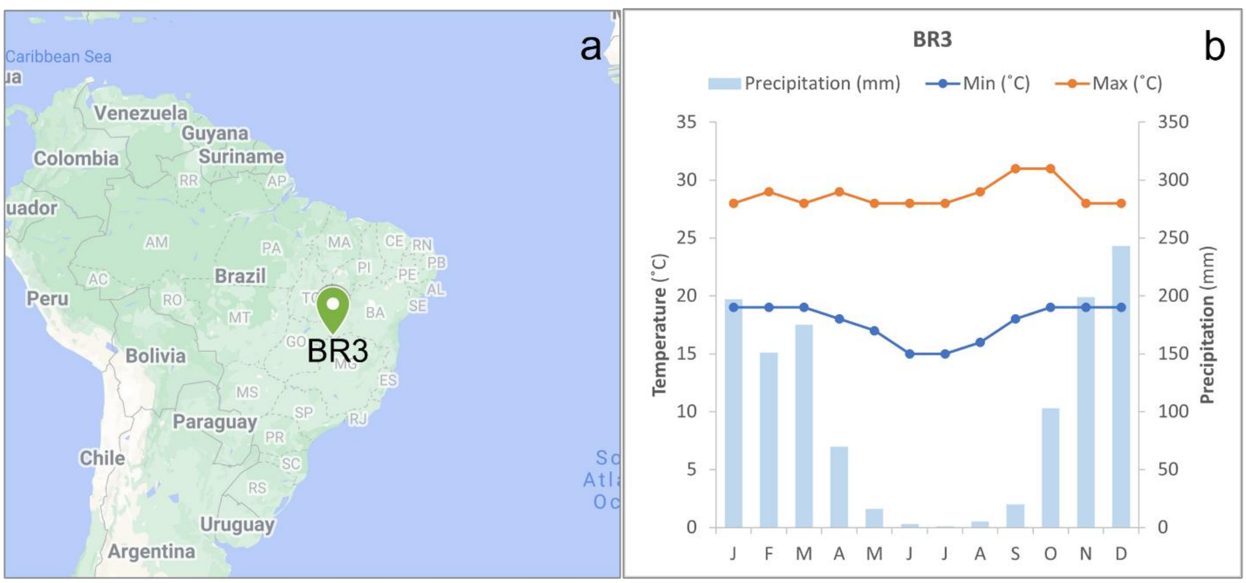


**Fig. 7.** Location of the case study BR3 (Google Maps© image) (a) and the monthly climatic data for the area (b). Climatic data is derived from a 30-year observed data series. Source: climatetempo.com.br.

Crops produced in the area are: soybean and maize in BR3a and soybean, sorghum (*Sorghum spp.*) and pearl millet (*Pennisetum glaucum*) in BR3b. Livestock (Nelore) is for beef production. There are no trees in BR3a, while BR3b the forestry component is composed of Eucalyptus for wood production.

BR3 is presented as BR3a and BR3b, which represent production areas of Low Carbon Brazilian Beef (LCBB) and Carbon Neutral Brazilian Beef (CNBB). The CNBB production system is already a brand concept which aims at certifying meat production based on criteria, concepts and practices to value a more efficient livestock production system which aims at neutralizing GHG emissions by the herd during its productive cycle. CNBB involves the implementation of adequate practices of herd and pasture management, soil correction and fertilization, integrated livestock-forest (ILF) or crop-livestock-forest (ICLF) systems, through established processes parametrized and audited by regulations and representatives from the value chain, along with technical support from Embrapa (Almeida et al., 2016; Alves et al., 2017). CNBB requirements include: (1) adoption of ILF and ICLF systems based on the "Low Carbon Agriculture" of the Brazilian National Plan (ABC Plan) and the use of Embrapa guidelines; (2) Assessment of the farm production system baseline GHG emissions based on data from the IPCC and PECUS Network (www.cppse.embrapa.br/redepecus); (3) Carbon content estimates for the forest component according to Embrapa recommendations; (4) Calculations for GHG neutralization based on PECUS Network; (5) Concession of use for the brand concept to partners legally authorized by Embrapa and (6) Systems audited by independent auditors linked to companies accredited for public or private agencies. Similarly, the LCBB production system is based on criteria, concepts and practices to value a more efficient integrated livestock systems in mitigating GHG emissions by the herd during its productive cycle, but without the presence of the trees (Almeida & Alves, 2020). However, to date, there are no production systems in Brazil with validated LCBB guidelines, warranting research in this reference area that will permit the elaboration of these guidelines to create the LCBB protocol. Fig. 8 exhibits the aerial and ground views of the area.


**Fig. 8. Aerial view (a) and ground view (b) of the case study BR3.**

Circularity in BR3 involves the use of plant remains from the pruning of Eucalyptus trees to promote nutrient cycling while the presence of trees allows for a more favorable thermal comfort for the animals to gain weight at the CNBB systems. In addition, both at the CNBB and at the LCBB, pasture management by height is carried out, monitoring the entry and exit of animals from the paddock according to the development of the plants, in which about 40 cm of height determines the entry of animals, whereas 20 cm determines the exit of animals. Plant remains from Brachiaria grass allows adequate soil coverage, which avoids water, soil and nutrient losses by evaporation and erosion, which in turn, decreases the need for fertilizer application and provides a more favorable condition for microbial activity and carbon storage in the soil. Additionally, the constant evaluation of soil fertility allows the optimization of fertilizer applications, according to plant demand and soil nutrient availability, leading to a more rational use of inputs. Circularity is also present in the greater weight gain of the animals, due to the offer of better-quality pasture, which reduces the time the animals spend on the pasture, thus reducing methane emissions per animal per area and provides an increase in animal stocking per area, enabling a 'land-saving effect' and prevents the deforestation of new agricultural areas.

# 4 Outlook

The general characterization of the case studies presented here will be used in other WPs for biophysical contextualization of the case studies in the SENSE project. Results from WP2 (circularity and ecological indicators), WP3 (near real-time monitoring of GHG emissions and carbon and nutrient cycling) and WP4 (multidimensional sustainability assessments) can further enrich the information currently presented here. The Technical Briefs will be uploaded to the project's website for dissemination and communication purposes.

# 5 References


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