

Adapting to climate change: Strategies for Brazilian agricultural and livestock systems



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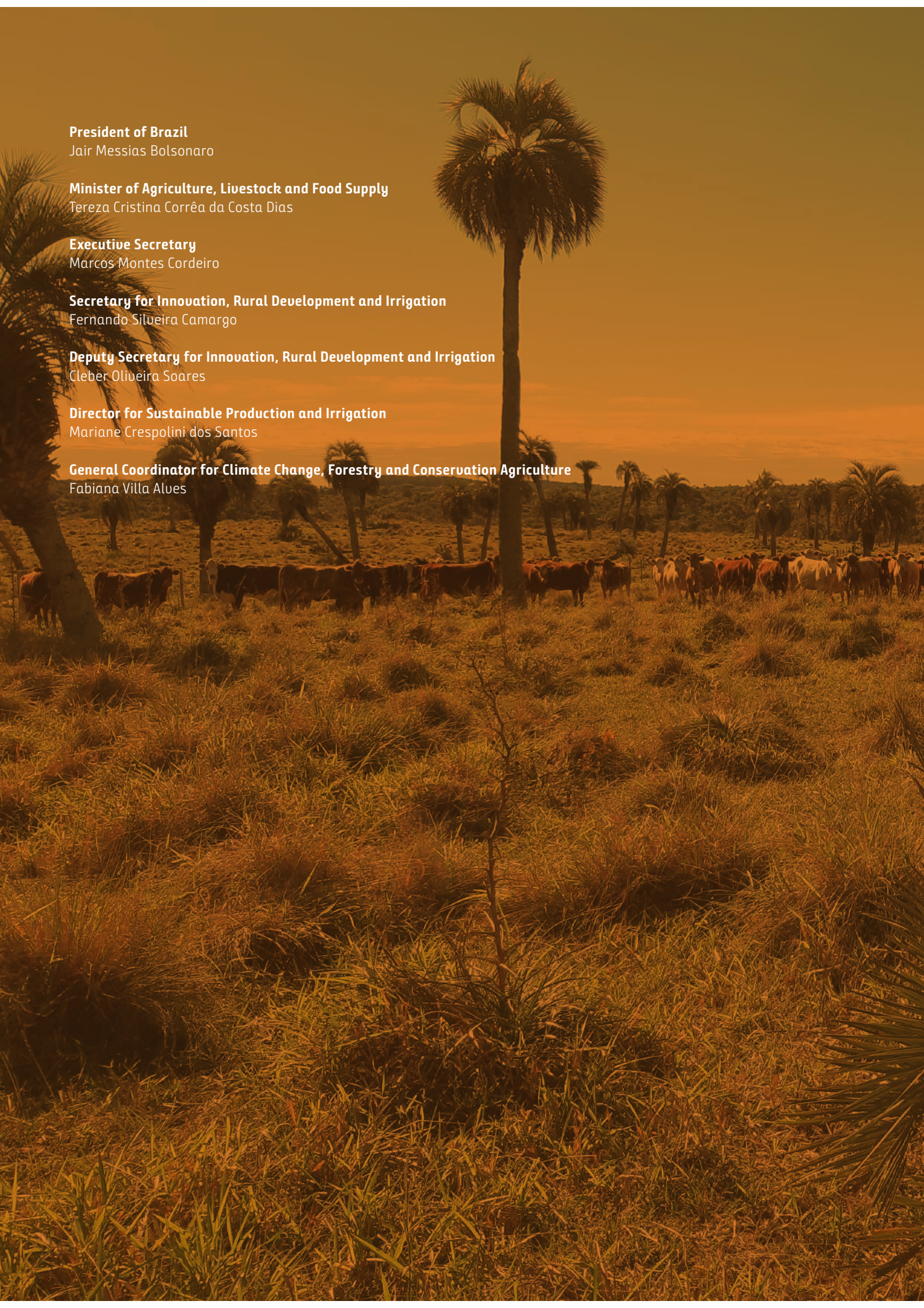
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**Adapting to climate change: Strategies for
Brazilian agricultural and livestock systems**

MAPA'S Mission

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development of agriculture
and livestock

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PREFACE

Adapting to climate change demands sectoral initiatives as sectoral initiatives for adaptation to climate change are part of an established of an established national institutional arrangement. There are numerous public and private institutions directing their efforts to achieve the commitments made to Brazilian and international society in favor of sustainable development, and a history of initiatives contributing to efforts to tackle climate change.

The National Policy on Climate Change (NPCC) was instituted in 2009 by Law no. 12,187 and regulated by Decree 7,390/2010, formalizing Brazil's voluntary commitment to the United Nations Framework Convention on Climate Change (UNFCCC) to greenhouse gas emissions. According to the law, the objectives achieved by the NPCC must be in aligned with sustainable development, aiming at economic growth, the eradication of poverty and the reduction of social inequalities.

As part of the PNM, in 2010, the Sectorial Low Carbon Emission Agriculture Plan - Plano ABC was developed. The purpose of the plan is to organize and propose actions to adopt sustainable production technologies, chosen to respond to the country's GHG emission reduction commitments in the agricultural sector. Above all, however, it aims to encourage, motivate, and support the agricultural sector in its implementation of actions that strengthen the resilience of agroecosystems, thus increasing adaptive capacity to climate change.

Agriculture has developed a strong capacity for adaptation, due to the historical displacement of humanity to new areas and new climatic characteristics, in addition to the climatic variability to which it is exposed. Therefore, numerous data has been collected by various institutions and people on issues related to the agricultural sectors and their adaptation to climate variability in Brazil. More specifically, regarding climate change, what is observed is that research, instruments, programs, initiatives have a wide range of different approaches and strategies.

This study is a fundamental step in the task of understanding this wide range of approaches being developed in Brazil and setting the guidelines and essential details of the Program for Adapting Brazilian agricultural systems to climate change, within the scope of the revision of the ABC Plan and its next cycle of implementation.

We would like to thank all the collaborators and institutions that contributed to this strategy, and wish them a fruitful read ahead!

Tereza Cristina

Minister of Agriculture, Livestock and Food Supply



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ACRONYMS

ACQ	Slash and Burn Agriculture Areas
APA	Environmental Protection Area
APA	Alternative Producers Association
ATER	Technical Assistance and Rural Extension
BAG	Active Germplasm Bank
BFN	Biodiversity Project for Food and Nutrition
C	Carbon
CAPES	Coordination for the Improvement of Higher Education
CBDR	Common but Differentiated Responsibilities
CBL	Caatinga Buffel Leguminosa
DMI	Dry Matter Intake
CNA	National Confederation of Agriculture
CNPq	National Council for Scientific and Technological Development CO Carbon Monoxide
CO ₂	Carbon Dioxide/Carbon Gas
CONSEA	National Council for Food and Nutrition Security
COP	Conference of the Parties
TOC	Total Organic Carbon
EMATER	Technical Assistance and Rural Extension Company
EMBRAPA	Brazilian Agricultural Research Corporation
FACEs	Free-Air CO ₂ Enrichment
FAO	United Nations Food and Agriculture Organization

BNF	Biological Nitrogen Fixation
GCCRC	Center for Research in Genomics Applied to Climate Change
GHG	Greenhouse Gases
GST	Global Assessment Process
ha	Hectare
IBGE	Brazilian Institute of Geography and Statistics
IDSM	Mamirauá Sustainable Development Institute
ICL	Integrated- Crop-Livestock
ICLF	Integrated-Crop-Livestock-Forest
INPA	National Institute of Amazon Research
IPBES	Intergovernmental Platform for Science and Policy on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ISA	Agroecosystem Sustainability Indicators
ISNA	Water Needs Satisfaction Index
MAPA	Ministry of Agriculture, Livestock and Food Supply MATOPIBA Maranhão, Tocantins, Piauí and Bahia
GCM	Global Climate Models
MCTI	Ministry of Science, Technology, and Innovations
MDS	Ministry of Social Development
MMA	Ministry of the Environment
SOM	Soil Organic Matter
N	Nitrogen

N ₂ O	Nitrous Oxide
NDC	Nationally Designated Contributions
SDG	Sustainable Development Goals
GMO	Genetically Modified Organisms
UN	United Nations
PAA	Food Purchase Program
PAIS	Integrated and Sustainable Agroecological Production
PECUS	Project Dynamics of Greenhouse Gases in Brazilian Agricultural Production Systems
PGPMBio	Minimum Price Guarantee Policy for Socio-biodiversity Products
PLANAPO	National Agroecology and Organic Production Plan
ABC Plan	Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in Agriculture
PNA	National Plan for Adapting to Climate Change
PNAE	National School Feeding Program
PNAM	National Food and Nutrition Policy
NPCC	National Policy on Climate Change
PROAGRO	Agricultural Activity Guarantee Program
PRONA	National Program for Strengthening Family Agriculture
PSR	Subsidy Program for the Rural Insurance Premium
RCP	Representative Trajectories of Concentration Scenarios
SABIIA	Open and Integrated Agricultural Information System
AFSs	Agroforestry Systems

IS	Integrated System
SisGen	National System of Management of Genetic Heritage and Associated Traditional Knowledge
t	Ton
T-FACEs	Temperature-Free-Air CO ₂ Enrichment
UNFCCC	United Nations Framework Convention on Climate Change
PU	Production Units
ZAEs	Agroecological Zoning
ZARC	Climate Risk Agricultural Zoning

INTRODUCTION

This publication is part of the Sectorial Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in Agriculture - ABC Plan. The ABC Plan aims to organize and propose actions for the adoption of sustainable production technologies, selected with the objective of increasing productivity and economic profitability, as well as the resilience and adaptive capacity of national agricultural systems.

With the adoption of "ABC technologies", the expectation is that Brazil will increase food production, contributing to food security, in a sustainable manner, without the need to increase the area dedicated to agricultural activity. At the same time, efforts are being made to ensure that production systems are more resilient to climate change and more efficient in controlling greenhouse gas (GHG) emissions associated with agricultural activities. However, methods and approaches are still being developed to assess what defines resilience of agroecosystems, the needs and adaptation capacities, their co-benefits, as well as the dimension of the socioeconomic impacts of climate change in the agricultural sector.

Adaptation to climate change refers to changes in processes, practices, and structures to mitigate possible damage caused by climate change, or to take advantage of the opportunities associated with such changes (UN, 2020). Adaptation in agricultural systems has become a central element in climate policies and research (BERRANG-FORD et al., 2015). as they are the most comprehensive systems in the occupation of land use on the planet (ANANDHI. 2017), According to FAO (2017), adaptation in the agricultural sector consists of changes in elements of natural systems and agricultural production, as well as in socio-economic, institutional, or public policy instruments, which are developed as a response to and in preparation for climate change and current and expected climatic variability. Adaptation in the agricultural sector also includes its impacts, with the objective of preventing or mitigating harmful effects, focusing on exploring the beneficial opportunities.

According to LOBELL et al, (2008), adaptive capacity is a key factor that defines the future severity of climate change impacts on food production. Therefore, the development of adaptation strategies to counteract the impacts of climate change is globally (IPCC, 2014) and nationally (WALTHALL et al., 2012) evident. However, adaptation strategies are still often presented as shopping list format, with options for people to choose from a range of alternative practices, policies and/or technologies without deeper considerations on broader or systemic outcomes (THOMSEN et al., 2012). PRESTON (2015) states that conceptual models, tools, and methods developed by researchers have not yet evolved sufficiently to compose guidelines on how to adapt to climate change. Although many studies use one or more approaches and/or levels of adaptation as a basis, most of these studies do not generate a methodology that develops quantitative values for the pre-selected adaptation strategy, and are commonly measured only according to biophysical variables (ANANDHI. 2017) .

On the other hand, adaptation efforts should fundamentally contribute to building paths towards sustainable food production and food security for all (FAO, 2017). The same FAO report highlights that the Paris Agreement establishes adaptation to climate change as one of its key objectives, It advocates for the need to improve adaptive capacity, strengthen resilience, and reduce vulnerability to climate change.

Adapting to climate change: Strategies for Brazilian agricultural and livestock systems aiming towards sustainable development. To reduce vulnerability and increase resilience and adaptive capacity to climate change, decisions by researchers, farmers, and family farmers delivering a series of agricultural and non-agricultural adaptation strategies, which vary significantly between the various groups of farmers.

Given this context, this publication aims to identify methods and approaches that are being adopted to assess the resilience and adaptive capacity of Brazilian agricultural systems, including social, economic, and environmental benefits resulting from the strategies adopted by these systems.

To this end, researchers and research groups were identified, as well as eventual technical groups, who work on the topic and who received a consultation script, in which they inserted the requested information. The final result of this compilation of experiences is this publication entitled "Adaptation strategies of Brazilian agricultural and livestock systems to climate change". In the following pages, our aim is to identify and highlight the multiplicity of initiatives, actions, concepts and approaches that exist for adapting to climate change, as well as identify possible gaps, challenges, opportunities and needs in the process of strengthening resilience and the adaptive capacity of Brazilian agroecosystems.

It is our hope that this information survey will guide you through the diversity of experiences in progress in the various Brazilian regions. and help you understand the stages of research and technological development under the perspective of sustainable agricultural production systems, Above all, this publication seeks to identify how the different strategies build the resilience of agricultural production systems and allows them to increase their capacity for adapting to climate change. Based on gathered information, we were able to identify management systems and different methodologies and techniques applied for this purpose. The result is a map that includes ongoing experiences and their degree of development and applicability, to guide the identification of central elements and processes for the establishment of effective policies and actions to promote resilience and build the adaptive capacity for agricultural production systems in Brazil.

As highlighted by the IPCC (2014) and WALTHALL et al, (2012), the development of adaptation strategies is vital to counteracting the impacts of climate change. Therefore, the methodological proposal for organizing and analyzing the data collected through these scripts had as a central focus understanding the conceptual logic that directs the development of adaptation strategies by Brazilian researchers for agricultural systems in relation to climate change, categorizing them in four strategic axes. Categorizing strategies follow a deductive approach (MORETTI et al., 2011), in other words, the categories are previously formulated based on the results from a literature review, discussions and definitions proposed with the MAPA team. The categories are: I) Use of genetic resources; II) Infrastructure, production technologies and equipment; III) Use and conservation of biodiversity; and IV) Integrated landscape management. The categories were thus defined to facilitate the comparison of the results presented by the researchers. Organizing adaptation options in the agricultural sector according to players and types of action facilitates adaptation assessment and planning, as it identifies players and clarifies possible interactions that can influence adaptive capacity (WALTHALL, et al., 2012). According to the authors, it is possible to establish a spectrum of intention and action in adaptation options following resistance, resilience, and transformation strategies, describing an increasing gradient in the adaptive capacity of an agricultural system.

The survey of experiences initially started from a detailed search for papers and researchers in different platforms and institutions. The key words that guided the survey are related to agriculture, crops, climate change and its consequences. Then, several researchers were invited to participate in the Adaptation Compilation by sending their script by email. To deepen the analysis and development of each axis, technical-scientific reviewers with experience in the theme were invited to produce an introductory text with an analysis of each topic and studies sent by the researchers.

The publication ends with a critical analysis of submitted research, focusing on comparing the diversity, differences, similarities, and trends of the approaches adopted in each one and among the strategic axes of adaptation of Brazilian agricultural systems to climate change.

In general, there is a convergence between the results found in the other countries' national experience and those submitted by Brazilian researchers regarding the difficulty of establishing a clear conceptual framework on adaptation to climate change. Although mechanisms are being developed in some countries, mainly linked to the National Adaptation Program (NAP) established by the UNFCCC Conference of the Parties (COP), there is still a long way to go. This gap is also evident in the Brazilian context. It is our hope that this compilation will contribute to the discussion, to guide effective actions to promote resilience and strengthen the adaptive capacity of agricultural production systems in Brazil, thus ensuring their productive capacity, income, and the sustainability of rural life and of the national economy.

Enjoy your reading!

Editors

Referências bibliográficas

ANANDHI. A. CISTA-A: Conceptual model using indicators selected by systems thinking for adaptation strategies in a changing climate: Case study in agro-ecosystems. *Ecological Modelling* 345. 41–55. 2017.

BERRANG-FORD. L.. PEARCE. T.. FORD. J.D. Systematic review approaches for climate change adaptation research. *Reg. Environ. Change* 15. 755–769. 2015.

Food and Agriculture Organization of United Nations (FAO). Tracking adaptation in agricultural sectors: Climate change adaptation indicators. 2017. Disponível em: <http://www.fao.org/3/a-i8145e.pdf>. Acesso em 09 jul. 2020.

IPCC. C.C.I. Adaptation, and Vulnerability. Part A. In: Field. C.B.. Barros. V.R.. Dokken. D.J.. Mach. K.J.. Mastrandrea. M.D.. Bilir. T.E.. Chatterjee. M.. Ebi. K.L.. Estrada. Y.O.. Genova. R.C.. Girma. B.. Kissel. E.S.. Levy. A.N.. MacCracken. S.. Mastrandrea. P.R.. White. L.L. (Eds.). *Climate Change: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. Cambridge. United Kingdom and New York. NY. USA. 1132 p. 2014.

LOBELL. D.B.. BURKE. M.B.. TEBALDI. C.. MASTRANDREA. M.D.. FALCON. W.P.. NAYLOR. R.L. Prioritizing climate change adaptation needs for food security in 2030. *Science* 319. 607–610. 2008.

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MINISTERIO DO MEIO AMBIENTE (MMA). Plano Nacional de Adaptação a Mudança do Clima. Volume II: Estratégias Setoriais e Temáticas. Brasília. DF: Ministério do Meio Ambiente. 371 p. 2016.

MORETTI, F., van VLIET, L., BENSING, J., DELEDDA, G., MAZZI, M., RIMONDINI, M., ZIMMERMANN, C., FLETCHER, I. (2011). A standardized approach to qualitative content analysis of focus group discussions from different countries. *Patient Education and Counseling*, 82, 420–428. 2011.

PRESTON, B. L., MUSTELIN, J., MALONEY, M. C. Climate adaptation heuristics and the science/policy divide. *Mitigation Adaptation Strategy Global Change* 20, 467–497. 2015.

THOMSEN, D.C., SMITH, T.F., KEYS, N. Adaptation or manipulation? Unpacking climate change response strategies. *Ecol. Soc.* 17, 20. 2012.

UNITED NATION. Climate Change. What do adaptation to climate change and climate resilience mean? 2020. Disponível em: <https://unfccc.int/topics/adaptation-and-resilience/the-bigpicture/what-do-adaptation-to-climate-change-and-climate-resilience-mean>. Acesso em: 21 set. 2020.

WALTHALL, C. L., HATFIELD, J., BACKLUND, P., LENGNICK, L., MARSHALL, E., WALSH, M., ADKINS, S., AILLERY, M., AINSWORTH, E. A., AMMANN, C., ANDERSON, C. J., BARTOMEUS, I., BAUMGARD, L. H., BOOKER, F., BRADLEY, B., BLUMENTHAL, D. M., BUNCE, J., BURKEY, K., DABNEY, S. M., DELGADO, J. A., DUKES, J., FUNK, A., GARRETT, K., GLENN, M., GRANTZ, D. A., GOODRICH, D., HU, S., IZAURRALDE, R. C., JONES, R. A. C., KIM, S-H., LEAKY, A. D. B., LEWERS, K., MADER, T. L., MCCLUNG, A., MORGAN, J., MUTH, D. J., NEARING, M., OOSTERHUIS, D. M., ORT, D., PARMESAN, C., PETTIGREW, W. T., POLLEY, W., RADER, W., RICE, C., RIVINGTON, M., ROSSKOPF, E., SALAS, W. A., SOLLENBERGER, L. E., SRYGLEY, R., STÖCKLE, C., TAKLE, E. S., TIMLIN, D., WHITE, J. W., WINFREE, R., WRIGHT-MORTON, L., ZISKA, L. H. *Climate Change and Agriculture in the United States: Effects and Adaptation*. USDA Technical Bulletin 1935. Washington, DC. 186 p. 2012.

Local and International Governance: challenges and opportunities to encourage structural adaptation actions for the Brazilian agricultural sector

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Climate change, as well as many other crises that have afflicted humanity throughout our brief existence on this planet provides opportunities for nations who invested in developing technologies and a scientific framework adjusted to the domestic reality, which have sufficiently qualified human resources and whose societies are able to understand and adjust their behavior dynamically.

In order to face these challenges, the United Nations Framework Convention on Climate Change (UNFCCC), universally accepted by all countries that are United Nations (UN) signatories, established the following fundamental principles: the climate system must be protected for the benefit of present and future generations; the specific needs and special circumstances of developing Countries must be fully considered; Parties should take measures to prevent, avoid or minimize the causes of climate change and mitigate its negative effects; Parties have the right to sustainable development and must promote it, considering economic development as essential for the adoption of measures to face the present and inevitable impacts of climate change, which are already being felt by this generation.

However, the reality and practice of political processes, which govern both international diplomacy and the intricacies of domestic politics, are laden with peculiarities. There are several political and economic interests that influence this dynamic. The reality imposed by international politics tends to emphasize, for developing nations, actions focused on mitigating greenhouse gases but do not support or prioritize an equal level of investments towards fostering resilience and adaptive capacity. International climate change governance, and even the UNFCCC's Subsidiary Implementation Body (SIB), has shown little effectiveness in promoting investments that result in systemic gains in developing countries' adaptive capacity, as opposed to the flow of resources available for projects and initiatives that aim to promote actions for reducing greenhouse gas emissions (mitigation).

For developing countries, effective investments in adaptation, besides being scarce, are also rarely connected or integrated with national governance. In these countries, even investments to systematize indicators are not prevalent, causing them to sometimes be confused with actions aimed at the preservation and conservation of natural resources, and sometimes with those aimed at sustainable development.

Despite the global and temporal dimension of climate change problems, it is necessary to emphasize that the solutions to this issue must be thought out and adopted locally, on a scale and timeline compatible with a few human generations (RAYNER; MALONE, 1998). Particularly exposed to the dynamics of the climate and its fluctuations, the agricultural sector has inherent political challenges that involve the design of specific policies capable of promoting gains in terms of resilience, profitability, and sustainability in the field, in a consistent manner.

The fifth report on impacts, adaptation, and vulnerability from Working Group II of the Intergovernmental Panel on Climate Change (IPCC) indicates that humanity is on a path of reducing aptitude and worsening the productive capacity of several crops that are key to both food production and bioproducts (IPCC, 2014). The kinetics of the processes associated with climate change are in a planetary scale and result in inertia, where its order of magnitude can be more than fifty years. Therefore, with the awareness that we are still on an upward path of greenhouse gas emissions, the construction of domestic policies must contemplate and prioritize the development of scientific knowledge and production strategies compatible with the predicated level of planetary entropy.

According to the IPCC's special earth report, food products face challenges of institutional fragmentation and, nevertheless, suffer from the lack of communication and engagement between players at different levels, which results in policies with shallow and obtuse objectives (IPCC, 2019). In a scenario of high international competitiveness and considering the potential disruptive role that the negative effects of climate change may have on poorly adapted economies, the special report on land use indicates that intersectoral coordination between public health, transport, environment, water, energy, and infrastructure is strategic to ensuring the positive results of domestic policies with social, environmental, and economic benefits.

Thus, planning and risk assessment tools must start to incorporate models and scenarios in a structural way, in order to ensure that the horizon of debate and problematization is not overshadowed by the immediate nature of the present reality. For agriculture, the design of sectoral climate change governance necessarily involves: the translation of a delicate balance between the dimension of multilateral governance, particularly in the context of the United Nations and its conventions; the dimension of the dynamics and commercial relations between exporting countries and consumer markets; and, finally, the domestic dimension, dependent on sectoral policies engaged in producing tangible and measurable results that can, in the final analysis, add value to agricultural products.

In the international arena, and especially since 2009, the Empresa Brasileira de Pesquisa Agropecuária (Embrapa) has collaborated with the Ministry of Agriculture, Livestock and Food Supply (MAPA) and the Ministry of Foreign Affairs (MRE), in strategic negotiations with the UNFCCC. Starting in 2020 and spanning over the next decade, the great political challenge posed by climate change will result from the implementation of the Paris Agreement¹ and, in the context of the UNFCCC, the promotion of an economic model that values production systems that are less and less intensive in fossil carbon. For Brazil, the primary objective of a strategy for adapting to the impacts of climate change must include improving the understanding of tropical agricultural systems and their agronomic, environmental, and social differential and potential. It is fundamentally relevant that a solid monitoring and communication strategy will allow us to forge, alongside society, a positive perception about the multiple benefits resulting from the tropical and sustainable agricultural model developed in Brazil, in addition to the relevant role of this sector as a provider of bioproducts, food security and energy - the main tripod of the agricultural bioeconomy.

¹ Available at: <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>.

Once other economic variables are isolated, such as distance traveled to reach the consumer market or market reserve barriers, the trend in coming years is that environmental predicates and other social qualities will be increasingly relevant according to the metrics by which the products are valued and, consequently, penetrate and access international markets. When the Paris Agreement entered into force in 2020, a new cycle began towards increasing the Convention's transparency mechanism by reducing the current differences between monitoring obligations for Annex I and Non-Annex I Countries. The Paris Agreement will provide a single model for reviewing national inventories and a single database, thus fostering comparability. This new instrument will certainly represent a challenge for developing countries, but also an incredible opportunity for the dissemination of technological predicates and differentials. This entirely new structure developed under the Paris Agreement has the objective of feeding the global evaluation process (GST) which aims to periodically make the Agreement more ambitious, imposing, through the revision of the nationally designated contributions (NDCs), dynamism in a continuous process to increase domestic efforts.

In this context, building the image of the agricultural product is certainly something intrinsically related to a long-term strategy and that adheres to the process that will come into force with the Paris Agreement. It is natural, therefore, that this environment will be used as a showcase by those capable of demonstrating sustainability in their domestic actions and who wish to positively impact the image of their production systems and technologies.

Along these lines, it will be up to the Brazilian agricultural sector to systematize and clearly characterize how policies and technologies, including those already incorporated by the ABC Plan, present benefits quantified in a robust way to society, particularly with regard to their contributions to adapt to the potential negative impacts of climate change, to the conservation and improvement of the resilience of productive systems, food security, integrated landscape management and in controlling GHG emissions.

We believe that, with regards to sustainability and resilience under the perspective of food and nutritional security, that so depends on the action of the components of biodiversity and environmental services, other topics should integrate the list of challenges of those responsible for the design and support of the related public policies. We can highlight a few of these topics: increased promotion of the genetic variability of species and crops, both in fields of crops and in areas of environmental recovery, avoiding genetic bottlenecks and homogeneous landscapes; prioritization and fostering of planting honey and fruit species in programs for the recovery of degraded areas for the benefit of pollinating animals and seed dispersers; support for integrated pest management and the concomitant application of good practices in using pesticides; increased use of bioproducts that improve soil and plant resilience to stress and that increase the soil carbon content; and monitoring the reduction of the groundwater tables, enabling adequate management of the water used in irrigation.

For example, more information acquired from modeling the buffering effect of different percentages of forests, wetlands, and other natural ecosystems in reducing extreme climatic impacts in productive landscapes, will greatly assist the country's chances in keeping its position as a major long term competitive food producer, thanks to national adaptation efforts.

Adding to the effort of the last decades, and especially after the decision to implement the ABC Plan, the development of actions focused on aggregating the quality and productive capacity of Brazilian soils has been gaining kinetics. Under the auspices of the National Soil Survey and Interpretation Program (Pronasolos), from 2018, a series of attributes will be analyzed, which will enable the development of a whole new set of conservation and management technologies, that are better adapted to constant climatic variations. Throughout the chapters of this publication, other relevant initiatives will be presented in greater detail, including examples of projects developed with the aim of improving the adaptive capacity of productive systems to the potential negative impacts of climate change and with potential co-benefits in the control of emissions, increasing removals or mitigating GHGs.

These policies and innovations generated by projects and programs will improve the food production system (SCHMIDT-TRAUB et al., 2019) and, at the same time, develop appropriate indicators that also give visibility to the socio-economic and environmental efforts towards sustainability built during the last decades by Brazilian agriculture.

References

IPCC – Intergovernmental Panel on Climate Change. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R. K. & Meyer, L. A. (eds.)]. Geneva, Switzerland: IPCC. 2014.

IPCC – Intergovernmental Panel on Climate Change. Summary for Policymakers. In: SHUKLA, P. R. et al. (eds.). Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security and greenhouse gas fluxes in terrestrial ecosystems. 2019. No prelo.

RAYNER, S.; MALONE, E. L. Ten suggestions for policymaker: Guidelines for an international social science assessment of human choice and climate change. [S. L.]: Pacific Northwest National Laboratory. 1998.

SCHMIDT-TRAUB, G.; OBERSTEINER, M.; MOSNIER, A. Fix the broken food system in three steps. Nature. v. 569 (7755). p. 181-183. 2019.

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1

USE OF GENETIC RESOURCES



Collection, conservation, improvement, and recommendations on using genetic resources aiming at climate change

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Climate change is characterized on a global scale as an increase in the concentration of atmospheric CO₂, an increase in temperature and a greater occurrence of extreme rain events, affecting the availability of water in the soil. These factors and their interactions affect the growth and development of plants and, consequently, the productivity of agricultural crops and livestock.

Currently, the world's population food supply is based on a small number of cultivated species, such as rice, corn, potatoes, and wheat. This dependence on few types of crops and the narrow genetic basis of each crop released into the market are factors that make the whole agri-food system vulnerable. If biotic or abiotic stress occur, it may result in a significant drop in production. This is not unprecedented in history. One example is the great famine from 1846 to 1849 in Ireland, when approximately 25% of the population died of hunger due to a potato plague caused by a fungus called *Phytophthora infestans*, which practically decimated the entire crop of that country. The same is true for abiotic stress factors, as shown in climate change studies. The consequences can be drastic if no new genetic materials are adapted to these conditions. Crop diversification protects the entire production system and its consumers, enriches the quality of the human diet and recognizes food culture associated with the traditions of countries and peoples.

In order to successfully launch new crops into the market, studies focusing on the evaluation of genetic resources for the adaptation of agricultural production systems to climate change need to take into account the following lines of research: collection, introduction and conservation of germplasm; domestication of species; characterization and evaluation of genotypes, biotechnology, genetic improvement and development of new crops; and recommendations for new crop use and management practices. In addition, producers must have access to new material and technical recommendations for proper cultivation.

Expanding the genetic basis for the characteristics of interest in the germplasm collections is the first step to guarantee success in selecting desired genotypes. There are different ways to expand this genetic base: germplasm collection in areas where the plants are already adapted to climatic stress conditions, whether they are wild species related to the cultivated species targeted by the breeding program or varieties grown by local farmers and introduction of genetic material from other national or international sets, be they characterized or not. Therefore, the maintenance of genotypes in institutional germplasm banks is essential to ensure that genetic materials of real or potential value can be properly preserved for their

immediate or future use. The collection and introduction of materials adapted to abiotic stresses and their efficient conservation and documentation is essential to provide breeding programs with exotic alleles to those already found in the breeders' collections.

This also ensures that these materials are not extinguished by situations such as the emergence of new cities or plantations in the locations of native plant populations.

Plants adapted to swampy places such as the Pantanal may have developed structures such as aerenchymas that allow for more efficient gas exchange. Short-cycle plants found in places with a very short wet season may have very fast and efficient growth and fruiting mechanisms to quickly complete their vegetative cycle. Locations with low levels of rainfall can shelter plants adapted with a deep root system to reach a large area of soil and, consequently, a greater chance of capturing water, or with small leaves and thorns that reduce transpiration. These characteristics are composed of a set of interesting alleles that should be part of the breeder's collection. When this material is collected, it can be tested in different environmental conditions, crossed with more productive and promising materials and the best progenies can be selected as more adapted to the climatic conditions in which they were tested.

The domestication of new species can contribute to diversify people's diets. Species still considered wild often provide interesting characteristics to the human diet, such as high content of amino acids or antioxidants. However, cultivating the plants the way they are today does not guarantee commercial scale, either because of productivity or the extensive vegetative time until harvest. Domesticating species can contribute to the expansion of crops and their use in human consumption.

Research associated with preventive improvement, that evaluates genotypes against a certain stress before it reaches the country, are fundamental to safeguard Brazilian production from major climate changes. There are preventive improvement studies with very successful results in Brazil, such as those associated with quarantine pests. One of the main examples of preventive improvement was Dr. Alcides Carvalho and the Instituto Agrônomo team's development of coffee plants that are rust-resistant. When the rust arrived in Brazil in 1970, the team already had material resistant to it, considering the research had started in 1953. Preventive improvement programs are needed to preempt abiotic stresses such as those that will be observed in extreme cases and associated with climate change.

The assessment and identification of new genotypes that are more adapted to climate change depend on studies of various scales and may involve only one climate variable or several of them and their interactions. Studies in closed growth chambers (phytotron) allow more precise control of temperature, CO₂, luminosity, photoperiod and water availability, conditions which are quite different from the natural environment. In greenhouses or in the countryside, there is the possibility of partially controlling the environment using irrigation systems, open top chambers, FACEs (Free-Air CO₂Enrichment) or T-FACEs (Temperature-Free-Air CO₂Enrichment), which allow the combination of the effect of water availability, temperature and CO₂ enrichment. Equipment with CO₂ injection in an open environment has a very high maintenance cost, which often makes its use unfeasible. Another option is carrying out experiments in places with a climate similar to that projected by the climate change scenarios for the area of interest.

One of the challenges of research in a modified environment is the definition of the climatic scenarios used in the experimentation. Generally, climate change treatments are based on global projections and variations above or below the current value. There is a need to improve regional climate scenarios and define scenarios with respect to extreme events.

To circumvent the experimental difficulties related to the study of climate change scenarios, research groups have studied, based on simulations with mathematical models, the effect of scenarios and alternatives for adaptation. To ensure this, international partnerships have been established with universities and a research center that develop simulation platforms, such as DSSAT (Decision Support System for Agrotechnology Transfer) and APSIM (Agricultural Production Systems Simulator), among others. Using these platforms requires primary data on growth and production of agricultural crops and pastures for their parameterization, which is not always available. Based on the parameterization of the models, scenarios are analyzed in terms of the vulnerability of genetic materials and of production systems.

Another major bottleneck for the identification of plant genetic resources adapted to climate change and its application in plant breeding programs is large-scale phenotyping, especially in a short period of time and with low labor demand. The development of this type of phenotyping methodology requires high investments in technologies and training qualified personnel. These methodologies are based on sensors and high-resolution cameras that detect different types of images in different plant tissues and scales and develop platforms for data collection and methodologies for processing and analyzing that data, including the development of algorithms, models, and software. The methodologies can be applied at different scales, from tissue-specific or remote sensing and geotechnologies with using unmanned flying vehicles (drones) and satellites. Each type of morphophysiological characteristic and tissue/morphology of the crops/species of interest requires a specific methodology, which signals great opportunity for methodological development. Besides this, existing literature has not reached a conceptual consensus regarding the characterization of what exactly would be resistance, tolerance, adaptation, resilience, and survival to abiotic stress factors. This is the main reason why it is difficult to establish appropriate methodologies.

Biotechnological tools can also be applied to identify genomic regions related to climate change tolerance (drought, waterlogging, increase in atmospheric CO₂ concentration, among other stresses) and the development of plants adapted to these conditions. Genes and regulatory regions of the genome that provide greater tolerance have been sought using approaches such as transcriptome analysis and genomic selection under controlled stress conditions, both in cultivars of interest and in selected genetic resources based on their natural adaptation to the desired trait. Gene editing systems such as genetic transformation and, more recently, CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) have been used to incorporate specific genes that act on metabolic pathways that confer greater capacity for plants to tolerate and/or resist these stresses, such as the abscisic acid pathway in the case of drought tolerance. Such approaches are applied directly to elite germplasm or cultivars that are already developed and do not have the desired characteristic.

After obtaining promising material for the desired conditions, new cultivar must be evaluated in conditions close to final use conditions to define recommendations and appropriate management practices. Ideally, these studies should be carried out in large areas, in places likely to establish various biotic and abiotic interactions that can influence the performance of the material. We know that interactions between plants, animals and microorganisms are very important and often fundamental for certain crops to adapt in some regions. Many microorganisms have already been identified as plant growth promoters, such as nitrogen-fixing bacteria, phosphate solubilizers, and indole-acetic acid producers, most of which can already be found on a commercial scale. There are microorganisms that acidify the soil and others that produce compounds that kill other pathogenic microorganisms. Research on the interaction of plants and microorganisms that evaluates plant growth under conditions of abiotic stress is also of fundamental importance, as it substantially reduces time spent in obtaining new adapted cultivars.

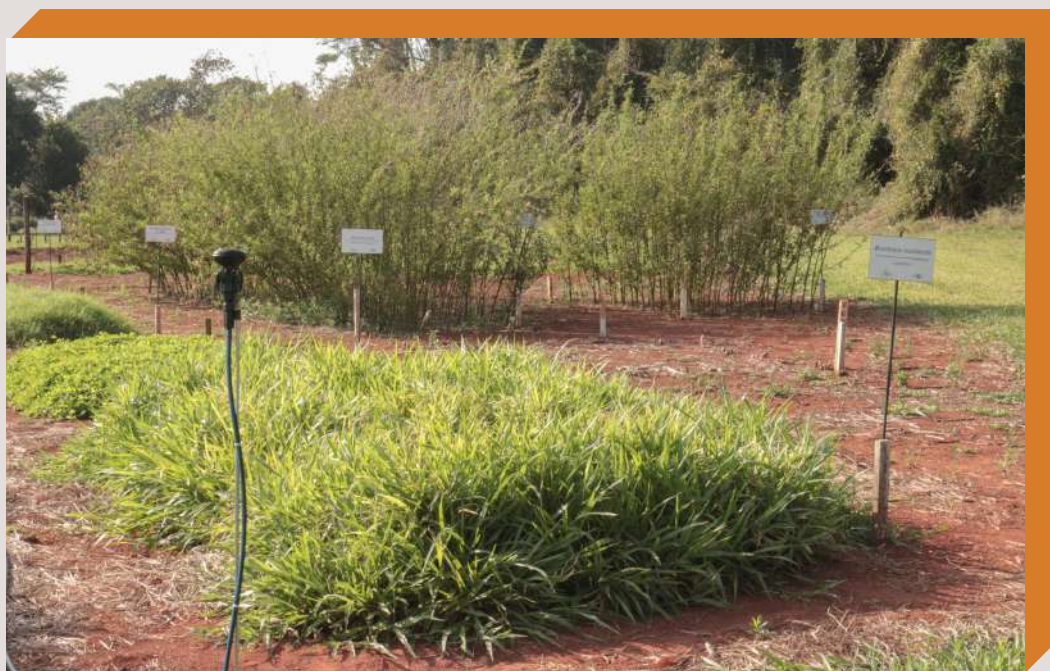
In Brazil, there are several research groups working on adapting agriculture and livestock to climate change (Examples: figures 1 and 2). Most of the work focuses on generating knowledge, given the need to expand the development of technologies and create mechanisms to boost adoption in the most vulnerable regions.

Figure 1: Embrapa demonstration field with forages.



Crédit: Juliana Sussai.

Figure 2: Embrapa demonstration field with forages



Crédit: Juliana Sussai.

This compilation is a small sample of the research focused on genetic resources aimed at adapting Brazilian agricultural systems to climate change. 16 of the studies submitted were directly related to the topic “genetic resources” (pages 32 to 63); another 16 studies were indirectly related to the theme and were inserted in chapters 2 (pages 78, 90 and 100), 3 (pages 112, 114, 116, 118, 120, 126 and 130) and 4 (pages 144, 146, 148, 152, 156 and 158).

The research gathered in Chapter 1 includes the following classes of crops: temporary crops (melon, beans, rice, cowpea, soy, corn, and sugar cane) and permanent crops (grapes and coffee), horticulture (onions and potatoes), livestock (natural and planted pastures) and forest production (eucalyptus). A cattle evaluation project was also included. In the other chapters, research related to genetic resources focused mainly on the study of natural species (natural pastures of the Caatinga and Pantanal biomes, natural fruits of the Cerrado and Caatinga, araucaria, butiá etc.) and focused on zoning, the development of biodiverse production systems, the diversification of people's diets and the domestication of natural species.

Among the research directly related to the topic "genetic resources", most focuses on the regions of Central Brazil and the Semi-Arid region and involves solutions for adapting agriculture in the Caatinga, Cerrado, Atlantic Forest and Amazon biomes. Drought is the main climatic factor addressed, but there are also studies considering variations in temperature, CO₂ concentration, irradiance, extreme flooding and droughts, salt stress and interactions between more than one of these factors.

The research presents different gauges of experimentation, from plant or animal level to ecosystem and landscape level. The tests at plant or animal level focus mainly on genetic, biochemical, metabolic, or physiological responses of plants/animals to climate factors and are mostly carried out in controlled environments (phytotron chambers or greenhouses) or in small plots. Biotechnological approaches have been applied to identify genes and develop cultivars adapted to climate change. Biotic interactions between plants/animals and microorganisms are also investigated. In the case of plants, studies focused on the relationship with pathogenic microorganisms. In the case of animals, studies focused on the relations with rumen microorganisms, which affect the feed efficiency and animal ability to adapt to the environment.

The trials at the plant community level are aimed at eco-physiological, production or disease occurrence assessments and are usually carried out in small plots. Open top chambers, FACEs, T-FACEs, irrigation systems and other mechanisms are used to cause changes in the plot's microclimate. Resource production and efficiency and the occurrence of diseases are the main aspects evaluated.

Studies on larger scales contemplate production systems, regions, or ecosystems. They are usually carried out in large plots, in some cases permanent, and focus mainly on production, product quality and resource efficiency. Studies on larger scales work to validate technologies for posterior transfer to the productive sector.

The main results in this compilation are related to the advancement of knowledge, the development of technological and pre-technological assets and the recommendation of agricultural practices or processes. The knowledge generated relates to plants and animals' mechanisms of response to climate factors and their interactions with microorganisms. Pre-technological assets correspond to genes and molecular markers related to responses to stress, which can assist in the selection and development of new cultivars. Technological assets correspond to the development of new cultivars, via genetic improvement, selection and/or genetic modification. Agricultural practices or processes are mainly related to the recommendation of genetic material for specific conditions, combinations of plants for intercropped cultivation or in crop-livestock-forest (ICLF) and agroforestry (SAFs) integration systems, plant management practices, irrigation management practices and preventive or curative disease control practices.

The sample of studies gathered in this compilation suggest that there is no homogeneity between the methodological approaches, which was expected due to the great variety of species and environmental conditions. On the other hand, the definition of several concepts and indicators would contribute to swifter advances in adapting Brazilian agriculture to climate change.

In Brazil, there are research groups investigating strategies for adapting agriculture and livestock to climate change using genetic resources, but further progress is needed to increase the resilience of

production systems and ensure the sustainability of national agricultural and livestock production in the future. Despite the existing competences and capacity for research in the country, the volume of results is still small compared to the size of national agriculture and livestock production. The actions of different institutions are not well orchestrated, which often makes it difficult to develop a solution ready for adoption by the productive sector. In addition, the possibility of validating results at the scale of a production system for long-term scenarios is limited.

The following actions can contribute to increasing the country's capacity to adapt to climate change:

- Encourage innovation: strengthen public science and technological institutions and establish mechanisms that facilitate interaction between public and private institutions;
- Collection, introduction and conservation of germplasm: support the actions of public institutions responsible for the collection, introduction and conservation of germplasm in the country;
- Domestication of new species: identify wild species with the potential to reduce the country's vulnerability to climate change and support domestication actions;
- Preventive genetic improvement: identify, through scenario studies, the priority crops for preventive improvement actions; encourage the development of large-scale phenotyping methods to identify promising accesses from the point of view of adaptation to climate change; encourage the establishment of research networks focused on the development of new cultivars through traditional genetic improvement and molecular genetics techniques;
- Recommendations for use: encourage the establishment of research and development networks associated with preventive genetic improvement networks that evaluate materials on a large scale and determine recommendations for their use in each region; and
- Technology transfers: facilitate and encourage the establishment of public-private partnerships for the multiplication and commercialization of seeds from adapted cultivars, especially in the most vulnerable regions; promote the establishment of technical assistance and rural extension networks that promote the adequate use of new technologies by producers, especially in the most vulnerable regions.

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FORAGES FOR THE SEMI-ARID REGION: A STRATEGY TO ENSURE FOOD SECURITY FOR HERDS IN THE BRAZILIAN SEMI-ARID REGION

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From 2011 to 2017 the Brazilian semi-arid region faced a long period of drought, which decisively affected the agricultural production in the region and strengthened the livestock. Embrapa developed a strategy called Mais Forragem (More Forage) which made technologies available to eliminate forage production seasonality. Two main axes guide the strategy: offering adapted and productive forages to reduce food costs and providing management tools for food planning on rural properties. An unprecedented partnership with the National Agriculture Confederation Institute (CNA) rolled out the strategy in 2013. Thirteen technological reference units were implemented for network assessment of more than 20 forage options. The options denominated “forage menu” include plants with different drought resilience strategies: escape (annual forage for silage), tolerance (perennial grasses and woody species for single and intercropped use) and resistance (cacti). The trial was conducted in all states in the Northeast and North of Minas Gerais: Maranhão (Fortuna), Piauí (SR Nonato), Ceará (Ibaretama), Rio Grande do Norte (Lajes), Paraíba (Tenório), Pernambuco (São João), Alagoas (Batalha), Sergipe (Carira), Bahia (Baixa Grande, Ipirá and Itapetinga) and Minas Gerais (Carlos Chagas and Montes Claros). The goal of the network is to develop recommendations of the most suitable forage menus for the various regions in the Semi-Arid of Brazil. Considering the complexity of managing various sources of forage, the “Forage Budget” app (<https://orcamentoforageiro,cnpc,embrapa.br/>) was developed, to assist in the producers’ decision-making process. The app was launched in 2017 and more than 5,000 people accessed it. The annual forages evaluated were sorghum cultivars (BSS Ponta Negra and BRS 658), corn (BRS Gorutuba, BRS 2022 and Bandeirante) and millet (IPA Bulk and BRS 1301) developed by Embrapa and partners for less water demanding conditions. The perennial grasses (massai, tamani, piatã, paiguás, African star, tifton, buffel aridus, buffel biloela, corrente and andropogon) are mostly unprecedented in the semiarid environment (Figure). The woody plants (gliricidia, leucena and moringa), rich in proteins, were part of the experiment. Finally, cacti (small palm, African elephant ear, Mexican elephant ear, IPA-Sertânia and giant palm), popular in periods of long drought, finalized the menu (Figure). The first results

were released to more than 1,000 producers in 12 field days in 2019. Local results can be accessed through technical bulletins. The initiative continues with its phase II, expanding the database, and building a forage menu simulator for producers. The project was funded by CNA.

RESULTS

- Mobile app for forage planning to guide technicians and producers in their use of the native Caatinga pasture and combination with available forage sources;
- Recommendations of annual and perennial forages and cactus plants for thirteen different locations in the Brazilian semiarid region;
- Training more than 5.000 technicians and producers how to use the “Forage budget” app in two years; and
- Training in management practices and forage recommendations for more than 1.000 technicians and producers in one year.

NEXT STEPS AND RECOMMENDATIONS

- Development of a simulator to recommend a forage menu for the Northeast;
- Expansion of tests for new forages for the Semi-Arid;
- Recommend integrated and intensive systems for the semiarid region; and
- Making the “Forrageiras” portal for the semi-arid region available on the internet.

DATA PUBLISHED IN:

CAVALCANTE. A. C. R. Producción y utilización de forrajeras convencionales cultivadas en el Semiárido Brasileño. In: IÑIGUEZ ROJAS. L. (org.). La producción de rumiantes menores en las zonas áridas de Latinoamérica. Brasília: Embrapa. 2013. p. 313-339. u. 1.

CAVALCANTE. A. C. R.; BARBOSA. C. M. P.; OLIVEIRA. L. F. M.; BUENO. L. G.; GUEDES. F. L.; ANTONIO. R. P. Oficina temática para produção e disponibilização de sementes e mudas de plantas forrageiras para o ambiente Semiárido. Sobral: Embrapa Caprinos e Ovinos. 2018. (Comunicado Técnico 184).

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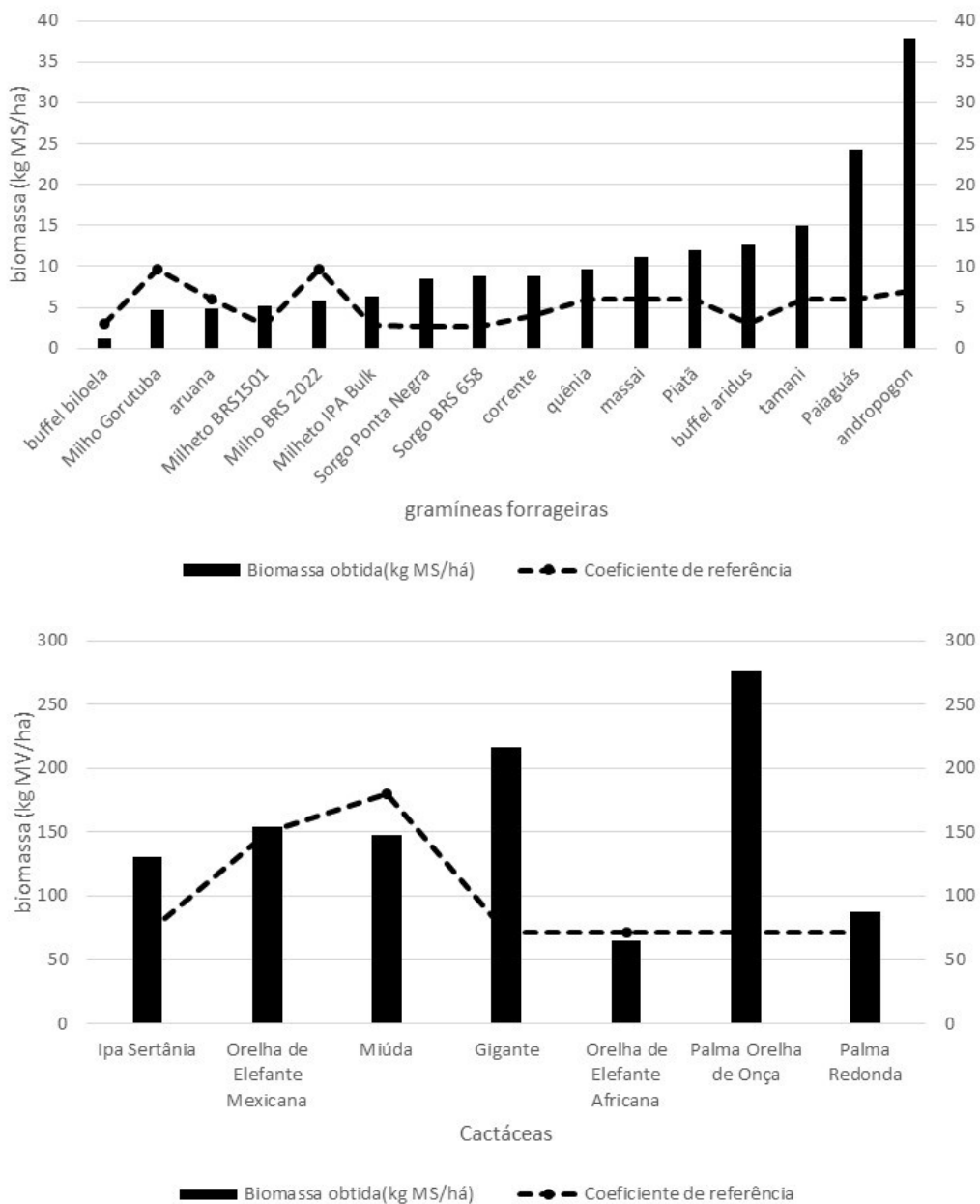
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Figure 1: Partial results of production of grasses (kg of dry mass) and cacti (kg of green mass) per hectare.



INTERCROPPING GRASSES AND LEGUMES FOR PASTURE DIVERSIFICATION AND SUSTAINABLE INTENSIFICATION OF LIVESTOCK IN THE AMAZON

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Brazil has 112 million hectares of cultivated pastures (IBGE, 2017), of which 52% are degraded and 25% in degradation (DIAS-FILHO, 2014), according to estimates. Livestock intensification is the main strategy for reconciling increased productivity with reduced environmental impacts (STRASSBURG et al., 2014).

The intensification of livestock is associated with the reform or recovery of pastures, which includes the supply of nutrients through fertilizers, mainly nitrogen (N). However, high costs limit Brazilian farmers from adopting pasture fertilization especially in the Amazon (ANDRADE, 2010; 2012). In this scenario, using grass pastures intercropped with legumes with biological N fixation capacity (FBN) becomes a practice of great interest.

This Embrapa initiative received financial support from Banco da Amazônia and the Association for the Promotion of Forage Improvement Research (Unipasto), and it aims to promote the sustainable intensification of livestock production systems on pasture in the Amazon biome.

From 1998 onwards, degradation of pastures and restrictions on deforestation led producers to seek alternatives to recover degraded pastures and intensify production systems in the Amazon. Since 1980, using the leguminous *Pueraria phaseoloides* had been promoted for pastures intercropped with *Panicum* and *Brachiaria* grasses and was adopted in 480,000 ha in Acre. However, livestock showed little compatibility with some of the grasses that farmers began using, such as African star grass (*Cynodon nlemfuensis*). It also did not persist in pastures managed under rotational grazing system, with stocking rates above 1,5 animal unit/ha (VALENTIM; ANDRADE, 2005a).

In 2000, producers in Acre demanded legumes adapted for use in intensive production systems. On occasion, using forage peanut (*Arachis pintoi* cv. *Belomonte*) was being validated in 20 properties, in association with African star grass, in the process of recovering degraded pastures in soils with low permeability, where *Cu*, Marandu had died. The success of these innovators promoted rapid dissemination of the technology among other producers facing similar problems (Table 1). In 2001, the *Belomonte* cultivar was recommended for supporting diversification of pastures in

Acre. Forage peanut is also intercropped with cultivars of *B. brizantha*, *B. decumbens*, *B. humidicola* and *P. maximum* (VALENTIM; ANDRADE, 2005b) (Figure 1).

RESULTS

- Main advantages of grass pastures intercropped with forage peanuts:
 - » Increased animal weight gain;
 - » Increased pasture carrying capacity;
 - » Good tolerance to waterlogged soils;
 - » High resistance to grazing; and
 - » Cost reduction with fertilization and animal protein supplementation.
- The *Belomonte* cultivar is adopted in 79.555 ha in Acre, with an annual benefit of R\$ 82.3 million (EMBRAPA, 2019); and
- Pastures of grasses intercropped with forage peanuts provide an annual productivity of 13@ live weight (LW)/ha in the breeding, rearing and fattening cycle and 16@ LW/ha in the rearing and fattening cycle. These pastures have the potential productivity of up to 35@ PV/ha/ year.

NEXT STEPS AND RECOMMENDATIONS

Figure 1: Pasture of *Brachiaria brizantha* intercropped with forage peanut cv. *BRS Mandobi*, in Rio Branco-AC



Crédit: Judson Ferreira Valentim.

- The challenge is to support the adoption of intercropping grasses with forage peanuts in the 48 million hectares of pastures cultivated in the Amazon biome (INPE; EMBRAPA. 2016). This has been restricted by the low supply and the high cost of imported seeds;
- To overcome this challenge, Embrapa launched the BRS Mandobi cultivar in 2019, which is propagated by seeds to be used in pastures intercropped with grasses in the Amazon and Atlantic Forest biomes;
- This cultivar can potentially be used in other biomes. However, the technology still must be validated in these regions;
- The limitation for expanding the adoption of BRS Mandobi is the development of a seed harvester. Embrapa – Instrumentação and Embrapa – Acre are developing equipment that makes mechanized harvesting feasible, maintains quality and reduces the cost of seeds (PORTIOLI et al., 2019); and
- The next step requires resources and partnerships with the private sector to validate the prototype under field conditions for the production of forage peanut seeds.

REFERENCES:

- ANDRADE, C. M. S. de. Importância das leguminosas forrageiras para a sustentabilidade dos sistemas de produção de ruminantes. In: SIMPÓSIO BRASILEIRO DE PRODUÇÃO DE RUMINANTES NO CERRADO. 1. 2012. Uberlândia. Anais [...]. Uberlândia: UFU. 2012. p. 47-96.
- ANDRADE, C. M. S. de. Produção de ruminantes em pastos consorciados. In: SIMPÓSIO SOBRE MANEJO ESTRATÉGICO DA PASTAGEM. 5.; SIMPÓSIO INTERNACIONAL SOBRE PRODUÇÃO ANIMAL EM PASTEJO. 3.. 2010. Viçosa-MG. Anais [...]. Viçosa: UFV. 2010. p. 171-214.
- DIAS-FILHO, M. B. Diagnóstico das pastagens no Brasil. Belém: Embrapa Amazônia Oriental. 2014. (Documentos 402).

Continued in Annex

DATA PUBLISHED IN:

EMBRAPA. Balanço Social 2018. Brasília: Embrapa – Secretaria de Desenvolvimento Institucional (SDI); Secretaria Geral da Embrapa (SGE). 2019. Disponível em: <https://bs.sede.embrapa.br/2018/index.html>. Acesso em: 8 jan. 2020.

ERMGASSEN, E. K. H. J. zu; ALCÂNTARA, M. P. de; BALMFORD, A.; BARIONI, L. G.; BEDUSCHI NETO, F.; BETTARELLO, M. M. F.; BRITO, G. de; CARRERO, G. C.; FLORENCE, E. da A. S.; GARCIA, E.; GONÇALVES, E. T.; LUZ, C. T. da; MALLMAN, G. M.; STRASSBURG, B. B. N.; VALENTIM, J. F.; LATAWIEC, A. Results from on-the-ground efforts to promote sustainable cattle ranching in the Brazilian Amazon. Sustainability. Switzerland. v. 10. n. 4. p. 65-90. Apr. 2018.

SHELTON, H. M.; FRANZEL, S.; PETERS, M. Adoption of tropical legume technology around the world: analysis of success. In: MCGILLOWAY, D. A (ed.). Grassland: a global resource. Netherlands: Wageningen Academic Publishers. 2005. p. 149-[169?].

Continued in Annex

Table 1: Key factors for the successful adoption of pastures intercropped with forage peanuts in Acre

Degree of Importance	Key factors in adopting technology
1º	Technology must be appropriate to the socioeconomic and environmental conditions of producers.
2º	Farmer's socioeconomic situation should be favorable to the adoption of technology.
3º	Embrapa long-term commitment - Acre researchers to the promotion and adoption of technology.
4º	Research process and participatory extension, market access and strong financial and environmental benefits for producers adopting technologies.
5º	Strategic partnership between researchers and producers and local institutions with the capacity to support the program.
6º	Using innovative producers as instructors and their farms as Technological Reference Properties.

Source: VALENTIM; ANDRADE. 2005b.

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RUMINANT HOLOGENOME- CHARACTERIZATION OF MICROORGANISM POPULATIONS IN RUMINANTS' DIGESTIVE TRACT AND THEIR IMPACT ON THE HOST'S FUNCTIONAL GENOME, PERFORMANCE, PRODUCT QUALITY AND ENVIRONMENTAL IMPACT

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The Hologenome is an evolutionary concept where both the host and its associated microorganisms (microbiota) form a cohesive biological entity known as holobiont, whose interaction affects the development and general fitness of the hologenome, considered an independent level of selection. In ruminants, microbial fermentation in the rumen produces methane as a by-product, a greenhouse gas with a high environmental impact. Since feed efficiency is one of the biggest costs of beef production and inversely proportional to the production of methane, the improvement of this characteristic has the potential not only to reduce the cost of production, but also to reduce the territorial expansion of production areas and methane emissions. Reducing production costs and improving product quality while mitigating environmental impacts are key factors in conquering new markets for Brazilian beef.

In a previous project financed by FAPESP, we produced structural and functional genomic data in a reference population of the Nellore breed, thus revealing the main players in the regulation of gene expression and how this expression relates to biological processes relevant to quality characteristics of the beef and feed efficiency in animals raised in confinement.

We are currently dedicating ourselves to data analysis to further integrate the different levels of genomic and phenotypic information, investigating genetic variations that explain the differences observed in gene expression.

In addition to the host's functional genome, we will investigate the profile of microorganisms and rumen metabolites in a new sample of Nellore cattle, raised on pasture and finished in confinement, contrasting animals fed with a traditional diet and those with a by-product diet, the latter aiming at alternatives that reduce environmental impacts.

Adding information regarding microbiota in the host's functional genomics data will answer crucial questions about the relationship between the microbiota's functional diversity and the host environment, also contribute to the design of selection and management strategies aimed at the efficient production of higher quality beef. This

information can assist in the estimation of the breed's genetic value for these traits, contributing to improve the reliability of genetic evaluations in breeding programs.

Funding sources: Embrapa, FAPESP, CNPq and CAPES.

RESULTS

So far, we have identified genes and regulatory elements (miRNA molecules, regions of DNA) that contribute to variations in feed efficiency and to the quality of Nellore carcass and meat, including characteristics that are not normally evaluated in breeding programs, such as tenderness, fat composition and the amount of minerals in the meat (Table 1). We also relate the level of expression of thousands of genes to the various performance and product quality characteristics.

NEXT STEPS AND RECOMMENDATIONS

For this body of information about the functioning of the genes to discriminate the best animals in the breeding routine to be useful, we still need to find the DNA variations that cause a gene to be more or less expressive, which is why we are reassessing the data, integrating the information of DNA, RNA, miRNA and proteins with the production measurements of each animal. In addition, we are investigating the relation between the individual microbiota and metabolite profile with the same measurements (feed efficiency, carcass, and beef quality), in order to develop methods to identify animals that produce better and more efficiently. Another purpose is to provide the knowledge bases for the development of methods that aim to control the composition of the microbiota, aiming at improving animal performance.

DATA PUBLISHED IN:

CARVALHO. M. E.; GASPARIN. G.; POLETI. M. D.; ROSA. A. F.; BALIEIRO. J. C. C.; LABATE. C. A.; NASSU. R. T.; TULLIO. R. R.; REGITANO. L. C. A.; MOURÃO. G. B.; COUTINHO. L. L. Heat shock and structural proteins associated with meat tenderness in Nelore beef cattle. a Bos indicus breed. *Meat Science*. v. 96. n. 3. p. 1318-1324. Mar. 2014.

MUDADU. M. de A.; PORTO NETO. L. R.; MOKRY. F. B.; TIZIOTO. P. C.; OLIVEIRA. P. S. N. de; TULLIO. R. R.; NASSU. R. T.; NICIURA. S. C. M.; THOLON. P.; ALENCAR. M. M. de; HIGA. R. H.; ROSA. A. do N.; FEIJO. G. L. D.; FERRAZ. A. L. J.; SILVA. L. O. C. da; MEDEIROS. S. R. de; LANNA. D. P. D.; NASCIMENTO. M. L. do; CHAVES. A. S.; SOUZA. A. R. D. L.; PACKER. I. U.; TORRES JUNIOR. R. A. de A.; SIQUEIRA. F.; MOURAO. G. B.; COUTINHO. L. L.; REVERTER. A.; REGITANO. L. C. de A. Genomic structure and marker-derived gene networks for growth and meat quality traits of Brazilian Nelore beef cattle. *BMC Genomics*. v. 17. p. 1-16. Mar. 2016.

REFERENCES:

CESAR. A. S. M.; REGITANO. L. C. A.; KOLTES. J. E.; FRITZ-WATERS. E.; LANNA. D. P. D.; GASPARIN. G.; MOURÃO. G. B.; OLIVEIRA. P. S. N.; REECY. J. M.; COUTINHO. L. L. Putative regulatory factors associated with intramuscular fat content. *PLoS ONE*. v. 10. n. 6. p. 1-21. June 2015.

CESAR. A. S. M.; REGITANO. L. C. A.; POLETI. M. D.; ANDRADE. S. C. S.; TIZIOTO. P. C.; OLIVEIRA. P. S. N.; FELÍCIO. A. M.; NASCIMENTO. M. L.; CHAVES. A. S.; LANNA. D. P. D.; TULLIO. R. R.; NASSU. R. T.; KOLTES. J. E.; FRITZ-WATERS. E.; REECY. J. M.; COUTINHO. L. L. Differences in the skeletal muscle transcriptome profile associated with extreme values of fatty acids content. *BMC Genomics*. v. 17. p. 1-16. Nov. 2016.

Continued in Annex

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Table 1: Genome regions in which DNA base variations (Single Nucleotide Polymorphism – SNP) were associated with feed efficiency traits in Nelore cattle. The candidate genes column describes the genes found in the region associated with food efficiency characteristics.

Characteristics	SNP window	No. of SNPs in window	Explained % variability	Cr.	Candidate genes
CAR	rs132846819-rs136767848	217	1.50	8	
	rs109535395-rs134508640	50	1.42	18	DEPP1. TUBB3
	rs109365529-rs132654030	186	1.12	11	PTGS1
	rs136295413-rs41980878	260	1.12	21	-
CMS	rs133031353-rs42739324	237	3.76	24	HRH4. ZNF521
	rs134105133-rs133615999	161	2.00	13	-
	rs133460769-rs109902312	255	1.29	9	-
CA	rs110424374-rs133308150	73	6.06	12	-
	rs41942246-rs134122046	191	5.99	20	GDNF
	rs42594525-rs109404921	182	1.52	15	LIN7C
	rs109105703 -rs136356118	189	1.40	18	-
EA	rs133645581-rs137479730	231	2.58	9	-
	rs134914044-rs42277860	203	2.30	1	-
	rs136028559-rs110570158	250	1.04	14	-
	rs109171156-rs42987702	255	1.03	2	-

Caption: Residual Food Consumption (CAR). Food Conversion (AC). Dry Matter Intake (DMI). Average Daily Gain (ADG) and Food Efficiency (EA).

(Source: Own authorship).

BRS PAIAGUÁS IS MORE DROUGHT RESISTANT THAN OTHER BRACHIARIA

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Brachiaria (syn, Urochloa) species occupy about 70 million hectares in the Cerrado and Amazon biomes, but climate change may make using this grass unfeasible in some regions due to severe periods of drought. The aim of the project was to study the response mechanisms of types of Brachiaria to water stress and identify materials capable of surviving more severe droughts, reducing the vulnerability of livestock to climate change.

Plants have different drought response strategies. Some delay dehydration, which depends on mechanisms that provide greater absorption of water from the soil or less loss through transpiration. This allows plants to maintain their growth and display productivity during shorter and lighter periods of drought, however, it doesn’t always ensure plant survival in severe drought conditions.

In the case of perennial pastures cultivated in places subject to severe droughts, it is often more important to guarantee the survival of the grass than to provide high productivity in the short term. When the pasture does not survive the stressful environmental conditions, it won’t survive in the production systems. For this reason, it is important that plants used in regions subject to more severe droughts can withstand dehydration, survive and sprout when water is adequately available in the soil again. This drought response strategy is related to mechanisms that the plant uses to protect its growth points from dehydration.

To identify Brachiaria cultivars capable of surviving more severe droughts, two experiments were carried out in a greenhouse at INRA/CNRS/CEFE (Figures 1 and 2). In the first, the plants were grown in small pots to evaluate the strategies for tolerating dehydration in specific tissues, without the effect of differences in root depth on the plant’s hydration condition. In the second experiment, rhizotrons (long transparent tubes protected from solar radiation by opaque film) were used to evaluate the rate of root elongation and the depth of the roots.

The research was carried out with financial support from the Capes/Embrapa agreement and the CNRS/CEFE Experimental Infrastructure, involving Embrapa – Pecuária Sudeste and the Department of Animal Science Esalq/USP. The results have not been validated in the field.

The potential beneficiaries of the project are farmers in areas subject to prolonged droughts.

RESULTS

BRS Paiaguás is more capable of sprouting after a period of more severe drought than other brachiaria. The results obtained so far indicate that BRS Paiaguás may be a good alternative for locations with water deficit problems, especially in marginal areas, subject to more severe droughts.

In conditions of short, light droughts, the deepening of the roots combined with other mechanisms that delay dehydration, allows cv, Marandu and B, decumbens to continue growing and maintain good productivity. On the other hand, BRS Paiaguás, in addition to deepening the roots, activates water saving mechanisms that promote a slower depletion of water in the soil. Thus, the absorption and maintenance of hydration in parts of the plant that are important for survival is guaranteed during longer periods of drought.

BRS Paiaguás was also able to sprout after more severe periods of drought than the other two brachiaria (Figure 2). In one of the trials, the researchers stopped irrigation for longer periods and then started irrigating again to evaluate the plant’s regrowth. With approximately 8% humidity, more than half of the BRS Paiaguás plants were able to sprout, while those of cv, Marandu and B, decumbens showed a much lower percentage of sprouting. This result indicates that BRS Paiaguás activates mechanisms to protect its growth points, in severe drought conditions.

NEXT STEPS AND RECOMMENDATIONS

The characterization of plants’ response mechanisms to drought was carried out and BRS Paiaguás was identified as a species with the potential to reduce the vulnerability of livestock in areas subject to more severe droughts. For next steps, results under field conditions must be confirmed along with an economic analysis of the production systems.

DATA PUBLISHED IN:

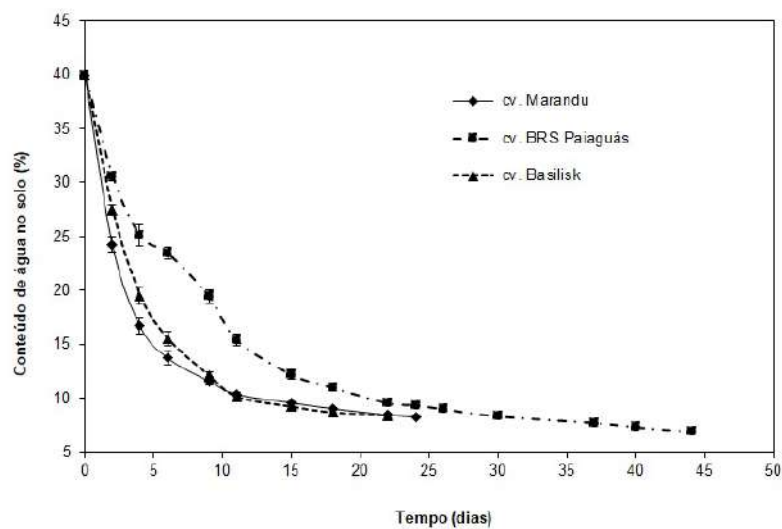
BELONI, T.; SANTOS, P. M.; ROVADOSCKI, G. A.; BALACHOWSKI, J.; VOLAIRE, F. Large variability in drought survival among *Urochloa* spp. cultivars. *Grass and Forage Science*. v. 73. n. 4. p. 947-957. July 2018.

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Figure 1: Soil water content in pots cultivated with cv. Marandu, B. decumbens cv. Basilisk and BRS Paiaguás



Note: The water content in the soil dropped more quickly for cv. Marandu and B. decumbens, indicating that BRS Paiaguás activates water saving mechanisms during periods of stress.

Source: Beloni et al. (2018).

Figure 2: Percentage of regrowth in cv. Marandu, B. decumbens and BRS Paiaguás plants after rehydration



Note: With about 8% moisture in the soil, more than half of the BRS Paiaguás plants were able to sprout after rehydration, while the cv. Marandu and B. decumbens plants practically did not sprout.

Credit: Tatiane Beloni.

INTEGRATING SYSTEMS TO INCREASE FOOD SECURITY FOR HERDS IN THE CAATINGA BIOME

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The production systems that are common in the Caatinga region are characterized by slashing and burning of vegetation, however, sustainable use models for the Caatinga are essential for its maintenance. In 1998, the agrosilvopastoral system was developed for the Caatinga, with the principles of non-use of fire, thinning of the Caatinga in savannah, enriching the underbrush with perennial species and preservation of riparian forests. From an ecological point of view, the model has brought numerous benefits, especially the maintenance of biodiversity and greater resilience of agricultural and livestock activities. However, this system proved to be very dependent on manpower, which limited its adoption.

Thus, a new proposal was developed with the same principles, but replacing the thinning in savannah by the belt model, which includes mechanization without altering biodiversity (Figure 1). The arrangements designed for opening of the area were belts of conserved vegetation interspersed with areas of deforested belts, with spacing between rows of native vegetation ranging from 10 to 20 meters, and conservation belt of 20 and 10 meters. The area was opened to maximize using firewood for energetic purposes, leaving only vegetation protected by law. In the thinned belts, millet (*Pennisetum americanum*) and sorghum crops were planted in consortium with massai grass (*Megathyrsus maximus cv. Massai*). Approximately between 80 and 100 days after planting, the consortium belts were harvested. All the forage harvested was ensiled to be used in times of food scarcity. Grazing took place during the dry period, after harvesting annual species. The area has already presented noticeable benefits related to the improvement of soil quality and the productivity of forage biomass. The system is expected to be a viable option for intensifying agricultural production in rural properties in the Brazilian semiarid region with minimal impact on the Caatinga.

RESULTS

- All crops benefited from the greater spacing between the belts of conserved native forest, with an emphasis on millet, which produced almost twice as much dry forage mass (Table 1);
- Significant contributions from native pasture in both belts, with yields similar to the yields from introduced exotic grass. The contribution of this forage component further denotes the sustainability of the Integrated Systems (IS) implemented and highlights the importance of native pastures for the balance of the forage supply in this biome; and
- All the collected material was stored in the form of mixed silage (annual crop, massai grass and native pasture) in a total of 45 tons, capable of feeding a herd of 71 animals (goat/sheep) for a period of 180 days, with moderate weight gain.

NEXT STEPS AND RECOMMENDATIONS

- The results are still preliminary and indicate IS as a viable and promising alternative for maintaining livestock activity in the Caatinga. Animal performance trials and the persistence of these IS over time are still ongoing. Studies of the carbon and nitrogen balance are being conducted to validate IS as a tool for mitigating climate change; and
- Machines are being adapted and tested to reduce dependence on manpower.

DATA PUBLISHED IN:

CONRADO, J. A. de A.; CAVALCANTE, A. C. R.; TONUCCI R. G.; CARNEIRO, M. S. de S.; CÂNDIDO, M. J. D. Forage production and preservation of species by enriching Caatinga with grasses and thinning areas into strips. *Revista Caatinga*, Mossoró, v. 32, n. 3, p. 814-825, July/Sept. 2019.

Figure 1: CLF Caatinga Integrated System. during the rainy season (A) and dry season (B). in Sobral-CE

Crédit: Ana Clara Cavalcante.

Table 1: Forage production by crops and total forage mass (kg DM ha⁻¹) in strips of 10 and 20 meters of integrated systems in the Caatinga

Belt width (meters)	Dry matter production (kg DM ha ⁻¹)				
	Sorghum	Millet	Massai	Native	MFT
10	6.329	3.115	3.799	3.098	16.341
20	7.925	5.892	4.584	3.804	22.205

Source: Unpublished data; author

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TECHNOLOGICAL ADJUSTMENTS FOR FORAGE PRODUCTION SYSTEMS THAT ENSURE THE SUSTAINABILITY OF HERDS IN THE BRAZILIAN SEMI-ARID REGION

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In the Brazilian Northeast, traditional agricultural practices follow the migratory model, which includes total deforestation, wood burning, extractive agriculture, and super-grazing. It is predominantly an extensive farming regime with low or no use of inputs, culminating in the process of soil degradation. Thus, there is a need to use management practices that promote greater land use efficiency, to achieve improved plant and animal productivity, and consequently, better income for farmers.

With these objectives in mind and with the joint efforts of research institutions Embrapa - Caprinos e Ovinos, Embrapa - Meio-Norte and universities, strategies were evaluated to generate technological alternatives, in order to mitigate foraging deficiencies in the region. With resources from Embrapa, through Public Call 06/2013 - Macroprogram 2, our team worked on the development of a project entitled "Food strategies for overcoming the forage seasonality of the Caatinga biome in the dry season". In this project, various solutions were assessed: "Evaluation of the Santa Fé System adapted for annual crops in consortium with forage grasses for the production of roughage under rainfed conditions", "Evaluation of the deferral of tropical forage grasses aiming at the production of forage in the critical period of the Brazilian semi-arid region," "Evaluation of performance of sorghum, millet, corn and sunflower varieties and hybrids to verify adaptive capacity and stability of roughage production", "Nutritional evaluation of silages containing annual crops and forage grasses under different growth stages, produced in Santa Fé System adapted to rainfed conditions in the Brazilian Semiarid Region." These systems presented very promising results for use in the region (Table 1).

Among the annual crops evaluated, the cultivation of corn (cultivar AL Bandeirante) intercropped with massai grass (Figure 1) simultaneously for silage production and use in the dry period of the year showed that it is possible to increase forage production by up to 30% in relation to the cultivation of the annual single culture, improving land use efficiency and decreasing the system's production costs (about 68.6%) in relation to the purchase of bulky food acquired in the market during the dry period of the year (eight months), to breed 53 sheep. Another result, which would also be beneficial for agricultural systems, would be the

formation of a pasture that could be deferred for use in the transition period or in the dry period of the year. The deferral of *Megathyrsus* grasses makes it possible to use forage without major damage up to the 120 days of sealing. After that, the area will be ready for no-till planting of the annual crop in the following year, while reducing erosion processes and providing sustainability to the agroecosystem.

RESULTS

- Recommendation of the best consortium of annual crops for grain production with tropical forage grasses, presenting greater production and soil conservation in dryland conditions;
- Recommendation of the best time of deferral and use of forage grasses in the semiarid region;
- Recommendation of the annual crop with greater adaptive capacity and stability for the production of roughage under dryland conditions in the Semiarid Region; and
- Recommendation of the best association of annual crop with grasses for silage production.

NEXT STEPS AND RECOMMENDATIONS

- Technological adjustments for using the massai grass consortium with other annual productive crops adapted to the semiarid region;
- Consortium of forage legumes adapted to the semiarid with annual crops; and
- Climatic risk zoning in upland cultivation systems in order to minimize the risks related to climatic phenomena.

DATA PUBLISHED IN:

POMPEU. R. C. F. F.; FONTINELE. R. G.; CÂNDIDO. M. J. D.; SANTOS. F. G. R.; SOUZA. H. A.; GUEDES. F. L.; CAVALCANTE. A. C. R.; ROGÉRIO. M. C. P.; TONUCCI. R. G.; MARANHÃO. S. R.; SANTOS NETO. C. F. Estrutura e composição químico-bromatológica do cultivar BRS Massai sob épocas de vedação e idades de utilização. Sobral: Embrapa Caprinos e Ovinos. 2018. (Comunicado Técnico 172).

POMPEU. R. C. F. F.; MARANHÃO. S. R.; SOUZA. H. A.; CÂNDIDO. M. J. D.; CAVALCANTE. A. C. R.; GUEDES. F. L.; ROGÉRIO. M. C. P.; ARAÚJO. R. A.; FONTINELE. R. G.; MAGALHÃES. J. A. Desempenho agrônômico de *Megathyrus maximus* cultivares Massai e Tamani sob diferentes regimes hídricos em duas estações (seca e chuvosa). Sobral: Embrapa Caprinos e Ovinos. 2018. (Boletim de Pesquisa e Desenvolvimento 04).

POMPEU. R. C. F. F.; SOUZA. H. A.; MARTINS. E. C.; GUEDES. F. L.; ROGÉRIO. M. C. P.; BUENO. L. G.; TONUCCI. R. G.; ARAÚJO NETO. R. B.; PONTE FILHO. F. A. M.; MARANGUAPE. J. S. Viabilidade e produtividade de milho consorciado com capim-massai para produção de silagem e alimentação de ovinos no Semiárido. Sobral: Embrapa Caprinos e Ovinos. 2017. (Comunicado Técnico 165).

ROGÉRIO. M. C. P.; POMPEU. R. C. F. F.; GUEDES. F. L.; TONUCCI. R. G.; SOUZA. H. A.; MAGALHÃES. J. A.; CARNEIRO. M. do S. S.; GUEDES. L. F.; OLIVEIRA. D. S.; SILVA. S. F. Sistema de Integração Lavoura-Pecuária em condições de sequeiro: garantia de reserva de forragem de qualidade. em forma de silagem. para o Semiárido. Sobral: Embrapa Caprinos e Ovinos. 2018. 22 p. (Comunicado Técnico 180).

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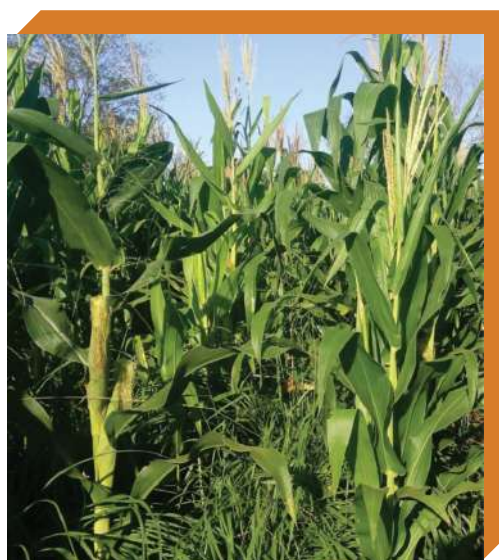
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Table 1: Economic indicators of silage of three different forage plants cultivated in rainfed system in the Brazilian Semi-arid Region

Economic indicators (Cost/year)	Corn (1.0 ha)	Consortium corn + massai grass (1.0ha)
Effective Operating Cost of crop activity (R\$)	3,273.78	3,433.78
Share of the cost of harvesting and ensiling in the crop's EOC (%)	56.35	53.72
Effective Operational Cost per kg of forage for crops (R\$/kg MN)	0.08	0.06
Effective Operational Cost per kg of crop silage (R\$/kg MN)	0.22	0.15

Source: Pompeu et al. (2018).

Figure 1: Massai grass intercropped with corn



Crédit: Pompeu et al. (2017)

IMPACT OF CLIMATE CHANGE ON THE PHYSIOLOGICAL PRODUCTIVE PERFORMANCE AND THE FORAGE QUALITY OF PANICUM MAXIMUM CV MOMBAÇA GRASS

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As a result of climate change, extreme climatic events such as droughts, floods and more intense and more frequent heat waves are expected. The IPCC (2018) recently concluded, based on consistent scientific evidence, that global warming and climate change are already occurring and that the increase in global average temperature could reach values greater than 2°C higher than expected. Brazil is the second largest beef producer and the largest exporter in the world and, due to its low cost, more than 90% of this production happens on pastures. However, there is not enough information and data to estimate the impact of pastures on climate change (mitigation) and the impact of climate change on pastures (adaptation). Detailed studies on the response of tropical forages to climate change are needed to support forecasting models, which are fundamental for pasture management under future global and regional climate change scenarios.

The main objective of the research was to determine molecular, physiological, biochemical responses, yield and forage quality of leaf biomass in plants of *Panicum maximum* cv. Mombasa in a future scenario of IPCC climate change RCP6.0, which foresees an increase in concentration of atmospheric carbon dioxide [CO₂] of up to around 600 ppm, in addition to an increase in environmental temperature of about 2°C (Figure 1). The effects of water deficiency were also researched throughout the experiments. These were carried out on the Campus of the University of São Paulo, in Ribeirão Preto, that has a rainy season in the summer and a dry season in the winter, with native Atlantic Forest vegetation.

For the experiments, an innovative technology called Trop-T-FACE, which combines FACE (Free air carbon dioxide enrichment) and T-FACE (Temperature free air-controlled enhancement) systems, in which the levels of carbon dioxide and the ambient temperature are automatically increased using computerized systems of CO₂ fumigation and a ceramic heater system, respectively (Figure 2).

RESULTS

- Forage plants such as the *Panicum maximum* cv. Mombasa grass respond positively to the

increase in the high concentration of CO₂ and the temperature by 2°C only under conditions of adequate water and nutrient availability;

- In situations of water deficiency, the responses of the plants to the increase in temperature are unfavorable and affect their physiological performance, growth, the production of biomass and the nutritional quality of forages;
- The elevation of the temperature by 2°C also causes an increase in the soil temperature, which alters the metabolism of the soil microbiota, causing a 2 to 3-fold increase in nitrous oxide emission due to the decomposition of nitrogen fertilizer;
- There are contrasting effects on the efficiency of nutrient use by forage plants due to the increase in environmental temperature and water deficiency;
- Transcriptomics and metabolomics revealed that high temperature and elevated CO₂ result in changes in transcription and metabolite profiles associated with environmental response, secondary metabolism and stomatal function; and
- Under conditions of high CO₂ concentration, the leaf/stem ratio decreases significantly.

These results have great scientific, social, and economic impacts because they shed light on the ability of C4 grasses to adapt to the climate expected for the coming years, in addition to providing practical information of interest to the target audience, which are farmers and ranchers. The project counted with two sources of financing: FAPESP (Process 2008/58075-8) and CNPq (Grant Process 446357/2015-4).

NEXT STEPS AND RECOMMENDATIONS

The effects of raised temperatures (+2°C) and water deficiency on forage grass species that present different growth patterns of the root system will be

studied to select materials that are more resistant to drought and high temperature.

(*Panicum maximum* Jacq.) response to elevated [CO₂] and temperature. *Metabolomics*. v. 15. n. 51. p. 1-13. 2019.

Continued in Annex

DATA PUBLISHED IN:

HABERMANN. E.; OLIVEIRA. E. A. D. de; CONTIN. D.; DELVECCHIO. G.; VICIEDO. D.; MORAES. M. de; PRADO. R. de M.; PINHO. K. de; BRAGA. M.; MARTINEZ. C. A. Warming and water deficit impact leaf photosynthesis and decrease forage quality and digestibility of a C₄ tropical grass. *Physiologia Plantarum*. v. 165. n. 2. p. 383-402. 2019.

HABERMANN. E.; SAN MARTIN. A.; CONTIN. D.; BOSSAN. V.; BARBOZA. A.; BRAGA. M.; GROppo. M.; MARTINEZ. C. A. Increasing atmospheric CO₂ and canopy temperature induces anatomical and physiological changes in leaves of the C₄ forage species *Panicum maximum*. *PLoS One*. v. 14. n. 2. e0212506. 2019.

WEDOW. J. M.; YENDREK. C.; MELLO. T.; CRESTE. S.; MARTINEZ. C. A.; AINSWORTH. E. Metabolite and transcript profiling of Guinea grass

REFERENCES:

IPCC – Intergovernmental Panel on Climate Change. Special Report. Global Warming of 1.5 °C. [S. l.]: IPCC. 2018. Disponível em: <https://www.ipcc.ch/sr15/>. Acesso em: 5 jul. 2020.

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Figure 1: Organization levels studied during research development to determine the performance of *Panicum maximum* cv. *Mombasa* under conditions of future climate simulation with high CO₂ concentration, high temperature and water deficiency in field conditions.



Source: Authors.

Figure 2: Detail of a portion of the T-FACE System (Temperature free-air controlled enhancement) for simulating global warming under field conditions.



Credit: Carlos Alberto Martinez.

INCREASING THE PRODUCTIVE EFFICIENCY OF CROPS IN THE CONTEXT OF CLIMATE CHANGE

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Cultivation systems are directly influenced by climatic elements. In this way, climate change (the increase in the concentration of atmospheric CO₂, increased temperatures, and changes in precipitation) may cause significant impacts on agricultural production. With this prognosis, there is a strong demand for research to evaluate these effects. Such assessments are supporting research on mitigating the effects and adapting agricultural activities to future climate changes. Embrapa has a fundamental role in these actions, as it has been developing research in partnership with several institutions in Brazil and abroad, aiming to develop technologies for sustainable agriculture in the face of climatic scenarios.

The studies carried out address the main climatic elements that are undergoing changes and their possible impacts and propose adaptation measures that increase the resilience of the crops. In the semiarid region, simulations of the scenarios of increased temperature, CO₂ and water deficits have been carried out so far, through experimentation under controlled conditions for onion, cowpea and buffel grass (Figure 1). Plants are evaluated from seed germination to final production. In this initial stage of the work, we seek to select materials tolerant to high temperatures and water deficit, which are extremely important to increase or maintain the productive potential of agricultural activity, adding resilience in the face of climate changes. In addition, the study provides for adaptation measures through technologies such as efficient management in using water and soil, use of genetic diversity, polyculture, agroforestry systems, among others. The search for crops that are more sustainable and adaptable to climate change will be imperative to ensure food security. The main beneficiaries will be farmers and public policy makers.

The studies were financed by Embrapa and were complemented by FACEPE and CNPq, which sponsored scientific initiation scholarships and the training for a technician.

RESULTS

For the cultivation of onion, the increase in temperature hinders bulbs formation, reducing productivity. The fertilizing effect of CO₂ has been neutralized in environments with high temperatures. As for irrigation, under controlled conditions, a reduction of 20% in the water depth was verified, with no losses in production. Thus, we conclude that adjustments will be necessary in the onion production system, to reduce farmer's vulnerability and to increase the system's resilience, in addition to promoting the sustainable use of water resources. This will only be possible through investing in research that fosters technological development for the adaptation of onion cultivation in the context of climate change. For buffel grass, the increase in air temperature alters its vegetative development without increasing the forage mass. For cowpea, the increase in temperature causes the flowers to abort, with a direct impact on grain production. In addition, the minimum amount of water to be applied in each phenology is being evaluated to optimize efficient water use for production. Thus, the screening of cultivars tolerant to the increase in temperature and water deficit increases the adaptive capacity and the resilience of crops, ensuring sustainable development and food security.

NEXT STEPS AND RECOMMENDATIONS

Studies aiming to increase the productive efficiency of the crops through suggesting materials that are tolerant to high temperatures and water deficits will be essential in adapting to climate change. In addition, determining the minimum amount of water needed for production will contribute to maintaining the sustainability of production systems. The selected materials will be recommended to compose multifunctional agroecosystems.

DATA PUBLISHED IN:

BARROS. J. R. A.; RÉGO. M. T. C.; COSTA. N. D.; YURI. J. E.; ANGELOTTI. F. Produção de cebola em diferentes regimes de temperatura no Submédio do Vale do Francisco. In: JORNADA DE INTEGRAÇÃO DA PÓS-GRADUAÇÃO DA EMBRAPA SEMIÁRIDO. 3.. 2018. Petrolina. Anais [...]. Petrolina: Embrapa Semiárido. 2018. p. 75-78. (Documento 284).

SANTOS. R. M.; VOLTOLINI. T. V.; ANGELOTTI. F.; AIDAR. S. T.; CHAVES. A. R. M. Productive and morphogenetic responses of buffel grass at different air temperatures and CO₂ concentrations. Revista Brasileira de Zootecnia. Viçosa-MG. v. 43. n. 8. p. 404-409. Apr. 2014.

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Figure 1: Experiments under controlled conditions to assess the impact of increases in temperature, CO₂ and water deficit on production.



Crédit: Francislene Angelotti.

GENETIC IMPROVEMENT OF EUCALYPTES FOR THE DEVELOPMENT OF CULTIVARS INTENDED FOR MULTIPLE WOOD USES AND POPULATIONS WITH THE POTENTIAL TO OVERCOME POSSIBLE ADVERSITIES CAUSED BY CLIMATE CHANGE

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The global trend of gradually replacing fossil energy sources with fuels from biomass benefits Brazil enormously, expanding the need to increase the area of forest plantations and promoting the strengthening of partnerships with specific segments of the private sector for the development of products that are appropriate to clonal forestry. Currently, there is a lack of genetic material that is adapted to face the natural edaphoclimatic limitations in certain regions under the concept of forest plantations that serve multiple uses, especially in a scenario aggravated by climate change.

The objective of the project was to expand opportunities for field experimentation, improvement in multi-environments and product validation, contributing so that the territorial expansion of eucalyptus plantations, even under possible effects of global climate change, may take place in the future and be less subject to the risk of compromised production.

The project brought together actions from the Eucalyptus Genetic Improvement Program (PMGE) to launch products prepared for planting in rural properties in the country, with the raw material produced being applied for multiple uses, with emphasis on energy and wood solids (Figure 1). Emphasis was placed on obtaining wood for sawn products and energy, considering not only traditional production systems, but also silvopastoral and agroforestry systems. Using practical processes to produce hybrid experimental seeds by open pollination, the improvement of techniques for the early selection of technological characteristics of wood, the application of controlled pollination in a pot crossing orchard and genetic prospection and transformation studies make up a set of innovative actions presented in the technical content of this project.

The project aimed to meet the demands of man-made forest plantations and demands for the production of material from forest origin, mainly on small and medium sized rural properties, established in different and diverse Brazilian regions.

- In order to understand the thermal, water and biotic stresses that affect the productivity of wood from notably clonal genotypes, the specific objective of the project was to identify genotypes that are tolerant to the environmental stresses mentioned;

- Predominantly conventional forest production systems were used, through experimental/ technological reference units established in seminal and clonal form, and developed actions in the Atlantic Forest, Cerrado, Caatinga and Amazon biomes;
- As a methodology, the experimental field modules were systematically monitored through assessments on survival, wood production and the direct and indirect effects on trees caused by different stresses, evaluating their nature and intensity;
- The project seeks to contribute to climate change adaptation through identifying and using genotypes with adaptive responses consistent with desired silvicultural performances, that have greater capacity for survival under observed conditions, reflected by the productivity of wood;
- The target audience, in general, was represented by forest nurseries, rural farmers and wood consumers;
- The budget allocated to R&D was provided by Embrapa from direct and indirect resources contributed through partnerships with seedling producers, forest-based companies, cooperatives and mining companies.

Acronyms of the species:

PEL: *Eucalyptus pellita*; URO: *Eucalyptus urophylla*; CLO: *Eucalyptus cloeziana*; GRA: *Eucalyptus grandis*; ADB: *Eucalyptus badjensis*; VIM: *Eucalyptus viminalis*; BEN:

Eucalyptusbenthamii; CRE: *Eucalyptuscrebra*; TOR: *Corymbia torelliana*; and MAC: *Corymbia maculata*.

RESULTS

- Pre-commercial eucalyptus, clonal and seed cultivars, adapted to current edaphoclimatic conditions and climate change scenarios;
- Development of BRS 362, BRS 363, BRS 364 Porteira, BRS QUARENTA and BRSCI 9601 Expoente cultivars;
- PEL clones for use per se and as parental clones in potential crosses for Central Brazil;
- Implementation of long-term strategies to explore PEL, URO, CLO, GRA, TOR, MAC and CRE variability in order to obtain new clones;
- Management of BAD, VIM and BEN experiments for seed production and definition of matrices for continuity of the breeding program;
- Genetic transformation protocol via *Agrobacterium tumefaciens* for eucalyptus clones and insertion of a gene that confers tolerance to water stress; and
- Database structuring.

NEXT STEPS AND RECOMMENDATIONS

- Producing propagating material from the cultivars generated available to the productive sector; and
- Empowering Embrapa's participation in forestry agribusiness, contributing to generate jobs and income for this sector.

REFERENCES:

- PALUDZYSZYN FILHO. E.; FARDIN. A. E.; SANTOS. A. M.; REIS. C. A. F.; SANTOS. P. E. T. dos; MACHADO. A. M.; RAFAEL. G. C. Base genética de melhoramento de eucaliptos e corímbias no norte do Estado de Goiás: resultados da cooperação técnica entre a Embrapa Florestas e a Anglo American Niquel Brasil – Codemin. Colombo: Embrapa Florestas. 2013. 50 p. (Documento. 248).
- PALUDZYSZYN FILHO. E.; OLIVEIRA. U. S. de; SANTOS. P. E. T. dos; REIS. C. A. F.; SANTOS. A. M.; LIMA. E. A. de. Base de melhoramento genético de *Eucalyptus* e *Corymbia* em Rio Verde-GO: resultados parciais da cooperação técnica entre Embrapa Florestas e Cooperativa Agroindustrial dos Produtores Rurais do Sudoeste Goiano – COMIGO. Colombo: Embrapa Florestas. 2014. 55 p. (Documento 271).
- PALUDZYSZYN FILHO. E.; SANTOS. P. E. T. dos. Programa de melhoramento genético de eucalipto da Embrapa Florestas: resultados e perspectivas. Colombo: Embrapa Florestas. 2011. 64 p. (Documento 214).

Continued in Annex

DATA PUBLISHED IN:

- BETTENCOURT. G. M. de F. Indirect organogenesis and genetic transformation protocol development for an elite clone of *E. urophylla*. 2016. Dissertação (Mestrado em Engenharia de Bioprocessos e Biotecnologia) – Setor de Tecnologia. Universidade Federal do Paraná. Curitiba. 2016.
- MÜLLER. B. S. F.; NEVES. L. G.; ALMEIDA FILHO. J. E. de; RESENDE JUNIOR. M. F. R.; MUÑOZ. P. R.; SANTOS. P. E. T. dos; PALUDZYSZYN FILHO. E.; KIRST. M.; GRATTAPAGLIA. D. Genomic prediction in contrast to a genome-wide association study in explaining heritable variation of complex growth traits in breeding populations of *Eucalyptus*. *BMC Genomics*. v. 18. p. 1-17. 2017.

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Figure 1: Performance evaluation experiment of wild *Eucalyptus crebra* imported from Australia, installed at Embrapa – Semiárido (Petrolina-PE), demonstrating the high tolerance of germplasm to the accentuated water and thermal stresses in the semi-arid region of northeastern Brazil and also the high potential for improving the species for the production of wood. Age > 5 years Average height: around 10 meters..

Crédit: Visêdo Ribeiro de Oliveira.

COFFEE PLANTS IN THE CONTEXT OF GLOBAL CLIMATE CHANGE

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From the pre-industrial period until 2019, anthropogenic action promoted an increase in the atmospheric concentration of CO₂ from about 280 ppm to 415 ppm, a concentration which may well exceed 700 ppm during the second half of the current century, accompanied by an average temperature increase of above 2°C (IPCC, 2014; 2018) and changes in rainfall patterns, etc. If this is confirmed, these changes will be responsible for significant metabolic changes in different crops, with significant impacts on the productivity and quality of agricultural products for human and animal nutrition. In light of this scenario, an international (Brazil-Portugal), interinstitutional (UENF, UFES, UFV, ISA /UL, FCT/UNL, INIAV) and interdisciplinary team (from anatomy to the molecular area), has carried out several studies aiming to assess the impact of climate change on coffee, taking into account, above all, the increase in [CO₂], increase in air temperature and water stress, at the level of plant metabolism and grain quality. The experiments associated with interactions between increases in [CO₂] (380 vs. 700 ppm) and temperature (from 25/20 °C to 42/34 °C, day/night) carried out in Portugal (Figure 1) (ISA/UL) were carried out in controlled environmental conditions, using Brazilian genotypes of *Coffea arabica* (Arabica coffee) and *C. canephora* (Robusta coffee). This research intends to evaluate the individual and simultaneous impacts of the increased temperatures and [CO₂] on anatomical, physiological, biochemical and molecular aspects. At Embrapa - Meio Ambiente, Jaguariúna-SP, in 2011 an experiment in field conditions with *C. Arabica* was initiated. The free-air-CO₂-enrichment device (FACE) delivered 200 ppm above the current concentration (~590 ppm). The last phase of the experiment developed mitigation strategies against impacts of drought conditions according to the increase in [CO₂]. Another experiment was carried out in Campos dos Goytacazes, north of the state of Rio de Janeiro, at the Universidade Estadual do Norte Fluminense (UENF) and in a greenhouse, with the objective of studying the effects of temperature increase (based on a seasonal variation) on the physiological aspects, both at leaf levels and at entire plant levels. Experiments are also being carried out at the Federal University of Espírito Santo (UFES), São Mateus, in the north of the state of Espírito Santo. In field conditions, the performance of Conilon coffee grown under tree canopy of species like the

rubber tree (*Hevea brasiliensis* Willd. ex A.Juss.) Müll. Arg.) and Australian cedar (*Toona ciliata* M. Roem) are being studied currently. This cultivation strategy can mitigate the effect of thermal stress. This research, which entailed a strong component of advanced training of human resources, was financed by the Portuguese Foundation for Science and Technology (projects PTDC/AGR-PRO / 3386/2012; PTDC/ ASP-AGR/31257/2017; LEAF units: UID/AGR/04129/2013; GeoBioTec: UID/GEO/04035/2013), CAPES, CNPq, FAPERJ, FAPES, Embrapa and Consórcio Pesquisa Cafés.

RESULTS

- Coffee plants show relevant tolerance to high temperatures (up to 37/30 °C);
- Strong negative impacts were observed at 42/34 °C. However, the increase in [CO₂] (700 ppm) enhanced plant metabolism at all temperatures and significantly mitigated the impact of elevated temperatures;
- Exposure to high temperatures in the last stages of fruit ripening caused depreciation in the quality of the grains, but the high [CO₂] contributed to preserve quality;
- Under natural fluctuations, supra-optimal temperatures resulted in increases in the air vapor pressure deficit, which compromised the gas exchange of the individual leaves and the entire plant;
- In FACE, adult Arabica coffee plants showed high leaf stomata conductance under high [CO₂], which allowed for high photosynthesis in the dry season, both in leaf and whole plant scale, which allowed better investments in carbon in turnover of fine roots in soil with less water deficit. Under increased [CO₂] the quality of the brew did not suffer, although
- some delay occurred compared to plants grown on 400 ppm CO₂. Productivity under field conditions

was higher in the three first years under elevated [CO₂], but in the fourth the productivity was similar between CO₂ concentrations;

- Intercropping with tree species promoted a microclimate under the canopy that was more favorable to coffee, mainly associated with the reduction of irradiance and temperature, as well as an increase in the relative air humidity.

NEXT STEPS

- Study mitigation strategies against the negative implications of the climate in cultivation;
- Identify the acclimatization responses of coffee plants in order to use this information in breeding programs;
- Study the interactions between increased temperature and/or CO₂ concentration with water stress on a whole plant scale, as well as in the floral biology of the coffee plant;
- Study effects of shading associated with soil water stress.

DATA PUBLISHED IN:

BATISTA-SANTOS. P.; LIDON. F. C.; FORTUNATO. A.; LEITÃO. A. E.; LOPES. E.; PARTELLI. F.; RIBEIRO. A. I.; RAMALHO. J. C. The impact of cold on photosynthesis in genotypes of *Coffea* spp. – Photosystem sensitivity, photoprotective mechanisms and gene expression. *Journal of Plant Physiology*. v. 168. n. 8. p. 792-806. 2011.

DAMATTA. F. M.; AVILA. R. T.; CARDOSO. A. A.; MARTINS. S. C. V.; RAMALHO. J. C. Physiological and agronomic performance of the coffee crop in the context of climate change and global warming: a review. *Journal of Agricultural and Food Chemistry*. v. 66. n. 21. p. 5264-5274. 2018.

Continued in Annex

REFERENCES:

IPCC – Intergovernmental Panel on Climate Change. Summary for policymakers. In: FIELD. C. B. et al. (eds.). *Impacts, adaptation and vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York, United Kingdom: Cambridge University Press. 2014. p. 1-32.

IPCC – Intergovernmental Panel on Climate Change. Summary for policymakers. In: MASSON-DELMOTTE. V. et al. (eds.). *Global warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Switzerland: World Meteorological Organization. 2018. p. 1-24.

Continued in Annex

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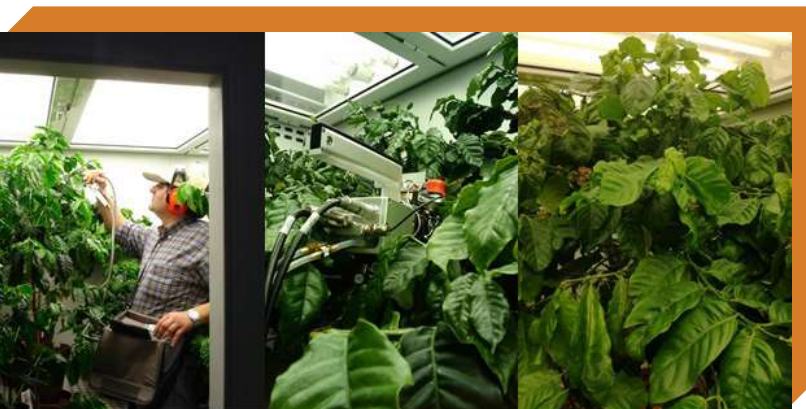


Figure 1: Studies under controlled environmental conditions (temperature, relative humidity, irradiance, photoperiod and [CO₂]) in EHHF 10000 growth chambers, ARALAB, Portugal) in *C. arabica* genotypes (cv. Icatu and IPR108) and *C. canephora* cv. Conilon Clone 153.

Crédit: José Cochicho Ramalho.

TECHNOLOGICAL ADVANCES TO COPE WITH WATER DEFICIT STRESS IN SOY

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Losses related to drought are a challenge for grain production. Drought events in recent decades have been more frequent, probably associated with climate change resulting from global warming. Several soybean-producing regions in Brazil have suffered significantly from droughts, but also from excessive rainfall and high temperatures due to climate change. Forecasts indicate that climatic extremes tend to increase, causing these events to happen more frequently and last longer. Embrapa - Soja, in partnership with institutions (national and international), conducts research to identify strategies associated with climate zoning, genetic improvement and biotechnology and crop and soil management to reduce losses caused by droughts and other stresses resulting from climatic extremes.

In this project and other projects, physiological, agronomic and molecular evaluations of soybean genotypes are being produced, aiming at the development of genetic improvement strategies that allow for obtaining more drought tolerant strains, which can be used in growing and harvesting commercial varieties that are adapted to all the producing regions of Brazil. The project has been generating important results, such as the characterization of new varieties of soybeans and other genotypes with potential for drought tolerance and the definition of plants that are more adapted to the different edaphoclimatic conditions in Brazil. The drought-tolerant genetically modified (GM) soybean lines that are being developed in a partnership between Embrapa and research institutions in Japan (JIRCAS/RIKEN/ University of Tokyo) were also characterized under field conditions. These strains, overexpressing different genes (AtAREB1A, GmDREB2, AtNCED and AtGolS) are being used in crosses with elite genotypes and will be subject to biosafety analysis in the future and then released commercially (Figure 1). The characterization of the genotypes provided data for updating the agricultural zoning of soybeans and for studying the impacts of climate change. In addition, the project contributed to advancing the knowledge and understanding of how genotypes which are more tolerant to water deficit respond when subjected to different crop management conditions, such as, for example, rotation with more aggressive root system cultures, which promote a better physical/chemical structure of soil. In relation to GM plants, the results obtained in a controlled greenhouse environment and also in the field showed promising strategies, where the GM genotypes showed greater yield

stability in the face of water deficit. The project is ongoing, has nationwide coverage and is part of Embrapa's research program. These strains are being introduced in a breeding program to eventually become commercial cultivars.

RESULTS

In this project, genetically modified strains have already been developed with genes that confer drought tolerance (AtAREB1A, GmDREB2, AtNCED and AtGolS), and have already been tested in a controlled environment and in the field, showing promising results in conferring increased drought and heat tolerance in soy. The goal is to develop cultivars that have more efficient biochemical-physiological processes in water saving and use and that are more tolerant to drought and high temperatures.

NEXT STEPS

Continuing with the initial laboratory and greenhouse testing and obtaining phases, the project is in the stage of crossing the GM strains with elite genotypes from the Embrapa Soja breeding program and expanding the testing network to the Midwest. The main challenge is the regulation of these GMOs, considering the high cost and time required for the approval of transgenics. For this reason, Embrapa has been looking for partners in the private sector that are participating in the studies, expanding the testing areas of GM plants in Brazil. If the positive results continue to be confirmed, there is a great possibility that these partners will help Embrapa to deregulate transgenics in Brazil and in the rest of the countries importing soybeans from Brazil. It is also important to mention that all the results obtained so far are serving as the basis for Embrapa's new research on Genome Editing using the CRISPRs technique. The regulation of Using these techniques in many countries has considered, in a case-by-case assessment, products obtained as non-GMOs/transgenic. This is the case in Brazil with Normative Resolution No. 16, of the National Technical Commission

on Biosafety. As a result, the cost of commercial release is drastically reduced, allowing Brazilian public or private companies to have a much better chance of launching biotechnology-based products in Brazilian agribusiness.

DATA PUBLISHED IN:

FERREIRA-NETO. J. R. C.; SILVA. M. D. da; BENKO-ISEPPON. A. M.; PANDOLFI. V.; BINNECK. E.; NEPOMUCENO. A. L.; ABDELNOOR. R. V.; KIDO. E. A. Inositol phosphates and raffinose family oligosaccharides pathways: structural genomics and transcriptomics in soybean under root dehydration. *Plant Gene*. v. 1. p. 100202. 2019.

FUGANTI-PAGLIARINI. R.; FERREIRA. L. C.; RODRIGUES. F. A.; MOLINARI. H. B. C.; MARIN. S. R. R.; MOLINARI. M. D. C.; MARCOLINO-GOMES. J.; MERTZ-HENNING. L. M.; FARIAS. J. R. B.; OLIVEIRA. M. C. N. de; NEUMAIER. N.; KANAMORI. N.; FUJITA. Y.; MIZOI. J.; NAKASHIMA. K.; YAMAGUCHI-SHINOZAKI. K.; NEPOMUCENO. A. L. Characterization of soybean genetically modified for drought tolerance in field conditions. *Frontiers in Plant Science*. v. 8. p. 1. 2017.

GIORDANI. W.; GONÇALVES. L. S. A.; MORAES. L. A. C.; FERREIRA. L. C.; NEUMAIER. N.; FARIAS. J. R. B.; NEPOMUCENO. A. L.; OLIVEIRA. M. C. N.; MERTZ-HENNING. L. M. Identification of agronomical and morphological traits contributing to drought stress tolerance in soybean. *Australian Journal of Crop Science*. v. 13. p. 35-44. 2019.

Continued in Annex

Figure 1: Genetically modified (GM) strain overexpressing the transcription factor AtAREB1 subjected to water deficit in a greenhouse. *Legenda: BR 16 (Cultivar convencional utilizada na transformação); 1Ea2939 e 1Ea15 (Linhagens GM superexpressando o gene AtAREB1).*



Crédit: Embrapa Soja.

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DEVELOPING A POTATO GERMPLASM THAT IS MORE ADAPTABLE TO CLIMATE CHANGE

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The potato (*Solanum tuberosum*) is the fourth most important crop in the world. In Brazil, it is the second most economically important vegetable. Potato agribusiness involves about five thousand producers in the states of MG, SP, PR, RS, GO, BA and SC, with an annual production area of between 130 and 140 thousand ha. In view of the global climate change scenario, the prognosis is for a reduction of between 18 and 32% in world potato production by 2050. For Brazil, the estimate is a 23% drop in production (HIJMANS, 2003). The development of cultivars that are adapted to this new scenario is one of the main ways of mitigating the negative effect of global warming on potato production. However, there is a shortage in the supply of potato germplasm with greater tolerance and adaptation to water deficit and resistance to exposure to high temperatures.

Since 2008, Embrapa's potato breeding program has developed research that identifies and selects germplasm that is more adaptable to the climate change scenario (Figures 1 and 2). The activities were carried out in the Pampa biome, in the southern region of Brazil, and was funded by Embrapa, CAPES and CNPq. Initially, methodologies for germplasm screening were tested. Regarding drought tolerance assessment, the hydroponic system was adopted through polyethylene glycol 6000. For heat, the evaluations were carried out in growth chambers and exposed to two temperature gradients, a control, with a thermal range from 14 to 27°C, and heated (supra-optimum), with a range from 24 to 34°C. Chlorophyll fluorescence was also assessed. Based on the results, the maximum quantum efficiency of photosystem II can be used to select heat tolerance in potatoes. Parallel to phenotyping, a diversity panel was created as part of the Embrapa potato breeding program, consisting of 151 genotypes, aiming to identify regions of the genome that explain the greatest tolerance to drought and heat stresses. This panel was genotyped with 8,303 SNPs (Single Nucleotide Polymorphisms). So far, 70% of the panel (108 genotypes) have been assessed for response to water deficit. Seven clones performed better when under stress. Morphological and physiological variables, associated with more or less tolerance to water deficit, were identified and presented heritability values ranging from 0.16 to 0.69. Stable expression genes were also selected for use as reference genes in gene expression studies by RT-qPCR subject to the

water deficit condition. Regarding phenotyping for heat, 18 genotypes were thoroughly evaluated, of which two stood out. The results obtained so far have greatly contributed to the development of a potato germplasm that is more adapted to the climate change scenario. Crosses between genitors that add characteristics that are more adapted to heat stress and water deficit are being carried out and, thus, populations are being developed with the goal of obtaining potato cultivars that perform better under stressful conditions.

RESULTS

- Establishment of a methodology for evaluating potato germplasm regarding its response to water deficit;
- Definition of a methodology for evaluating potato germplasm regarding its response to heat exposure;
- Identification of morpho-agronomic and physiological characteristics associated with potato tolerance to water deficit and heat stress;
- Identification of potato genotypes with greater tolerance to water deficit stresses and exposure to supra-optimum temperatures.

Figure 1: Germplasm with characteristics desirable for commercial cultivation



Crédit: Embrapa.

NEXT STEPS AND RECOMMENDATIONS

Segregate populations from crossbreeding between genitors that add heat stress and water deficit adaptation characteristics to provide potato cultivars that meet society's demand.

DATA PUBLISHED IN:

CASTRO. C. M.; REISSER JUNIOR. C.; PEREIRA. A. da S.; ROHR. A. Potato germoplasm enhancement for drought tolerance at Embrapa Brazil. In: ANNUAL MEETING OF THE POTATO ASSOCIATION OF AMERICA. 97. 2013. Québec. Program & Abstracts [...]. Québec: PAA. 2013. p. 72.

KNEIB. R. B. Variabilidade genética. respostas fisiológicas e morfoagronômicas para tolerância ao calor em batata. 2019. Tese (Doutorado em Agronomia) – Programa de Pós-Graduação em Agronomia. Universidade Federal de Pelotas. Pelotas. 2019.

PEREIRA. A. da S.; CASTRO. C.; LENZ. E.; KNEIB. R.; TERRES. L.; AZEVEDO. F.; ROCHA. D.; SILVA. G. da. Resposta esperada de seleção para caracteres de rendimento e desordens fisiológicas para três populações híbridas de batata sob condições de calor. In: CONGRESO DE LA ASOCIACION LATINOAMERICANA DE LA PAPA – ALAP. 26.. 2014. Colombia. Tema: Papa. alimento ayer. hoy y siempre. Memorias [...]. Mar del Plata: Alap. 2014. p. 182.

Continued in Annex

REFERENCES:

HIJMANS. R. J. The effect of climate change on global potato production. American Journal of Potato Research. v. 80. p. 271-280. 2003.

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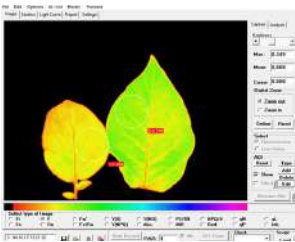
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Figure 2: Methodologies used in evaluating potato germplasm for tolerance to water deficit and supra-optimal temperatures.

Stress	Reference	Methodology
Drought	Evaluation in hydroponic system with addition of Reisser Junior polyethylene glycol 6000 (PEG), simulating deficit of et al. 2015-0.024 megapascals (Mpa)	 <p>Reisser Júnior et al. 2015 Rohr. 2016</p>
Supra-optimal temperature	Growth chamber evaluation with thermal range from 24 to 34°C	 <p>Kneib. 2019</p>
	Chlorophyll fluorescence analysis	

Source: Embrapa - Clima Temperado.

IMPACT OF CLIMATE CHANGE ON WATER STRESS IN BEAN CROPS CULTIVATED DURING THE WET SEASON

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The common bean (*Phaseolus vulgaris* L.) is the most cultivated and consumed legume in Brazil and plays an especially significant role in the Brazilian diet. Reductions in agricultural productivity associated with climate change and an absence of adaptation are expected in the future, which will result in severe consequences for Brazil's food security. In South America, there is a projected reduction in productivity for the common bean mainly due to the increase in temperatures and drought. Thus, the bean breeding program will play an important role in adapting common beans to climate change. Here, we evaluate the historical and future probabilities (2030) of occurrence, intensity, and impact of seasonal variations in water deficiency, which are the most important limiting factors for common beans in the state of Goiás, where the Cerrado biome predominates (Figure 1). 26 climatic stations located in the state of Goiás were assessed, with daily data on rainfall, maximum and minimum temperatures, and global solar radiation for the period from 1980 to 2013, which will be our baseline, and three soil classes - Latosol, Argisol and Cambisol, which represent 64, 19 and 6% of the agricultural area in the state of Goiás. As future climate data, 12 global climate models (GCM) were used, presenting daily data for the variables of maximum and minimum temperature, precipitation and global solar radiation for four RCPs (scenarios of representative concentration trajectories: 2.6; 4.5; 6.0 and 8.5). Two methods of correcting bias in GCM data were applied in this study, the delta method that applies the correction to the mean and the CF method that applies the correction to the variance and mean. The development, growth and productivity of common beans were simulated using the CSM-CROPGRO model for two cultivars, Pérola and BRS Radiante. The simulations were carried out considering seven sowing dates for the wet season (November 1st to December 30th), two cultivars (Pérola and BRS Radiante), three soil classes and baseline climatic data (1980 to 2013) and future climatic data (2020 to 2045 - 96 scenarios and four RCPs).

Target audience: researchers and teachers.

Funding sources: CGIAR - Climate Change Research Program, Agriculture and Food Security (CCAFS), subproject "A methodological development of an online tool for the identification of Target Population Environments: improving the predictions of agricultural production using crop models" and Project MON 02.12.12.002.00.00 - "Intercomparing,

improvement and adaptation simulation models for agricultural crops for application in climate change (AgMIP-BR)".

RESULTS

Beans in the state of Goiás are cultivated during three periods of the year: wet season, dry season, and winter. This study focused on the wet season, with sowing between November and December. During the wet season, two environmental groups - highly favorable environment (HFE) and favorable environment (FE) - covering 62% of the bean cultivated area in the state of Goiás were observed. For each group, two drought profiles were obtained (without drought deficiency, reproductive deficiency) considering all sowing dates and cultivars. The results suggest that, in comparison with the historical period (1980– 2005), climate change will make water deficiency more frequent, but less severe, across the region due to the positive interaction between beans and the increase in atmospheric CO₂. The probability of drought occurrence increased from 16% (baseline) to 43% (2030, RCP 8.5). The results are consistent with RCPs, although the benefits of rigorous mitigation (RCP 2.6) are evident. In addition, we highlight the importance of sowing in early November and using short cycle cultivars, thanks to the possibility of escape minimizing the impacts of droughts which also demonstrated higher yields (cv. Radiante - early flowering and early maturity for most situations of drought) in both environments. In this study, the short cycle cultivar (cv. Radiante) generally outperformed the other cultivar in terms of stability and productivity. The shorter cycle characteristic of cv. Radiante minimized the impacts of droughts, illustrating how this feature can be a powerful tool in conditions of climate change. We conclude that adaptation to drought due to climate change is necessary for Embrapa's improvement program.

NEXT STEPS AND RECOMMENDATIONS

The next stage of this study aims to put into practice the strategies suggested in Embrapa Arroz e Feijão's bean breeding program.

REFERENCES:

HEINEMANN, A. B.; RAMIREZ-VILLEGAS, J.; STONE, L. F.; DIDONET, A. D. Climate change determined drought stress profiles in rainfed common bean. *Agricultural and Forest Meteorology*. v. 246. p. 64-77. Nov. 2017.

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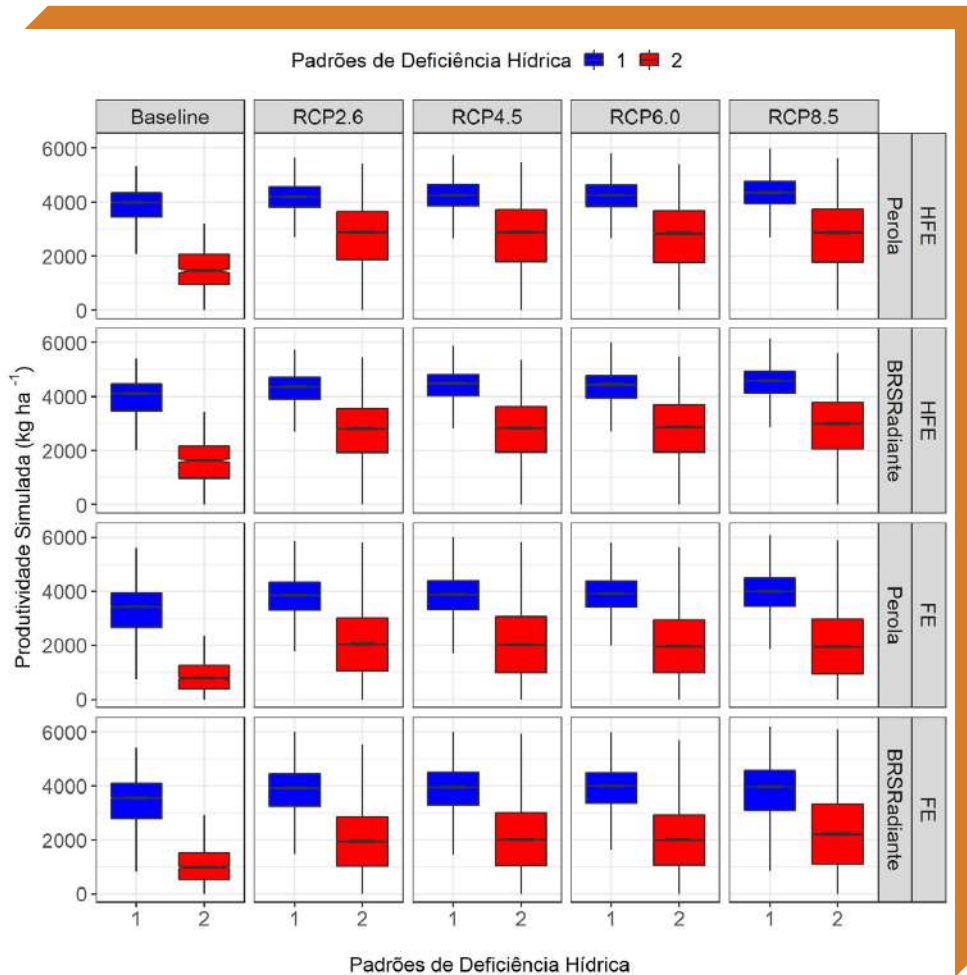
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Figure 1: Variation of simulated current (baseline) and future (RCPs 2.6, 4.5, 6.0 and 8.5) common bean yield for the wet season, for the Pérola and Radiante cultivars



Caption: HFE and FE are environmental groupings, with HFE being highly favorable and FE favorable, respectively. The drought profile 1 is without deficiency and 2, water deficiency in the reproductive phase. The thick horizontal line represents the median.

Source: Authors.

IMPLICATIONS FROM THE UPLAND RICE IMPROVEMENT PROGRAM DUE TO CLIMATE CHANGE

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O arroz é considerado um dos principais alimentos no Brasil. Assim, para acompanhar o crescente aumento da demanda e os efeitos deletérios das mudanças climáticas, é necessário um aumento substancial de produtividade. De acordo com o último relatório do IPCC, na ausência de adaptação, a produtividade do arroz tropical provavelmente diminuirá a uma taxa entre 1.3% e 3.5% por grau de aquecimento. Existe, portanto, uma necessidade crescente de melhores cultivares adaptadas que combinem maior potencial de produção e tolerância à deficiência hídrica. Para obter esse incremento na produtividade, devido aos efeitos das mudanças climáticas, o programa de melhoramento vegetal exercerá papel principal para atingir esse objetivo. Sob mudanças climáticas, as metas dos programas de melhoramento de vegetais podem variar de acordo com os estresses abióticos que agem durante o ciclo da cultura, como resultado do acréscimo da temperatura e da variabilidade inter e intra anual da precipitação. Esse estudo aborda principalmente o bioma Cerrado. A hipótese é que as mudanças climáticas alterem as regiões atuais de produção de arroz de terras altas devido às mudanças nos padrões de deficiência hídrica até 2050, exigindo mudanças nas estratégias do programa de melhoramento de arroz de terras altas no Brasil central no século XXI. Foram utilizadas 51 estações climáticas localizadas no Brasil central (Goiás, Tocantins, Rondônia e Mato Grosso) com dados diários históricos de 1981–2005. Como dados de clima futuro, utilizamos 12 modelos de clima globais (MCG) que apresentam dados diários para as variáveis temperatura máxima, mínima, precipitação e radiação solar global para quatro RCPs (cenários de trajetórias representativas de concentração: 2.6; 4.5; 6.0; e 8.5). Dois métodos de correção de viés dos dados provenientes do MCG foram aplicados nesse estudo: o método delta, que aplica a correção na média, e o método CF, que aplica a correção na variância e na média, totalizando 96 cenários de clima (12 [MCG] x 4 [RCPs] x viés [2]). Sete tipos de solo e oito datas de semeadura que são representativas da região de produção do arroz de terras altas foram utilizadas. Dados de produtividade do arroz de terras altas foram obtidos utilizando o modelo de simulação de produtividade do arroz ORYZA v3, que foi parametrizado para permitir duas situações: alta resposta e baixa resposta da cultura do arroz ao aumento do CO₂ na atmosfera.

Fontes de Financiamento: CGIAR – Programa de Pesquisa em Mudanças Climáticas, Agricultura e Segurança Alimentar (CCAFS), subprojeto “A methodological development of an online tool for the identification of Target Population Environments: improving the predictions of agricultural production using crop models” e Projeto SEG 02.12.12.002.00.00: “Intercomparação, aprimoramento e adaptação de modelos de simulação de culturas agrícolas para aplicação em mudanças climáticas (AgMIP-BR)”, sendo o público-alvo pesquisadores e professores.

RESULTS

Changes were observed in the frequency and intensity of droughts, with reductions in yield in the range of 200–600 kg ha⁻¹ and reductions in yield stability in practically the entire area cultivated with upland rice. Given these changes, our analysis using simulation models of upland rice productivity suggests that the current strategy of the breeding program, which is selecting under stress-free conditions (projected to occur in less than 13% of the cultivated area) must be adjusted. We recommend a weighted selection strategy for the three environmental groups that characterize the region of production. For the most favorable environment (36–41% of the cultivated area, depending on the CPR), the selection must be made under conditions of terminal water deficiency and without water deficiency. As for the favorable environment (27–40% of the cultivation area, depending on the CPR), the selection must be made under water deficiency in the reproductive and final phase. Finally, for the least favorable environment (HFE, 23–27% of the cultivation area, depending on the CPR), the selection must be made to respond to water deficiency in the reproductive phase and for the joint occurrence of deficiencies in the reproductive and final phases. Improving the efficiency of the breeding program, targeting adaptive characteristics for drought tolerance, will increase the resilience of the upland rice cultivation system under climate change.

NEXT STEPS AND RECOMMENDATIONS

The next stage of this study aims to the strategies suggested in this study into practice in the upland rice breeding program of Embrapa Arroz e Feijão and to implement a system for selecting cultivars that are tolerant to water deficiency.

REFERENCES:

ANDRADE. C. M. S. de. Importância das leguminosas forrageiras para a sustentabilidade dos sistemas de produção de ruminantes. In: SIMPÓSIO BRASILEIRO DE PRODUÇÃO DE RUMINANTES NO CERRADO. 1.. 2012. Uberlândia. Anais [...]. Uberlândia: UFU. 2012. p. 47-96.

ANDRADE. C. M. S. de. Produção de ruminantes em pastos consorciados. In: SIMPÓSIO SOBRE MANEJO ESTRATÉGICO DA PASTAGEM. 5.; SIMPÓSIO INTERNACIONAL SOBRE PRODUÇÃO ANIMAL EM PASTEJO. 3.. 2010. Viçosa-MG. Anais [...]. Viçosa: UFV. 2010. p. 171-214.

DIAS-FILHO. M. B. Diagnóstico das pastagens no Brasil. Belém: Embrapa Amazônia Oriental. 2014. (Documentos 402).

Continued in Annex

DATA PUBLISHED IN:

RAMIREZ-VILLEGAS. J.; HEINEMANN. A. B.; CASTRO. A. P. de; BRESEGHELLO. F.; NAVARRO-RACINES. C.; TAO. L.; REBOLLEDO. M. C.; CHALLINOR. A. J. Breeding implications of drought stress under future climate for upland rice in Brazil. *Global Change Biology*. v. 1. n. 5. p. 2035-2050. May 2018.

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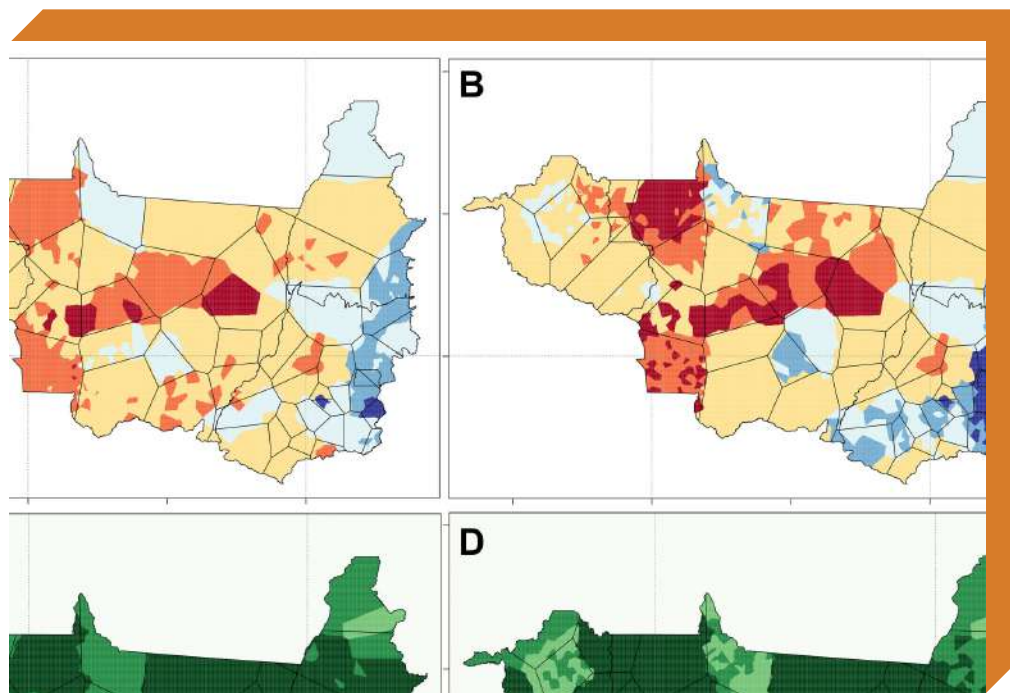
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Figure 1: Projected change in average productivity by 2050 (A, B) and agreement between global climate models (C, D) for RCP 2.6 (A, C) and RCP 8.5 (B, D) are expressed as a difference (in kg/ha-1) in relation to the average historical yield. The agreement of the model (C, D) is calculated as the percentage of simulations as a function of the 384 simulations of future scenarios (8 sowing dates x 12 GCMs x 2 BC methods x 2 CO2 parameterizations) that agree with the projected change (A and C).



Source: Authors.

IMPACTS OF GLOBAL CLIMATE CHANGE ON PHYTOSANITARY PROBLEMS

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*In memoriam: foi a precursora do tema no Brasil e coordenou as atividades do projeto CLIMAPEST em rede Nacional

Plant pathogens cause significant damage to crop yields, with about a third of production likely to be lost as a result of disease. Climate is directly related to the occurrence of these phytosanitary problems and, with climate change, changes are expected which will impact the intensity geographic and temporal distribution of pathogens, and consequentially, will interfere in the sustainability of production systems. In the new climatic scenario, places that are currently exempt from certain pathogens may develop a potential risk of occurrence. Thus, the prospect of these effects for different pathosystems is a strategic line of research for food security. Based on this type of study, it will be possible to recommend strategies for the management of diseases, both preventive and curative, increasing the resilience of agricultural systems. The main beneficiaries will be farmers and public policy makers.

In this sense, Climapest was a project that functioned as a national network and assessed the impact of climate change on diseases, pests, and weeds of 16 important agricultural crops across Brazil (Figure 1). Phytosanitary problems are among the main challenges of agricultural production and can jeopardize the sustainability of agroecosystems. By advancing knowledge, through assessing the impacts of climate change on more than 85 phytosanitary problems, the complex plant-disease/pest/weed interaction and the need for further studies for phytosanitary defense was confirmed.

In the Brazilian semiarid, studies on the impact of climate change on pests that affect Grapevine, cowpea and melons were carried out. In this region, the studies included experimentation in controlled conditions (growth chambers) and in the field (modified open top greenhouse) and the elaboration of maps with the geographical and temporal distribution of diseases. Studies were financed by Embrapa and further supported by FACEPE, CNPq and CAPES, through funding scientific initiation scholarships, academic masters degrees and training technicians.

RESULTS

Climate change may cause negative, positive, and neutral impacts on the different pathosystems studied. Such responses varied according to the specificity of each genus/species of microorganism and even according to the genetic variability of the different cultivars tested (Table 1). The information that was generated helps to anticipate the response and supports better choices of management strategies that will continue to have an effective action in controlling these diseases.

NEXT STEPS AND RECOMENDATIONS

Based on the impact assessment, scientific research will continue to play a decisive role in adapting and readjusting strategies and tools for crop protection. Uncertainties regarding the impacts of climate change on plant diseases will only be minimized through the generation of knowledge. The study of host-pathogen relationships forms the basis for the application of control measures. The challenge of the research is to understand the adaptive capacity of populations of pathogens and of host plants. We can state that more diversified, flexible and resilient agricultural production systems will be needed.

DATA PUBLISHED IN:

ANGELOTTI, F.; HAMADA, E.; MAGALHÃES, E. E.; GHINI, R.; GARRIDO, L. da R.; PEDRO JUNIOR, M. Climate change and the occurrence of downy mildew in Brazilian grapevines. *Pesquisa Agropecuária Brasileira*. v. 52. n. 6. p. 424-432. June 2017.

ARAUJO, A. L. S.; ANGELOTTI, F.; RIBEIRO JUNIOR, P. M. Severity of melon powdery mildew as a function of increasing temperature and carbon dioxide concentration. *Revista Brasileira de Ciências Agrárias*. v. 14. n. 4. e6916. 2019.

BETTIOL, W.; HAMADA, E.; ANGELOTTI, F.; AUAD, A. M.; GHINI, R. (ed.). *Aquecimento global e problemas fitossanitários*. Brasília: Embrapa. 2017.

REFERENCES:

HAMADA. E.; ANGELOTTI. F.; GARRIDO. L. da R.; GHINI. R. Cenários futuros de epidemia do oídio da videira com as mudanças climáticas para o Brasil. *Revista Brasileira de Geografia Física*. Recife. v. 8. p. 454-470. 2015.

HAMADA. E.; ANGELOTTI. F.; GARRIDO. L. da R.; GHINI. R.; NOGUEIRA. S. M. C.; PEDRO JUNIOR. M. J. Efeito das mudanças climáticas sobre a distribuição espacial da podridão amarga (*Greeneria uvicola*) da videira no Brasil. In: Congresso Paulista de Fitopatologia. 35. 2012. Jaguariúna. *Summa Phytopathologica*. v.38. 2012. Suplemento.

HAMADA. E.; ANGELOTTI. F.; GARRIDO. L. da R.; GHINI. R.; CARVALHO. M. C.; PALLADINO. R. P. Efeito das mudanças climáticas sobre a favorabilidade às podridões da uva madura e cinzenta da videira no Nordeste brasileiro. *Revista Brasileira de Geografia Física*. v. 4. p. 1100-1115. 2011.

SANTANA. C. V. da S. Interação entre fatores do ambiente e *Oidium* sp. em feijão-caupi. 2013. 69 f. il. Tese (Doutorado em Agricultura tropical) - Universidade Federal da Paraíba. Centro de Ciências Agrárias. Areia.

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Table 1: Climate favorability for the occurrence of plant diseases in the future climate scenario

Crop	Pathogen	Disease	Favorability	References
Cowpea:	<i>Oidium sp.</i>	Powdery	Reduction	Santana (2013)
Melon	<i>Phodosphaera xanthii</i>	Powdery	Reduction	Araújo (2019)
Grapevine	<i>Uncinula necator</i>	Powdery	Increase	Hamada <i>et al.</i> (2015)
Grapevine	<i>Plasmopara viticola</i>	Downy	Reduction	Angelotti <i>et al.</i> (2017)
Grapevine	<i>Botrytis cinerea</i> <i>Greeneria uvicola</i> <i>Glomerella cingulata</i>	Rotten	Reduction	Hamada <i>et al.</i> (2011) Hamada <i>et al.</i> (2012)
Grapevine	<i>Xanthomonas campestris</i> <i>pv. viticola</i>	Bacterial canker	No changes	Bettiol <i>et al.</i> (2017)

Source: Authors.

Figure 1: Experiments under controlled conditions to assess the impact of increased temperature (A) and carbon dioxide concentration (B) on grapevine diseases



Crédit: Francislene Angelotti.

GENOMICS APPLIED TO CLIMATE CHANGE RESEARCH CENTER

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Stresses exacerbated by global climate change have negatively affected agricultural production. In this decade, severe droughts and heat waves in the Midwest, Northeast and in the region of MATOPIBA (Maranhão, Tocantins, Piauí and Bahia), the country's newest agricultural frontier, caused losses of hundreds of millions of tons of Brazilian agricultural products (GUTIERREZ et al., 2014). The application of best agricultural practices and the development of varieties that are more adapted and tolerant to this new climate reality are necessary strategies to meet the growing demand for agricultural products.

Despite the indisputable importance of the role of research and development in the evolution of world agricultural production in food security, a decline in public funding for R&D has been observed worldwide (ALSTON et al., 2009). This decline is accompanied by an increase in private investments, mainly by companies in the seed sector, which, after a series of acquisitions and mergers, resulted in a greater concentration of participation in the world market and in technological domain (ETC GROUP, 2015; BRENNAN, 2016). With high investments and capacity for innovation, these large companies are able to continuously develop, through R&D pipelines that integrate genetic improvement and biotechnology, new cultivars with characteristics such as resistance to herbicides and pests and, more recently, tolerance to drought (PRADO et al., 2014; McELROY, 2004). Because they develop almost exclusively new technologies in the country of origin, where their research and development centers are located, the maximum performance of these technologies is not achieved in global consumer markets, where new discoveries are incorporated or adapted into local R&D programs.

It is strategic for the Brazilian agricultural sector, responsible for a quarter of the Gross Domestic Product, that national public and private institutions strengthen their scientific and technological production to contribute to the national development of technology and varieties appropriate to our demands. Facing the challenges of genetically adapting crops to stresses intensified by climate change requires long-term financing, interdisciplinary approaches and partnerships, often between public and private companies, which are closer to agricultural producers. At the end of 2017, a partnership between Embrapa, Unicamp and Fapesp created the Research Center in Genomics Applied to Climate Change

(GCCRC), uniting the competences of the two institutions in agricultural biotechnology. The center's mission is to develop, over the next 10 years, biotechnological assets that increase the tolerance of plants to drought and heat and transfer the technologies developed to the productive sector.

Figure 1 illustrates the steps in the research pipeline employed by the GCCRC: 1. Discovery: new genes and microorganisms are identified and suggested to be introduced into the pipeline; 2. Proof of concept: gene constructions and microbial inoculants are prepared, transgenic and edited plants are generated and the first tests, under controlled environmental conditions, such as growth chambers and greenhouses and to a lesser scale on the field, are carried out for initial observation of the effectiveness of strategies; 3. Large-scale breeding and testing: genes and inoculums discovered and selected in the previous steps are tested in larger-scale field experiments, in various locations and years. Promising transgenic genes and events are introduced in elite strains of corn; 4. Pre-launch: commercial cultivars containing GCCRC technologies are developed; and 5. Launch: the technologies developed by the center are launched to the agricultural market.

RESULTS

The GCCRC built a modern infrastructure to meet the demands of the pipeline, with new greenhouses and laboratories for plant transformation, bioinformatics, and phenotyping. The center's first scientific and technological results are already being achieved. Unexplored and unknown genes associated with responses to abiotic stresses have been discovered and the first are in the proof of concept phase for corn and being tested in the field for sugarcane. The team has already mastered the gene editing technology in corn and edited plants are being generated continuously. Synthetic microbial communities composed of beneficial microorganisms that increase corn yield in stressful conditions have been discovered and tested under controlled conditions and in the field.

NEXT STEPS AND RECOMMENDATIONS

The GCCRC uses the corn crop as a research target, but the technologies developed could potentially be transferred to other agricultural crops.

Recent efforts in the sequencing and assembly of the genome and microbiome of plants in the rupestrian fields open a new path to be explored in search of new genes and microorganisms adapted to hydric and nutritionally limiting environments. Following the pipeline rationale, new genes and microorganisms are continually being discovered and tested by the center.

DATA PUBLISHED IN:

ARMANHI. J. S. L.; SOUZA. R. S. C. de; DAMASCENO. N. B.; ARAÚJO. L. M. de.; IMPERIAL. J.; ARRUDA. P. A. Community-based culture collection for targeting novel plant growth-promoting bacteria from the sugarcane microbiome. *Frontiers in Plant Science*. v. 8. p. 1-17. Jan. 2018.

BARRETO. P.; YASSITEPE. J. E. C. T.; WILSON. Z. A.; ARRUDA. P. Mitochondrial uncoupling protein 1 overexpression increases yield in *Nicotiana tabacum* under drought stress by improving source and sink metabolism. *Frontiers in Plant Science*. v. 8. p. 1-20. Nov. 2017.

CAMARGO. A. P.; SOUZA. R. S. C. de; COSTA. P. de B.; GERHARDT. I. R.; DANTE. R. A.; TEODORO. G. S.; ABRAHÃO. A.; LAMBERS. H.; CARAZZOLLE. M. F.; HUNTEMANN. M.; CLUM. A.; FOSTER. B.; FOSTER. B.; ROUX. S.; PALANIAPPAN. K.; VARGHESE. N.; MUKHERJEE. S.; REDDY. T. B. K.; DAUM. C.; COPELAND. A.; CHENM. U. M. A.; IVANOVA. N. N.; KYRPIDES. N. C.; PENNACCHIO. C.; ELOE-FADROSH. E. A.; ARRUDA. P.; OLIVEIRA. R. S. Microbiomes of Velloziaceae from phosphorus-impoverished soils of the campos rupestres. a biodiversity hotspot. *Scientific Data*. v. 6. n. 1. p. 1-11. July 2019.

SOUZA. R. S. C.; ARMANHI. J. S. L.; DAMASCENO. N. B.; IMPERIAL. J.; ARRUDA. P. Genome sequences of a plant beneficial synthetic bacterial community reveal genetic features for successful plant colonization. *Frontiers in Microbiology*. v. 10. p. 1-18. Aug. 2019.

REFERENCES:

ALSTON. J. M.; BEDDOW. J. M.; PARDEY. P. G. Agricultural research, productivity, and food prices in the long run. *Science*. v. 325. n. 5945. p. 1209-1210. Sep. 2009.

BRENNAN. B. Bayer-Monsanto could create three crop-chemicals giants: chart. *Bloomberg*. 19 May 2016. Disponível em: <https://www.bloomberg.com/news/articles/2016-05-19/bayer-monsanto-could-create-three-crop-chemicals-giants-chart>. Acesso em: 16 jan. 2020.

ETC GROUP. Mega-mergers in the global agricultural inputs sector: threats to food security & climate resilience. ETC Group. 10 Oct. 2015. Disponível em: <https://www.etcgroup.org/content/mega-mergers-global-agricultural-inputs-sector>. Acesso em: 16 jan. 2020.

Continued in Annex

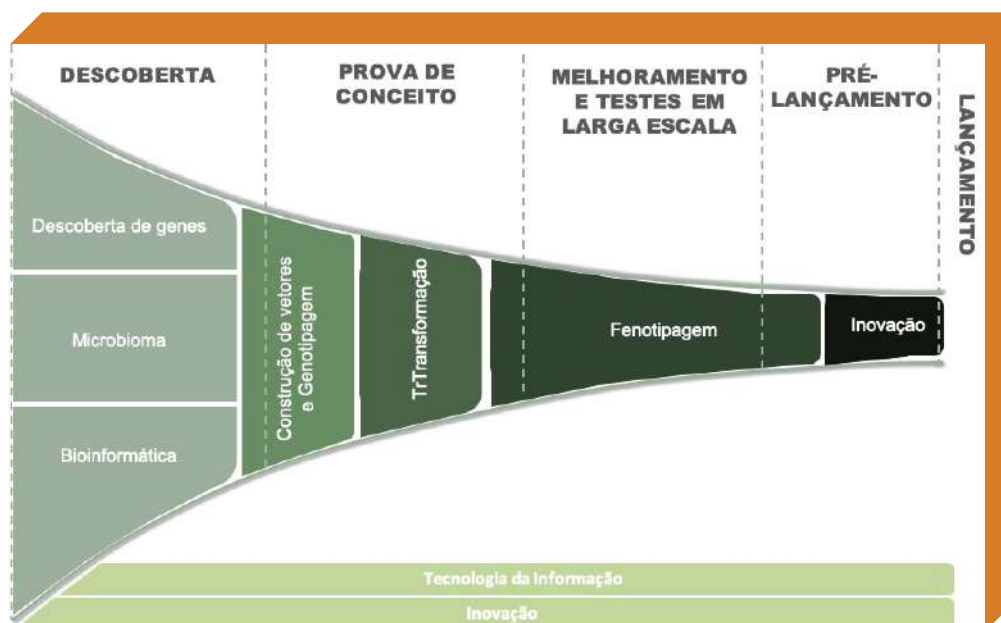
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Figure 1: GCCRC R&D Pipeline



Source: Authors.

2

**INFRASTRUCTURE
PRODUCTION TECHNOLOGIES
AND EQUIPMENT**

Crédit: Divaney Mamédio dos Santos



Infrastructure strategy, production technologies and agricultural equipment for adapting Brazilian agriculture to climate change

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Chapter 2 of this compilation adopts an operationally focused approach, with various projects that propose implementing adaptation actions locally and directly in the field. These proposals include proposals to build physical structures and management and production techniques and different types of equipment, although they were not initially proposed as solutions or alternatives in view of the impacts of climate change on agriculture. However, beyond the most intuitive adaptation measures, such as genetic improvement and irrigation, this chapter opens a broader discussion of actions that go from specific local management to actions to be adopted by farmers “within farms”, including structural actions that are or may be part of national policies and programs. From analyzing the three components of this chapter, it is intuitive to associate the adoption of management and production technologies and equipment with more “within the farm” tangible actions, and on the other hand, to associate strategic and infrastructure actions as more effective and efficient if approached in integrated ways and incorporated into regional and national programs and policies, however that is not our intention.

On the contrary, this chapter emphasizes the complementarity of approaches, recognizing not only the evident and more tangible actions implemented in the field as actions that promote adaptation, but also the efforts to organize information, research, development, and innovation, increase the adaptive capacity and resilience and, consequently, socio-economic-environmental, and even institutional sustainability. This is the case even if at first glance, they are not explicitly explained as such.

With this focus, the components of this chapter should collaborate for the development of an adaptation strategy that is based on the best set of information and knowledge available, and its effectiveness will depend on the implementation and infrastructure capable of ensuring its continuity over time, and a constant review and improvement process, with planned investments in science and technology. Much can still be developed and perfected regarding this in Brazil and in developing countries and, in terms of extreme events, probably in the developed world as well.

More objectively, in this more comprehensive approach to infrastructure, technologies and adaptation equipment, some main aspects to be considered are:

- Basic environmental information systems with currently used technologies and new technological options that promote resilience and adaptation to the negative impacts of climate change;

- Advancement of knowledge and scientific and technological development to improve knowledge production systems, using a broad definition of information management and universal access to knowledge, developed or adapted, as an innovative product per se;
- Projections of future scenarios integrating the various aspects of agricultural production systems sustainability (social, economic, environmental and institutional) to subsidize decision making on which scenarios to aim for and ways to achieve them, in terms of organization and information management, knowledge progression and the modeling of these systems;
- Models or new elements of rural development that include innovation and transfer of new technological options that promote resilience, adaptation, and sustainability against harmful effects of climate change; and
- Public policies, which are already part of the Plan for Low Carbon Emission Agriculture (ABC Plan), the National Adaptation Plan (PNA) and the National Policy on Climate Change (NPCC).

These aspects will be referenced whenever possible while assessing the studies presented in this compilation.

Given the various action options and local scale up the needs and specificities for the regional and national scope of public policies associated with this chapter in relation to listed fields, a well-defined methodological approach was not identified. However, it aggregates studies that collaborate to the country's evolution regarding these aspects.

Thus, some of the studies focused on identifying solutions for the most vulnerable national region and probably the one with the lowest adaptive capacity, the Semi-Arid. These studies are replicable technological solutions with some adaptation to the entire scope of the biome and even to the driest regions of the Cerrado. In general, they focus on living with drought, proposing better storage and using less available water mainly through cisterns, wells, and underground dams. One of the studies focuses on using biotreatments in aquaculture, using production management technology as a way of adaptation of to increased eutrophication caused by the increased water temperatures. This study also addresses economic aspects, quantifying economic benefits promoted by technology and social aspects related to basic sanitation, involving the various aspects of sustainability and its relationship with climate change. Social technologies were also proposed and should be simple, replicable and developed in integration with the local community with the aim of solving their problems. In addition, social actions are proposed to integrate agroecological techniques in the family farming environment to increase their resilience and reduce vulnerability, by promoting more appropriate techniques for soil management, incorporation of organic matter, biochar and inoculants, as well as the monitoring factors of production, and improving Farmer's decision making, production and income.

In another aspect regarding technology, there are studies scattered throughout the country with a focus on soil recovery and conservation management, covering techniques such as recovering gullies and using biochar and other techniques for accumulating carbon in the soil, such as no-till, crop rotation and crop-livestock-forest integration. Although some of these techniques are mitigating, adequate soil management and carbon accumulation improve soil fertility and water storage capacity, boosting adaptation or reducing these systems' vulnerability to climate change impacts. Some of these studies also address sustainable intensification through these techniques and analyze their economic and social improvements.

Conservation and adaptive management also comprises another set of studies focusing on the sustainability of livestock activities. In the Pantanal, management is associated with degradation and plagued native pastures, from using exotic species and flooding. In the Amazon, management focuses on reforming degraded pastures with no-till techniques. In the state of Rio de Janeiro, management includes a diverse set of techniques in the integrated management of micro-basins, incorporating the training of small farmers and producers, participatory research and social cohesion, focusing on reducing vulnerability and increasing resilience in the face of extreme events.

The last set of studies has as an integrated approach to information and knowledge management, a large part of which is incorporated to computerized support systems for decision making, ranging from farm level to state and national public policies. Several of the studies already commented on in the other groups or fields also incorporate information management and decision-making tools. One of the studies illustrates a tool that, when well suited to the domain being assessed, enables textual data mining and the selection of articles that best relate to a region, crop, biome, etc. thus speeding up the search for technological solutions for adapting to the impacts of climate change as well as more efficiently directing research.

Studies focused on Agricultural Climate Risk Zoning (ZARC) and Agroecological Zoning (ZAEs), integrated to state or national policies, are powerful tools to support public management, since they identify more vulnerable regions, and suggest the systems which are more adapted to regional climatic conditions and act as technological and good practice inducers, especially when integrated with a credit and/or agricultural insurance system. As a result, they increase systems' technical and economic efficiency through collaboration to increase farmers' productivity, income and the social conditions through adaptation and sustainability of their production environment. In the studies focused on simulating future agricultural scenarios, the approach is based on feeding the models applied in the zoning, with future climatic scenarios generated by global and regional atmospheric circulation models, enabling trend analyses of projected climate changes climate change impacts on pests, diseases, weeds and crop vulnerability. Through them, actions can be anticipated to increase the resilience and adaptive capacity of agricultural systems.

The sets of studies that contributed to subsidize the discussion of the theme related to adaptation to climate change are a small sample of a much larger universe of efforts in this regard and, obviously, can - and probably should - be frequently updated to keep track of the subject's evolution to direct actions in a more planned and effective way.

Based on this sample of studies, and knowledge from a slightly larger, but not exhaustive, universe, we can infer that most of them focus on solving local problems or applying techniques and locally adaptable technologies, which is a very positive point. There is also a reasonable amount of work focused on information management for decision making at various spatial scales, another positive point. The diversity of approaches for the different regions of the country, that are careful to respect their specificities, is yet another positive aspect.

This diversity of regions and specific situations, on the other hand, is also one of the greatest challenges, both for producers and for institutions focused on the subject, especially when associated with the diversity of technological options already established or at the frontier of science. We also can observe that infrastructures and even agricultural equipment used as tools for adaptation were not well covered in this sample of studies, with the exception of information management tools and software. Mechanization techniques, precision agriculture and other forms of management, and using drones and UAVs, internet of things in the field, massive data assessment and metadata are tools which still haven't been covered in depth.

This wide range of techniques, regions and situations increases the challenge of adaptation through infrastructure, technologies and equipment in a continental country like Brazil,

requiring capillarity to ensure the adequate diffusion of these technologies. Conducting this process in a positive and well-planned manner, transforming these apparent difficulties into competitive advantages, certainly depends on increased public adaptation policies, in its various spheres, far beyond what the ABC Plan covers today. Although partially covered by public policies, they are not usually associated with and does not aim primarily at adaptation, or the National Adaptation Plan. The National Policy on Climate Change in the agricultural sector and in other sectors is still almost exclusively focused on mitigating emissions, and this needs to change. Especially in the agricultural sector, it needs to focus on adaptation in a more serious and structured way, under the risk that, by focusing too much on reducing emissions, we threaten the sector's sustainability and national food security.

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RECOVERING GULLIES IN RURAL AREAS

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Land degradation is underdiscussed in the country. The large area available for agriculture and low adoption of soil conservation practices during agricultural and livestock production process are important starting points for understanding this issue. Reducing vegetation that covers the soil, the existence of soils that are sensitive to erosive processes, favorable terrain and inadequate agricultural practices can cause intense erosive processes, such as gullies. Gullies are big “tears” in the land that make agricultural production unfeasible and contribute to the silting of lakes and rivers.

In a scenario of climate change, extreme events tend to be more frequent. Prolonged drought or torrential rains will tend to occur more often and increase soil exposure to erosion. The direct consequence may be an increase in the number and impact of gullies on our water resources.

To illustrate the size of the problem, a mapping of the Barra Mansa river basin, located in the south of the state of Rio de Janeiro, mapped out 154 gullies (Table 1 and figure 1). Some with over 7,000 m² in area and 45m in depth. On average, the gullies were about 1,500 m² and 10 m deep. This river is a tributary of the Paraíba do Sul River, responsible for the water supply of almost 10 million people, in the state of Rio de Janeiro alone. These 154 gullies totaled the equivalent of 230,000 lost soil trucks that now silt lakes, rivers and the dams that supply the state. Thus, in order to adapt to climate changes, we urgently need to start a gully prevention program, as this problem will only worsen if nothing is done.

Since 2000, Embrapa, through a partnership between its Agrobiologia and Soil Units and the Federal Institute of Rio de Janeiro - Campus Pinheiral, started activities to reverse this process of extreme degradation. The technique is based on ordering water above the gully insertion point, on the construction of palisades within the gully drainage line and on revegetation with plants adapted to this situation of extreme degradation. For this purpose, legume species are used, inoculated with micro-rhizorrheal fungi and bacteria capable of fixating nitrogen in the air and making it available to plants. This enables a plant to be more efficient in obtaining water and nutrients from the soil.

In the first year, the production of sediments is reduced by more than 90%, as a result of the stabilization of the gully. With the development of plants, nucleuses of native vegetation are created, from the growth of planted seedlings. On average, R\$10.00/m² of gully is spent for its stabilization, including fencing and revegetation in and around the gully.

This technique is recommended for rural areas, where there are no residences nearby, considering that in situations where there are risks to human life, more sophisticated engineering practices that allow for more control of the processes are recommended.

Embrapa and CNPq were the project supporters. However, it is believed that river basin committees and water and energy supply companies are primarily interested in implementing gully prevention programs. The technique exists and works but needs to be scaled up.

RESULTS

- Stabilization of gullies, with a reduction of about 90% of the sediment produced in the first year;
- Three years after the implementation of the technique, the landscape effect of the vegetation can already be noticed;
- Six years after the implantation, the area is already colonized by other plant species and some animals, functioning as a nucleus that propagates vegetation and works as a refuge for fauna.

NEXT STEPS AND RECOMENDATIONS

The technology is ready to be applied on a large scale and should be part of official government and water and energy companies' programs, aiming to reduce the impact of climate change on accelerating erosion processes.

DATA PUBLISHED IN:

MACHADO. R. L.; RESENDE. A. S.; CAMPELLO. E. F. C.; MENEZES. C. E. G.; SOUZA. C. M.; FRANCO. A. A. Recuperação de voçorocas em áreas rurais. Seropédica: Embrapa Agrobiologia. 2006. 63 p. (Sistemas de Produção 4).

RESENDE. A. S. de; MACHADO. R. L.; CAMPELLO. E. F. C.; OLIVEIRA J.A.; FRANCO. A. A.. Soil and nutrient losses in erosion gullies at different degrees of restoration. Revista Brasileira de Ciência do Solo. v. 34. p. 945-954. 2010.

SILVA. G.T.A. Voçorocas no médio Paraíba: Padrões de ocorrência e potenciais impactos. 2013. Dissertação (Mestrado em Ciências Ambientais e Florestais) - Universidade Federal Rural do Rio de Janeiro.

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Table 1: Gullies in the Barra Mansa river basin, south of the state of Rio de Janeiro, by area class

Area class (m ²)	Nº. of gullies	Average area (m ²) and standard
< 100	1	52 ± 0
100-500	38	285 ± 126
500-1000	44	715 ± 148
1.000-1.500	21	1.213 ± 150
1.500-2.000	14	1.777 ± 152
2.000-3.000	15	2.421 ± 272
3.000-4.000	5	3.831 ± 81
4.000-5.000	7	4.390 ± 168
5.000-10.000	9	6.896 ± 1476
Total	154	1565

Source: adapted from Silva (2018).

Figure 1: Satellite image two years after the intervention (2002) and 19 years after the intervention (2019)



Note: It is noted that, in 2019, it is practically impossible to see the gullies (circled area). Pinheiral, RJ.

Source: Google Earth

NO-TILLAGE FOR PASTURE RENOVATION IN THE AMAZON

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Productive and well-managed pastures, besides ensuring the profitability of livestock activities, protect the soil against erosion and compaction, maintain their biological activity and increase the levels of organic matter and carbon in the soil.

Pasture degradation is a persistent problem in Brazilian livestock and will only be solved when the rate of recovery and reform exceeds the rate of degradation. Traditionally, degraded pastures are improved by planting forage in soil prepared with plows and harrows. However, this process increases the vulnerability of the soil to erosion, especially in areas with fragile soils or in sloping terrain. In the Amazon, due to the rainy climate, this risk is even greater, impairing future pasture productivity.

No-tillage can be a solution to this problem. However, in Brazil, despite the development of this technology having evolved greatly in agriculture since the 1990s (DENARDIN et al., 2008), there has still been little researched regarding its use in improving pastures.

In 2011, Embrapa Acre, together with CNPq as funder and the Research Support Foundation of the State of Acre (FAPAC), began developing no-till techniques for renovating degraded pastures in the Amazon (Table 1). Together with rural producers, three modalities of no-till planting were developed for pastures: broadcast seeding, row seeding, and no-till planting of stolons. These practices began being disseminated in 2014 through technical publications, lectures, field days and courses held in Acre, Amazonas, Rondônia and Mato Grosso. Adoption has been growing, according to reports from trained technicians and ranchers.

and increasing the seeding rate to compensate for the lower efficiency of seedling emergence;

- Sequential desiccation, with two applications of the herbicide glyphosate (30-40 days and 5-7 days before seeding), has been shown to be very efficient in reducing the volume of straw and increasing the efficiency of weed control;
- Broadcast seeding is suggested when there is no line seeder or when its operation is impossible, such as in sloping areas or on rocky soil. Demands higher seeding rate to compensate for lower seedling emergence efficiency. It has been adopted by small and larger producers. Small producers desiccate vegetation using backpack sprayers and Personal Protective Equipment (PPE) kit and manually distribute the seeds and fertilizers over the straw. Large farms seed the grass using agricultural planes;
- The main plus of directly planting seedlings is it saves time and money with soil preparation operations and demands less seedlings while offering better traffic conditions in the area on rainy days. The reduction in tractor operations reaches 36% when compared to the traditional method, in which the seedlings are spread over the previously harrowed ground and subsequently buried with a leveling harrow and a roller-compactor; and
- In direct seeding, the reduction of mechanized operations is even greater: 58% in no-till row seeding and 74% in no-till broadcast seeding.

RESULTS

- In no-till, excess straw makes sowing difficult and impairs the establishment of forages, which have small seeds and more fragile seedlings than agricultural crops (MASTERS et al., 2004). This was solved by previously managing the vegetation and adjusting the desiccation technique to reduce the volume of straw,

NEXT STEPS AND RECOMMENDATIONS

- The challenge now is to make these techniques more visible and to reduce farmer's perception of risk;
- "In Brazil, there is a limited number of models of row seeders configured for no-till pasture renovation. In addition, the performance of some models is still poor.
- No-till planting of stolons represents an improvement over traditional methods, but there is still a lot of room for improvement. The Brazilian agricultural machinery industry needs to explore better the immense potential of a sector that occupies 160 million hectares in the country, and which has been forced to use improvised implements for vegetative planting of pastures.

DATA PUBLISHED IN:

ANDRADE. C. M. S. de; ABREU. A. de Q.; ZANINETTI. R. A.; FARINATTI. L. H. E.; FERREIRA. A. S.; VALENTIM. J. F. Plantio direto a lanço dos capins Xaraés e Piatã no Acre. Rio Branco: Embrapa Acre. 2015. 13 p. (Comunicado técnico 188).

ANDRADE. C. M. S. de; FERREIRA. A. S.; ABREU. A. de Q.; SANTOS. D. M. dos. Técnicas de plantio direto. In: SIMPÓSIO DE PECUÁRIA INTEGRADA. 2.. 2016. Sinop. Anais [...]. Cuiabá: Fundação Uniselva. 2016. p. 54-92.

ANDRADE. C. M. S. de; SANTOS. D. M. dos; FERREIRA. A. S.; VALENTIM. J. F. Técnicas de plantio mecanizado de forrageiras estoloníferas por mudas. Rio Branco: Embrapa Acre. 2016. 22 p. (Circular técnica 72).

Continuação no Anexo

REFERENCES:

DENARDIN. J. E.; KOCHHANN. R. A.; BACALTCHUK. B.; SATTLE. A.; DENARDIN. N. D.; FAGANELLO. A.; WIETHÖLTER. S. Sistema Plantio Direto: fator de potencialidade da agricultura tropical brasileira. In: ALBUQUERQUE. A. C. S.; SILVA. A. G. (ed.). Agricultura tropical: quatro décadas de inovações tecnológicas, institucionais e políticas. Brasília: Embrapa Informação Tecnológica. 2008. v. 1. p. 1251-1273.

MASTERS. R. A.; MISLEVY. P.; MOSER. L. E.; RIVAS-PANTOJA. F. Stand establishment. In: MOSER. L. E.; BURSON. B. L.; SOLLENBERGER. L. E. (ed.) Warm-Season (C4) Grasses. Madison: ASA-CSSA-SSSA. 2004. p. 145-177 (Agronomy Monograph n. 42).

Table 1: Main positive and negative aspects of conventional and no-till pasture planting

Aspects	No-till	Conventional planting
Saves time, labor and fuel spent with mechanized operations	+	-
Requires less investment in herbicides, insecticides and nitrogen fertilizers	-	+
Allows greater flexibility in terms of planting time	+	-
Keeps the soil structured and firm, protected by straw, reducing the formation of mud during first grazing	+	-
Makes the ground more uniform for mechanized forage harvesting	-	+
Allows you to use the pasture that will be reformed during the dry season before renovation	+	-
Is less complex during the different stages of pasture renovation	-	+
Reduces problems with insects, mollusks and fungi	-	+
Buries the weed seeds that are on the surface of the soil	-	+
Allows greater erosion control	+	-
Maintains soil organic matter	+	-
Improves soil water availability for germination and seedling emergence	+	-
Is suitable for steep or rocky areas	+	-
Is suitable for pastures infested with woody weeds	-	+
Reduces atmospheric CO ₂ emissions	+	-

Source: Hampton et al. (1999); Leep et al. (2003); Ferreira et al. (2006); Hall e Vough (2007); Baker e Ritchie (2007); Andrade et al. (2015a); Andrade e Ferreira (2019).

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CONSERVATION MANAGEMENT EVALUATION ON THE ADAPTIVE CAPACITY OF AGRICULTURAL PRODUCTIVE SYSTEMS IN THE STATE OF RIO DE JANEIRO

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Strategies for adapting to and mitigating climate change can be complementary and generate economic and social benefits for the most vulnerable rural population. There are a number of soil and water conservation practices that contribute to increasing the resilience of agricultural systems in the face of extreme weather events and, at the same time, to increasing the carbon stock in the soil and consequently agricultural productivity. Changes in management practices in agricultural and forestry production systems, such as minimum cultivation, crop rotation, green manure, reduction of grazing pressure and suppression of deforestation, can increase agricultural productivity and its economic returns, which may contribute to food security and to reducing the vulnerability of the rural population. In the state of Rio de Janeiro where the majority of rural establishments have an area of less than 100 ha and in a current situation of intense degradation and susceptibility to erosion, the Rio Rural program operated from 2006 to 2018 providing financial incentives, training, participatory research, stimulating social cohesion and supporting the adoption of soil and water conservation practices aimed at increasing resilience and reducing the vulnerability of family farmers to extreme weather events (extreme rains in 2011 and drought in 2014). Embrapa Solos assessed the physical and chemical quality and the carbon stock of the soil in rural properties supported by Rio Rural. Areas with coffee, banana and persimmon plantations that received organic fertilization and/or green fertilization with legumes were evaluated; banana consortium areas with native tree species (SAF); and degraded pasture, recovered with rotational grazing. All areas were compared with reference areas (before and after interventions and/or Atlantic Forest areas) (Figure 1). The beneficial effect of conservation practices on soil quality has increased crop productivity and the resilience of agricultural systems in the face of extreme weather events. Reports from farmers during the drought that occurred in 2014 suggest that the adoption of such practices ensured water autonomy for a longer period than usual. This fact led to a 20% replication of practices through spontaneous adoption and using the farmers own resources without support from Rio Rural. Economic, social and environmental impact assessments carried out by Rio Rural corroborate that the environmental improvements were associated with gains in income and the elevation of the social capital, factors that will soon be integrated to the assessment of the adaptive capacity of rural communities.

RESULTS

- Organic fertilization and green fertilization have been associated with improved physical properties and soil fertility. There was an improvement in the aggregation, of the structured soil, less resistance to penetration, reducing soil compaction, favoring the development of roots and soil conservation, making the soils less susceptible to degradation, especially erosion;
- Rotational grazing favored the improvement of soil quality and the increase of the carbon stock up to 30 cm in depth and contributed to the increase and maintenance of pasture productivity. The increase in the carbon stock in the soil was directly related to the improvement of water retention, the cohesion of soil particles and the minimization of erosion. The carbon stock in a typical Red-Yellow Dystrophic Latosol in an area with (*Brachiaria brizantha*) pasture unmanaged during 20 years was lower than that found in the same area after paddocks were implanted for the establishment of rotational grazing in Varre-Sai, RJ; and
- For the same type of soil under the same physiographic conditions, monitoring data from the Rio Rural program indicated a reduction of 6 – 16 MgC ha⁻¹ in the soil carbon stock up to 30 cm under agricultural use in relation to soils under the remaining Atlantic Forest.

NEXT STEPS AND RECOMMENDATIONS

- There is a growing demand for simplified and low-cost methodologies for assessing the impacts of adopting sustainable management practices and for valuing sustainable agricultural systems. Researchers at Embrapa Solos in Rio de Janeiro are developing a tool to simplify the assessment of multiple ecosystem services promoted by sustainable agricultural systems. The tool adds a set of methodological protocols for simplifying the assessment of ecosystem services for erosion control, water supply and regulation, nutrient

cycling, carbon sequestration and maintenance of bee biodiversity in agroecosystems.

DATA PUBLISHED IN:**PROJECT COORDINATOR**

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AGUILAR. A. F.; MONTEIRO. J. M. G.; NEHREN. U.; ROBLEDI. M. A.; ALFONSO. S. P. Avaliação da viabilidade de implantação do mecanismo REDD+ no município de Cachoeiras de Macacu-RJ. Rio de Janeiro: Embrapa Solos. 2013. 45 p. (Boletim de Pesquisa e Desenvolvimento 231).

CAVALIN. M. O.; MONTEIRO. J. M. G. Boas práticas agrícolas no cultivo da banana na comunidade do Faraó. município de Cachoeiras de Macacu. estado do Rio de Janeiro. Rio de Janeiro: Embrapa Solos. 2012. 38 p. (Boletim de Pesquisa e Desenvolvimento 210).

CLEMENTE. E. de P.; OLIVEIRA. A. P. de; FONTANA. A.; MARTINS. A. L. da S.; SCHULER. A. E.; FIDALGO. E. C. C.; MONTEIRO. J. M. G. Erodibilidade dos solos da Região Serrana do Rio de Janeiro obtida por diferentes equações de predição indireta. Rio de Janeiro: Embrapa Solos. 2017. 52 p. (Boletim de Pesquisa e Desenvolvimento 262).

Continued in Annex

Figure 1: Cultivation of banana with trees, in the community of Faraó, in Cachoeiras de Macacu-RJ



Crédit: Joyce Monteiro.

CONSERVATION AND ADAPTIVE MANAGEMENT OF NATIVE PASTURES

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Native pastures occur all over the world and are extremely diverse, exhibiting spatial and temporal variability. In some regions of Brazil, such as the Pantanal wetlands, native pastures consist of the most valuable renewable natural resource, which has made these regions have a vocation for breeding cattle on pasture, the main production system in the region. In the region, the main determinant of the productivity of forage resources is precipitation and hydrology, which is governed by the flood pulse. There are long cycles of drought and flood that shape the landscapes and alter the botanical composition and the availability of forage, especially in the more humid areas, which in turn influence the pastures carrying capacity.

Objective: To understand the complexity and dynamics of native pastures in the face of climatic variations and to develop management strategies that ensure the sustainability of production systems.

The projects were outlined with a holistic view at the farm level of farms raising beef cattle in extensive systems in the Pantanal and plateau region (integrated to the Pantaneira plain). Associated with these studies, we seek the maintenance of germplasm banks of native forages, as well as domestic breeds locally adapted to forage resources and thermal stress for use on farm and future breeding programs.

To understand the ecosystems of native pastures, several methodologies have been used considering the spatiotemporal scales (Figure 1).

The evaluation of forage responses to different disturbances and climatic conditions has been made using the permanent plots methodology established by Biodiversity Research Program (Programa de Pesquisa em Biodiversidade – PPBio) and evaluated on the Fazenda Nhumirim since 2006, by using permanent grids. In Figure 2 there are pictures of the same area in years of extreme flood, extreme drought, and normal years. The data obtained is being evaluated by state and transition models, multivariate methods, development of decision-making systems (software) and precision technologies. Another methodology that has been used is the systemic evaluation of farms that use the FPS tool (Fazenda Pantaneira Sustentável),

based on sustainability indicators using fuzzy logic (SANTOS et al., 2017).

RESULTS

- Guide for identifying landscapes, pastures and forage species in the Pantanal;
- Tool to assess the sustainability of production systems on the Pantanal plains and on the plateau farms, including pasture aspect (SPF);
- Software to quantify ecosystem services of native pastures;
- Software to assess the quality of native pastures;
- Good management practices for native pastures;
- Determining flexible stocking rate for native pastures and multiple use in the Pantanal;
- Precision technologies for managing native pastures;
- Models that optimize using native and exotic forage resources to improve the efficiency of production systems; and
- Characterization of native forage species with potential for on farm management and future improvement.

NEXT STEPS AND RECOMMENDATIONS

With the implementation of the FPS program in the Pantanal, it will be possible to assess the degree of sustainability of pastures in the holistic context of the farm and to validate technologies and practices of adaptive management of native pastures. The Pantanal requires a diversity of forages that contribute to adaptive resilience, through the diversity of species and/or also functional diversity within species, that is, in some situations it is possible to work with a mixture of species/cultivars that meet the dynamics of facing current and future climatic variations. Therefore, farm conservation and management strategies will contribute to maintaining the variability of native forages, making evolution by natural selection (plasticity) possible in their natural environment. The maintenance of a key native forage germplasm bank in situ and ex situ (seeds) will also contribute to studying functional characteristics (phenotypic and agronomic

characteristics in response to environmental changes) and developing future breeding programs for the production of forages that are adapted to dynamic and complex environments such as the Pantanal.

DATA PUBLISHED IN:

SANTOS. S. A.; DESBIEZ. A.; CRISPIM. S. M. A.; COMASTRI FILHO. J. A.; ABREU. U. G. P.; RODELA. L. G. Natural and cultivated pastures and their use by cattle. In: JUNK. W. J.; DA SILVA. C. J.; NUNES DA CUNHA. C.; WANTZEN. K. M. (ed.). The Pantanal: ecology, biodiversity and sustainable management of a large neotropical seasonal wetland. Moscow: Pensoft Publisher. 2011. p. 327-353.

SANTOS. S. A.; DESBIEZ. A. L.; PEROTTO BALDIVIEZZO. H.; MAGALHÃES. J. A. Evaluating rangeland's grazing capacity for livestock and wild herbivores using Delta Diet tool and GIS technology. In: INTERNATIONAL GRASSLAND CONGRESS. 22.. 2013. Sidney. Australia. Proceedings [...]. Sidney: [S. n.]. 2013.

SANTOS. S. A.; POTT. A.; CARDOSO. E. L.; SALIS. S. M. de; VALLS. J. F. M.; GARCIA. J. B. Guia para identificação das pastagens nativas do Pantanal. Corumbá: Embrapa Pantanal. 2019. 218 p.

REFERENCES:

SANTOS. S. A.; LIMA. H. P. de; MASSRUHÁ. S. M. F. S.; ABREU. U. G. P. de; TOMAS. W. M.; SALIS. S. M. de; CARDOSO. E. L.; OLIVEIRA. M. D. de; SOARES. M. T. S.; SANTOS JÚNIOR. A.; OLIVEIRA. L. O. F. de; CALHEIROS. D. F.; CRISPIM. S. M. A.; SORIANO. B. M. A.; AMANCIO. C. O. da G.; NUNES. A. P.; PELLEGRIN. L. A. A fuzzy logic-based tool to assess beef cattle ranching sustainability in complex environmental systems. Journal of Environmental Management. v. 198. p. 95-106. Aug. 2017.

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Figure 1: Temporal dynamics of pasture landscapes and ecosystems in the Pantanal wetland



Crédit: Sandra Santos e Embrapa Pantanal

COMBATING CLIMATE CHANGE WITH SOCIAL TECHNOLOGIES APPLIED TO AGRICULTURAL SYSTEMS IN THE SEMI-ARID REGION OF BAHIA

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The research sought to understand which techniques, strategies and actions already adopted for surviving in the semiarid region in the state of Bahia are contributing to the fight against climate change. For this, the concept of Social Technologies (ST), understood as simple technologies, that are replicable and developed in interaction with local communities in order to solve socio-environmental problems in a given location (RTS, 2010), has become central.

Different STs already implemented in the Semiarid of Bahia were mapped. 68 different types of technology were mapped out. These were assessed to verify which of them used strategies that could be considered potential contributions to minimizing of climate changes. Twenty-seven STs were identified with these characteristics, most of them related to agricultural production. Among the examples of indicators sought in agriculture were:

- Use of water storage techniques;
- Adjustments in the period and variety of plantations;
- Crop rotation;
- Improvements in soil management and conservation;
- Promotion of energy efficiency in agricultural irrigation systems;
- Food processing for food security;
- Recovery of soils and degraded lands;
- Use of organic compounds/fertilizers;
- Dedication to crops with the energy potential to replace using fossil fuels;
- Reduced burning practices (VENTURA, 2013).

Subsequently, ten in-depth case studies were carried out, aiming to identify which of them were capable of, in addition to promoting the fight against climate change, also allow for sustainable and human development.

The study was carried out thanks to grants for doctoral studies funded by CAPES (Coordination for the Improvement of Higher Education Personnel).

RESULTS

As examples of STs with double potential for contribution, we identified:

- Integrated and Sustainable Agroecological Production (PAIS) (Figure 1): food production in an integrated agroecological system, using a drip irrigation system. Improvements in soil management and conservation; Reduction of fertilizers and energy intensity;
- Adapta Sertão: learning through action, for the development of new irrigation techniques, using saline waters. Among the techniques used: solar water pumps, special drip irrigation systems, adjustments to the period and variety of crops, reduction of fertilizers. Additionally, the food produced is processed and sold.
- Among the analyzed indicators, there are three that, to a greater or lesser degree of intensity, are present in all the analyzed STs: (I) "promotion of governance among social actors"; (II) "efficient use of natural resources"; and (III) "promoting economic sustainability". The indicators "employment and income generators" and "local economic development" were very expressive. The "achievement of endogenous development and technology transfer" and "promotion of food and nutritional security" also deserved a positive mention. However, a negative highlight was the limited presence of "capacity building".

Considering the need for agricultural production to be able to contribute to the resilience of communities, through mitigation, adaptation and sustainable and human development strategies, its main strengths were analyzed:

- Productive diversification compatible with local natural and water resources;
- Use of agroecology techniques;
- Articulation between organizations of at least two out of the three productive sectors (first, second and third sectors);

- Rescue/valuing local knowledge.
- Its main weaknesses were also analyzed:
- Absence of specific emphasis on strengthening community capacities to participate in decision-making processes linked to aspects of desertification and climate risks;
- Insufficient endogenous capacity to maintain the technology.

NEXT STEPS AND RECOMENDATIONS

The study is now complete. Based on the results identified, we can confirm the great potential that STs have to influence the fight against climate change in the Semiarid region of Bahia. Thus, we recommend:

- It be included in the strategies that will be adopted by the National Policy on Climate Change in Brazil, through the creation or revision of the sectoral mitigation plans, as well as the National Plan for Adaptation;
- Tap into international financing for the identification, systematization, strengthening and dissemination of agricultural ST to face climate change;
- Include ST as a new technological option to be incorporated in the carbon markets;
- Review of Science, Technology and Innovation policies aiming at greater integration between scientific and popular knowledge; and
- Expand political and technological capacities at the local level.

REFERENCES:

RTS – Rede de Tecnologia Social (Org.). Tecnologia social e desenvolvimento sustentável: contribuições da RTS para a formulação de uma política de Estado de ciência, tecnologia e Inovação. Brasília: Secretaria Executiva da Rede de Tecnologia Social (RTS). 2010.

VENTURA, A. C. Tecnologias sociais de convivência com o Semiárido baiano: estratégia para a governança global do clima. 2013. Tese (Doutorado em Administração) – Escola de Administração. Universidade Federal da Bahia. Salvador. 2013.

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DATA PUBLISHED IN:

FERNÁNDEZ, L.; VENTURA, A. C.; ANDRADE, J. C. S.; LUMBRERAS, J. Synergies and trade-offs between climate change mitigation and adaptation strategies: lessons from social technologies in the semiarid region of Bahia. Brazil. Latin America. Latin American Journal of Management for Sustainable Development. v. 3. p. 1-18. 2016.

VENTURA, A. C.; FERNÁNDEZ, L.; ANDRADE, J. C. S. O potencial das tecnologias sociais de convivência com o semiárido para a geração de sinergia entre mitigação e adaptação às mudanças climáticas: um caso ilustrativo. Revista Econômica do Nordeste. v. 50. p. 65-83. 2019.

VENTURA, A. C.; FERNÁNDEZ, L.; ANDRADE, J. C. S. Tecnologias sociais para enfrentamento às mudanças climáticas no semiárido: caracterização e contribuições. Revista Econômica do Nordeste. v. 44. p. 213. 2013.

Continued in Annex

Figure 1: Overview of the structure of Integrated and Sustainable Agroecological Production (PAIS)



Crédit: Fundação Banco do Brasil (2016).

BIOCHAR AS A SOIL CONDITIONER IN AGRICULTURAL SYSTEMS IN THE CERRADO

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This research work was carried out at the Capivara Farm of Embrapa Arroz e Feijão in Santo Antônio de Goiás, GO and at the Estrela do Sul Farm in the municipality of Nova Xavantina, MT. We tested the effects of incorporating biochar into the soil of upland rice and soybean production systems in the Cerrado. Here we refer to biochar as any type of material produced from carbonized vegetable waste in *pyrolysis*. *Pyrolysis* is seen as a promising approach to lowering the levels of CO₂ in the atmosphere, as it is a fast and controlled way of transforming biomass that is re-deposited on agricultural soils at a slower decomposition rate than organic matter in the soil (LEHMANN, 2007). Biochar characteristics such as recalcitrance, aromaticity and high specific surface make this material desirable as a soil conditioner, which can contribute to the lasting improvement of the chemical, physical-hydraulic and biological characteristics of the soil. This contribution can result over time through optimizing using fertilizers and attenuating or reversing soil degradation processes. In this sense, it is necessary to study the long-term effect of biochar on production systems. The biochar used in these studies was obtained from charcoal residue from eucalyptus planted forests produced by slow pyrolysis, at a temperature between 450-550 ° C, in the absence of oxygen. Vegetable charcoal residues are smaller than 8 mm. The biochar was ground to pass through a 2 mm sieve and incorporated only once in the 0-20 cm layer of Red Clay Oxisol (57% clay, 33% sand) in 2009, of sandy Plintisol (17% clay, 76% sand) in 2008, and of red yellow latosol frank sandy clay (31% clay, 67% sand) in 2006. In general, the total C content of the biochar varied between 50 and 77%, total N between 0.3 and 0.7%, pH (H₂O) between 7.6 and 7.9, K available between 780 and 3300 mg/kg, P available between 72 and 1000 mg/kg. The biochar is porous, rich in micropores $\leq 10 \mu\text{m}$ (Figure). The effect on soil properties and grain productivity was evaluated during the harvests, up to 5 years after the application of the biochar. In the Latosol and Plintisol we tested the doses of 8, 16 and 32 ton/ha of biochar. In the sandy clayey Oxisol we tested doses of 2, 4, 8 and 16 ton/ha. For all experiments, we included a reference, soil without biochar. The research was funded by Embrapa with support from CNPq, the Goiás Research Foundation, Federal University of Goiás, Mato Grosso State University and Wageningen University.

RESULTS

The organic OC in the Latosol increased at a rate of 0.25% for each ton of biochar applied 1.5 years after biochar application. In Plintisol the rate was 0.07% immediately and 1 year after application of the biochar. In the sandy clay Oxisol, the rate was 0.52% from 4 years after application of biochar. Crop rotation, present in integrated systems cultivated with soybean and brachiaria in the Latosol sandy clay and with upland rice followed by irrigated beans and millet in the Latosol, led to an increase in organic C in the soil over time. The soil C may have been physically protected in the biochar micropores and immobilized by microorganisms. In addition, the weathering of the biochar over time induces the activation and formation of phenolic and carboxylic groups adsorbed on the clay particles. On the contrary, on sandy soil in monoculture with upland rice, the effect of biochar on organic C increase was short-lived. However, the increase in total porosity with the application of biochar increased the water available to the plants by up to 4 mm in the 5-10 cm layer in the sandy soil. In sandy soil, upland rice productivity increased with the dose of biochar, especially in drier crops. An overview of the results of the studies conducted is shown in the table.

NEXT STEPS AND RECOMENDATIONS

Biochar can be used as a strategy to increase water available to plants in sandy soils, to contribute to the increase of organic C in clayey soils in the long term and to increase the pH of acidic soils. Improving soil quality positively affects crop productivity.

Biochar does not significantly increase the N₂O emission of nitrogen fertilizer applied to the soil

DATA PUBLISHED IN:

CARVALHO. M. T. de M.; MADARI. B. E.; BASTIAANS. L.; OORT. P. A. J. van; HEINEMANN. A. B.; SILVA. M. A. S. da; MAIA. A. de H. N.; MEINKE. H. Biochar improves fertility of a clay soil in the Brazilian savannah: short term effects and impact on rice yield. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*. v. 114. n. 2. p. 101-107. Dec. 2013.

CARVALHO. M. T. M.; MADARI. B. E.; BASTIAANS. L.; OORT. P. A. J. van; LEAL. W. G. O.; HEINEMANN. A. B.; SILVA. M. A. S. da; MAIA. A. de H. N.; PARSONS. D.; MEINKE. H. Properties of a clay soil from 1.5 to 3.5 years after biochar application and the impact on rice yield. *Geoderma*. v. 276. p. 7-18. Aug. 2016.

CARVALHO. M. T. de M.; MAIA. A. de H. N.; MADARI. B. E.; BASTIAANS. L.; OORT. P. A. J. van; HEINEMANN. A. B.; SILVA. M. A. S. da; PETTER. F. A.; MARIMON JUNIOR. B. H.; MEINKE. H. Biochar increases plant-available water in a sandy loam soil under an aerobic rice crop system. *Solid Earth*. v. 5. p. 939-952. Sep. 2014.

Continued in Annex

REFERENCES:

LEHMANN. J. Bioenergy in the black. *Frontiers Ecology and the Environment*. v. 5. n. 7. p. 381-387. Sep. 2007.

Carvalho. M. T. de M.; Madari. B. E.; Bastiaans. L.; Oort. P. A. J. van; Leal. W. G. de O.; Souza. D. M. de; Santos. R. C. dos; Matsushige. I.; Maia. A. de H. N.; Heinemann. A. B.; Meinke. H. Nitrogen availability, water-filled pore space, and N₂O-N fluxes after biochar application and nitrogen fertilization. *Pesquisa Agropecuária Brasileira*. v. 51. n. 9. p. 1203-1212. Set. 2016.

Petter. F. A.; de Lima. L. B.; Marimon Júnior. B. H.; Morais. L. A. de; Marimon. B. S. Impact of biochar on nitrous oxide emissions from upland rice. *Journal of Environmental Management*. v. 169. p. 27-33. 2016.

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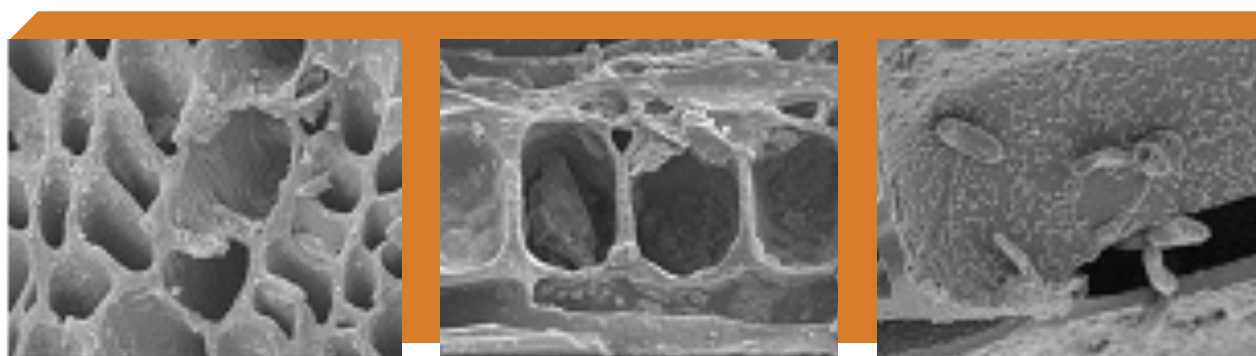
Table 1: Effects of using biochar as a soil conditioner on soil properties and grain yield during agricultural crops in a sandy and clayey soil in the Cerrado

	-----Plintosol-----		-----Latosol-----	
	Primeiras safras	Últimas safras	Primeiras safras	Últimas safras
Water holding capacity in the soil	?	↑	?	↓
Soil organic matter	↑	x	x	↑
Soil acidity	↓	↓	↓	↓
Grain productivity x x	↑	x	x	↓
N ₂ O emission	↑	x	x	x

↑ = INCREASED; ↓ = REDUCED; x == NO EFFECT; ? = NOT INVESTIGATED.

Source: Authors.

Figure 1: Electron microscopy image of micropore details of three types of charcoal biochar applied to clayey, sandy and sandy clayey soils



Source: Authors.

COVER CROPS AND GREEN MANURING FOR AGRICULTURAL ADAPTATION TO CLIMATE CHANGE AND REDUCTION OF GREENHOUSE GAS EMISSIONS IN THE CERRADO

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This scientific research aimed at identifying the best cover crops for surface mulching to favour soil carbon sequestration, pest control or nutrient cycling and the best manure crops for the supply of nitrogen to the cultivated plant (cotton, soy) in the Cerrado biome¹. Farmers, consultants, technical assistance and academics benefit from this information. Cover crops are usually grasses (eg. *Braquiaria ruziziensis*) used in crop rotation aiming at the formation of straw, essential for the maintenance of the Direct Tillage System or Crop Livestock Forest Integration (ICLF), fulfilling its role in helping crops adapt to the adverse impacts of the climate, especially high temperatures that have been worsening in the last years. Mulching results in protection of the soil surface against erosive rainfall, providing greater water infiltration and soil moisture retention, while enabling survival and better crop performance during summer dry spells. In addition, cover crops capture atmospheric carbon and nitrogen that are added to the soil on a large scale and quite efficiently. Green manures, usually legumes (eg. *crotalaria*), are plants that, in addition to producing a large mass of green matter and a deep root system, have the ability to fixate nitrogen through symbiosis with bacteria. This characteristic generates less use of nitrogenous mineral fertilizers for the subsequent crop (eg. corn, cotton, beans), benefiting the profitability of production and contributing both to the adaptation to climate change and to the reduction of greenhouse gas emissions, while preserving soil biodiversity. The project was financed by Embrapa, the Incentive Fund for the Cotton Chain in Goiás (FIALGO), the Fund for the Development of Cotton Agribusiness (FUNDEAGRO-Bahia), AGRISUS, CNPq and CAPES.

RESULTS

Brachiaria phytomass can exceed 10 t/ha of dry matter. Depending on the commercial crop and its cycle, dry mass values greater than 6 t/ha are sufficient to provide protection against high amplitudes of thermal variation in soils (SIDIRAS; PAVAN, 1986) and also against water erosion (ROTH et al., 1986; PORTELA et al., 2010), in addition to contributing to less weed infestation (OLIVEIRA JUNIOR et al., 2014). However, some cover crops, such as millet and pigeon pea, even producing up to 5 and 7 t/ha of dry matter, respectively, were not sufficient to control weeds prior to cotton planting under zero-till prior to direct sowing of cotton (FERREIRA et al., 2018).

The quantities of dry mass can exceed 11 t/ha for *Brachiaria brizantha* and capim colônião or *Panicum maximum* (FERREIRA et al., 2018). Due to their capacity for rooting at great depths, cover crops can mobilize nutrients from the deeper layers of the soil, making them available on the surface and favoring greater nutrition for crops in succession (MUZILLI, 1986; PACHECO et al., 2011), in addition to rationalizing nitrogen and potassium mineral fertilizer use, which have an energy and carbon footprint already purchased by producers (CARMO et al., 2016). The amount of nutrients that cover crops can mobilize depends on the desiccation time after sowing. *Brachiaria* intercropped or not with jack beans mobilized about 150 kg/ha of N and 120 kg/ha of K₂O during summer crop sowing. In addition to *brachiaria*, there are other crops that can be used as cover crops or green manures, as shown in Figure 1. It is very important to acquire high quality seeds for the production of a good amount of dry matter, in addition to preventing infestation of the area with weeds and phytopathogens. The selection of the cover plant to be used must also consider the existence of soil compaction, the presence of which type of nematode or the white mold infestation. Table 1 shows the recommendation for the quantities of seeds per hectare to be used for single cultivation in the Cerrado.

Figure 1: Options of cover crop species in the off-season of soybean and cotton between February and December in the Cerrado (from left to right: sunflower, sorghum, corn, *brachiaria*, pigeon pea, sun hemp, millet and fodder radish)



Source: Ferreira et al. (2012).

NEXT STEPS AND RECOMENDATIONS

This technology is already available and should be promoted and publicized in conjunction with the No-Till Systems and the ICLF in their different variations. The positive impact for the adaptation of agriculture to climate change associated with mitigation is quite evident and can be scaled to all Brazilian agriculture in its different dimensions.

DATA PUBLISHED IN:

CARMO. H. F. do; MADARI. B. E.; WANDER. A. E.; MOREIRA. F. R. B.; GONZAGA. A. C. de O.; SILVEIRA. P. M. da; SILVA. A. G.; SILVA. J. G. da; MACHADO. P. L. O. de A. Balanço energético e pegada de carbono nos sistemas de produção integrada e convencional de feijão comum irrigado. Pesquisa Agropecuária Brasileira. Brasília. v. 51. n. 9. p. 1069-1077. set. 2016.

FERREIRA. A. C. B.; BOGIANI. J. C.; SOFIATTI. V.; LAMAS. F. M. Sistemas de cultivo de plantas de cobertura para semeadura direta do algodoeiro. Campina Grande: Embrapa Algodão. 2016. (Comunicado Técnico 377). Disponível em: <http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1066067>. Acesso em: 05 jan. 2020.

FERREIRA. A. C. B.; BORIN. A. L. D. C.; LAMAS. F. M.; ASMUS. G. L.; MIRANDA. J. E.; BOGIANI. J. C.; SUASSUNA. N. D. Plantas que minimizam problemas do sistema de produção do algodoeiro no Cerrado. Campina Grande: Embrapa Algodão. 2012. 4 p. (Comunicado Técnico 371). Disponível em: <http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/943518>. Acesso em: 03 jan. 2020.

Continued in Annex

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Table 1: Quantity of seeds per hectare for single cultivation of cover crops in the off-season, between February and December

Espécie/cultivar	kg ha ⁻¹ de sementes com VC de 100% (*)	kg ha ⁻¹ de sementes com VC de 60%	kg ha ⁻¹ de sementes com VC de 40%
<i>Panicum maximum</i> Mombasa and Tanzania	2 - 3	3.3 - 5	5 - 7.5
<i>P. maximum</i> Aruana	2 - 4	3.3 - 6.7	5 - 10
<i>P. maximum</i> x <i>P. infestum</i> (Massai hybrid)	2 - 2.5	3.3 - 4.2	5 - 6.3
<i>Brachiaria ruziziensis</i>	2 - 4	3.3 - 6.7	5 - 10
<i>Brachiaria brizantha</i> Piatã, MG-5 (Xaraés) and MG-4 (Libertad)	3.5 - 5	5.8 - 8.3	8.8 - 12.5
Graniferous sorghum	10 - 15	16.7 - 25	25 - 37.5
Millet	10 - 12	16.7 - 20	25 - 30
<i>Crotalaria spectabilis</i>	8 - 12	13.3 - 20	20 - 30
<i>Crotalaria ochroleuca</i>	4 - 8	6.7 - 13.3	10 - 20
<i>Crotalaria juncea</i>	20 - 30	33.3 - 50	50 - 75
Cajanus cajan	20 - 30	33.3 - 50	50 - 75

Caption: (*) Amount of commercial seed to be used per hectare = [(amount of total pure germinated seed) x 100]/% quality of commercial seed (**)

(**) If the VC of the commercial seed is not provided, calculate it according to the following formula: VC = (% of germination x % of purity) / 100

Source: Ferreira et al. (2016)

SOIL CARBON IN INTEGRATED AGRICULTURAL PRODUCTION SYSTEMS IN THE CERRADO-AMAZON TRANSITION AREA

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The objective of this scientific research was to identify the origin and quantify C accumulation in the soil after 3.5 years of implantation of a crop-livestock-forest integration system (ICLF) in the transition region of the Cerrado and Amazon biomes. Recently, several studies have been conducted on the emission of Greenhouse Gases (GHG) in agriculture. Thus, systems such as the ICLF have been evaluated because they are considered promising both for greater efficiency in production and in the mitigation of GHG emissions and simultaneous accumulation of carbon both in the soil and in plant biomass. Two areas under ICLF (ICLF1 and ICLF3) were selected, systems with one row and three rows of *Eucalyptus urograndis* per row, respectively, an area under pasture and a forest in the municipality of Nova Canaã do Norte, Mato Grosso (Figure 1). The soil was dystrophic Red-Yellow Latosol, clayey. The area, cultivated since 1998, was converted to the ICLF system in 2009. Soil samples were taken at eight depths up to 1 meter. In the areas under ICLF, sampling was carried out in the area under the trees influence, in the pasture and in the transition zone; considering points in the tree lines and points away from them having them as a reference of distance. In the reference areas (pasture and forest), samples were collected in a cross section, at points approximately 50 m away from each other. The analysis of C stocks in the soil was performed for the 0.0-0.3 and 0.0-1.0 m layers.

An important observation in this study was the presence of trees in the system that, in just 3.5 years, favored accumulations of more than 20 t/ha of total organic soil carbon (COS) in the soil layer of up to 1 m, especially in areas with 3-row eucalyptus tree rows (Table 1). It is very common to see a significant accumulation only after 5 years under a certain type of management.

Compared to the area under pasture with 110.66 t/ha of COS in the 1 m deep layer, although the area under ICLF1 did not show any significant difference, the area under ICLF3 showed a positive balance of COS with 128.34 t/ha. The additional 17.68 Mg C ha⁻¹ in ICLF3 meant an annual accumulation rate of 5.05 Mg C ha⁻¹ between the pasture and the ICLF system. A possible cause of the weak impact of ICLF1 on the carbon accumulation in the soil could be due to the low total N content in the area.

Considering a 1 m deep soil layer, the surface layer (0.3 m) contained 49% COS. In the topsoil, no significant differences were observed between ICLF and Pasture. We found a strong indication that the trees played an important role in the accumulation or preservation of the subsoil.

RESULTS

Our results suggested that, in the edaphoclimatic conditions of the study site, agricultural systems that include forest components may represent viable solutions for the accumulation of COS, even in the short term, if soil fertility restrictions are not present.

NEXT STEPS AND RECOMMENDATIONS

Due to the results obtained, ICLF should be promoted as a practice that contributes to the mitigation of climate change and promotes the adaptation of the production system to a scenario of environmental changes. Monitoring the evolution of these systems in regards to their C soil accumulation is recommended during longer periods, which will allow for assessing the evolution and stability of the benefits of the soil due to implementing this system in the field.

DATA PUBLISHED IN:

OLIVEIRA. J. M. O.; MADARI. B. E.; CARVALHO. M. T. M. How soil carbon and nutrient availability in an integrated crop-livestock-forest system are related? In: WORLD CONGRESS OF SOIL SCIENCE. 21. 2018. Rio de Janeiro. Resumos [...]. Rio de Janeiro: IUSS/SLCS/BSSS. 2018. p. 1.

OLIVEIRA. J. M. O.; MADARI. B. E.; CARVALHO. M. T. M.; ASSIS. P. C. R.; SILVEIRA. A. L. R.; LIMA. M. L.; WRUCK. F. J.; MEDEIROS. J. C.; MACHADO. P. L. O. A. Integrated farming systems for improving soil carbon balance in the southern Amazon of Brazil. *Regional Environmental Change*. v. 18. n. 1. p. 105-116. 2017.

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Table 1: Carbon stock, based on the equivalent density of the soil, for the 0.0-0.3 and 0.0-1.0 m layers, in a dystrophic Red-Yellow Latosol, cultivated in a crop-livestock integration system -forest and continuous pasture in Nova Canaã do Norte, Mato Grosso, Brazil.

Area	0.0-0.3		0.0-1.0	
Pasture	55.76		110.63	
ICLF1 ¹	57.49	NS	123.58	**
ICLF3 ²	61.53	**	128.34	*

¹Integrated crop-livestock-forest system with a line of eucalyptus per row (ICLF1); ²Integrated crop-livestock-forest system with three lines of eucalyptus per row. Values are weighted averages. ICLFS averages were compared to Pasture averages using the T test. * P = 0.05, ** p = 0.01, *** p = 0.0001, NS = non-significant difference.

Figure 1: Integrated crop-livestock-forest system with one eucalyptus line per row (a) with three eucalyptus lines per row (b), in a Dystrophic Red-Yellow Latosol, in Nova Canaã do Norte, Mato Grosso, Brazil

Crédit: Janaina Oliveira/Beata Madari.

WATER CISTERNS: A STRATEGY TO CAPTURE RAINWATER AND COMBAT VULNERABILITY TO CLIMATE IN THE BRAZILIAN SEMI-ARID REGION

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Research carried out in the late 1970s by Embrapa aimed to capture rainwater through cisterns, in order to meet the needs of human consumption and small animals, and to make up for part of the crop water deficiencies for family farmers in the Caatinga Biome.

The research on cisterns - an ancient technology, considered the construction costs of the predominant model (masonry) and the area of rural residences to capture the volume of water that a family needed (Figure 1). Thus, materials were evaluated for the construction of the tank and using coated soil as a solution to increase the water catchment area. This model became popularly known as the “cisterna calçadão” or “sidewalk cistern”.

In these studies, parameters for dimensioning the volume of water and catchment areas were defined, considering the number of people per family, the average consumption per person per day, the region’s rainfall and the period without rain.

RESULTS

The results obtained were favorable and the technology was incorporated into public policies of the Ministry of Social Development (MDS), currently the Special Secretariat for Social Development, linked to the Ministry of Citizenship, offering families 16 million liters of water through cisterns.

In 2005/2006, studies were carried out to assess the technical and social viability of the human consumption cistern. The results revealed its viability and suggested, the need for ministries (Education, Health and Infrastructure) to interact, in order to adapt the Program to the characteristics of the families and enable them to maintain water quality, especially regarding using physical barriers (BRITO *et al.*, 2007).

It was observed that, in general, rainwater meets the physical-chemical parameters. However, the biological tests showed that 55.3% of the analyzed samples were potable, according to the Conama indicators (BRITO *et al.* 2007). This demonstrates that cistern waters can be managed to make them suitable for household consumption.

The success of the ‘cisterns’ program made it possible to use rainwater for food production (animal and vegetable), and the sidewalk cistern was also implemented. In the context of animal production, for the climatic conditions of Petrolina-PE, and, starting from an available volume of 52 thousand liters of stored water, an average daily consumption of 4.0 L/ animal, for a period of 250 days, the cistern is capable of providing water for a herd of around 50 heads of goats or sheep, considering an average of 1.0 liters of water per week. This is possible as long as the water management is carried out carefully, without waste. With this regulated consumption, it is possible to promote better animal performance.

As for the plant production component, the experiences of Embrapa Semiárido show that a cistern with the capacity to store 52 thousand liters of water is capable of maintaining a productive orchard with 20 fruit trees of different species, considering up to 5, 8 and 12 liters of water, three times a week, in the rainy, intermediate and drier periods, respectively. While also maintaining vegetable production in up to two plots with a total area of 8 m², applying 8 mm sheets per day (BRITO, 2016; BRITO *et al.*, 2018).

Performing the recommended water management, experiments have shown that in 900m² up to 929.3 Kg of fruit were produced per year (lemon, sweetsop, acerola, pink and sword mango), in years of average historic (500 mm) rainfall. Acerola trees alone, produced 357.8 kg, so each family could consume up to 1.0 kg of acerola per day, in addition to the other cultivated species.

It should be noted that, as the water applied to the fruit trees does not meet their evapotranspiration demands, consequently, it cannot be called “full irrigation”, but “deficit irrigation”, just as one cannot expect to obtain the maximum potential of crop production. The focus of using water from cisterns in vegetable production is to allow families to include fruits and vegetables in their diets, considering their diets are primarily amino acid based (kassava, cuscuz, beans, corn, potatoes etc).

Finally, the implementation of these technologies should focus on aspects that integrate the plurality of locally generated knowledge with the diversity of the agricultural systems practiced. Considering natural limitations is also important.

The biggest challenge of the rainwater collection and storage system is the high consumption rate, in order to meet the family's needs. As for the animal component, it was observed that the number of animals per family is always much greater than the supply of food and water available to meet their needs.

The results of these projects counted on resources from the National Treasury, the National Council for Scientific and Technological Development (CNPq) and the Banco do Nordeste do Brasil (BNB).

REFERENCES:

BRITO. L. T. de L. Manejo da água da cisterna do pl+2: dez anos de resultados. In: SIMPÓSIO BRASILEIRO DE CAPTAÇÃO E MANEJO DE ÁGUA DE CHUVA. 10. 2016. Belém. Tema: Desbloquear o potencial de aproveitamento da água de chuva para o Brasil. Anais [...]. Belém: UFPA/ABCMAC. 2016.

BRITO. L. T. de L.; MEDEIROS. J. C. de A. (In memoriam); SILVEIRA. S. M. B.; ARAÚJO. J. O.; CAVALCANTI. N. de B. Captação e uso de água de chuva em cisternas: uma estratégia para convivência com o Semiárido brasileiro. In: XIMENES. L. F.; SILVA. M. S. L.; BRITO. L. T. de L. (ed.). Tecnologias de convivência com o Semiárido brasileiro. Fortaleza: Banco do Nordeste do Brasil. 2018. p. 185-218.

BRITO. L. T. de L.; SILVA. A. de S.; D'ALVA. O. A. Avaliação técnica do programa de cisternas no Semiárido brasileiro. In: VAITSMAN. J.; PAES-SOUSA. R. (org.). Avaliação de políticas e programas do MDS: resultados. Brasília: MDS/SAGI. 2007. v. 1. cap. 5. p. 197-234.

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Figure 1: Production cistern in an experimental area of Embrapa – Semiárido



Crédit: Fernanda Biolo.

UNDERGROUND DAMS: CONTRIBUTING TO CLIMATE CHANGE RESILIENCE OF FAMILY BASED AGRO-ECOSYSTEMS IN THE SEMI-ARID REGION OF NORTHEASTERN BRAZIL.

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The Brazilian semi-arid region in the Caatinga Biome is considered one of the most vulnerable to climatic variations due to irregular rainfall, water deficiency, low capacity for adaptation and the poverty of the population. Currently, there is a set of social water technologies for capturing and storing rainwater in order to make the most of it, which has been used throughout the Brazilian semiarid by public policy programs. The underground dam is one of these technologies and, due to its importance for families, it is the subject of research developed by Embrapa and partners, aiming to contribute to family-based farmers resilience to the challenging weather of the Brazilian Northeast Semiarid. This research, developed since the 1980s, has contributed to sharing the experiences of farmers, development agents and researchers, through the exchange of popular and technical-scientific knowledge. The underground dam is a hydraulic structure that aims to intercept rainwater, by constructing a wall inside the soil that crosscuts the waters descent. With the underground dam, families are overcoming the social and environmental limitations of the Brazilian semiarid region, using this technology to perfect and balance the production process (Figures 1 and 2), however, some challenges have been faced regarding what is the best place to implement the dam in rural communities. In order to overcome this challenge, Embrapa and partners are developing an edaphoclimatic Zoning project for potential areas for the construction of underground dams in the Alagoas Semiarid - ZonBarragem. Through the project, it was possible to identify and spatialize geoenvironments with the potential for implementing underground dams. Based on the map generated as a result of the project, the Government of the State of Alagoas launched the State Program for Underground Dams. Over three decades, research projects and structural action, is developed with partners such as state and federal universities, federal institutes (IFs), federal, state and municipal government institutions and programs, Brazilian Semi-Arid Articulation (ASA), Brazilian Institute for Development and Sustainability (IABS), Faeal/Senar-AL and Sebrae-AL systems. The projects have relied on financial support from Banco do Nordeste, CNPq, Banco do Brasil, Sudene, Petrobrás, the World Bank and BNDES. International technical cooperation has also been established with institutions in Switzerland, Honduras, Mozambique and Cape Verde.

RESULTS

- Contribution to family's food sovereignty and nutritional security;
- Increased access to and multiple uses of water;
- Diversification and integration, providing greater resilience and sustainability to family-based agro-ecosystems;
- Strengthening social inclusion and the productive organization of women and youth;
- Surplus is sold at local free markets;
- Creates a solidary space that is self-managed and farmer-led; and
- Is aligned with five of the 17 Sustainable Development Goals (SDGs) in the UN 2030 Agenda: 1, 2, 5, 6 and 13.

NEXT STEPS AND RECOMMENDATIONS

- Edaphoclimatic zoning of potential areas for the construction of underground dams in the semiarid states of northeastern Brazil;
- Diagnosis and assessment of the resilience, stability and sustainability of agroecosystems with an underground dam;
- Technical-economic feasibility study of appropriate crops in underground dam areas; and
- Training of farmers and technicians in the selection, construction, types, models and management of the underground dam.

DATA PUBLISHED IN:

SILVA. M. S. L. da; LIMA. A. de O.; MOREIRA. M. M; FERREIRA. G. B.; BARBOSA. A. G.; MELO. R. F. de; OLIVEIRA NETO. M. B. de. Barragem subterrânea. In: XIMENES. L. F.; SILVA. M. S. L. da; BRITO. L. T. de L. (Ed). Tecnologias de convivência com o Semiárido brasileiro. Fortaleza: Banco do Nordeste do Brasil. 2019. cap. 2. p. 223-281.

SILVA. M. S. L da; MARQUES. F. A.; NASCIMENTO. A. F.; LIMA. A. O.; OLIVEIRA NETO. M. B.; FERREIRA. G. B.; MELO. R. F.; ANJOS. J. B.; PARAHYBA. R. B. Barragem subterrânea: acesso e usos múltiplos da água no Semiárido brasileiro. Brasília. DF: Embrapa. Instituto Brasileiro de Desenvolvimento e Sustentabilidade; Agência Espanhola de Cooperação Internacional/ Programa Cisternas; Recife. PE: ASA Brasil. 2021. 41 p. (Cartilha)

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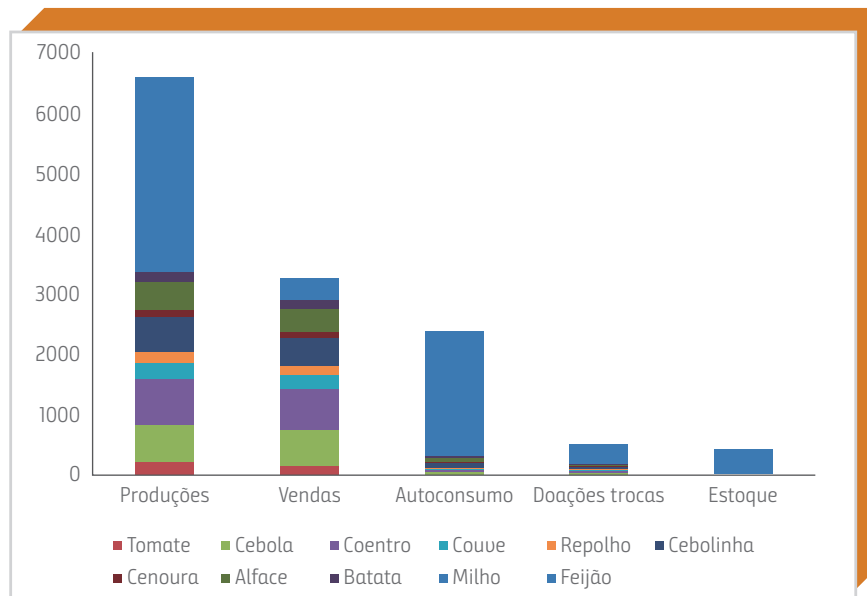
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Figure 1: Underground dam generating autonomy and dignity for families through food production.



Source: Maria Sonia Lopes da Silva.

Figure 2: Underground dam under construction and production



Crédit: Maria Sonia Lopes da Silva.

TECHNOLOGICAL ALTERNATIVES FOR HARVESTING RAINWATER TO INCREASE FOOD PRODUCTION AND INCOME THROUGH INCLUDING ANNUAL ENERGETIC CROPS IN THE FAMILY AGRO-ECOLOGICAL FARM SYSTEMS

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The underground dam is an impressive rainwater storage technology in the Brazilian semiarid region, that was disseminated in rural communities through the PI + 2 Program. In this region, rainfall irregularities compromise agricultural sustainability, a scenario which is aggravated by climate change. Research under these conditions can result in sustainable management recommendations for different water availability. In addition, using agroecological practices integrated with rainwater capture and storage technologies contributes to increasing the resilience of systems in the face of climate change (Figure 1). This Project aimed to reduce the risks of family farming systems in the Semi-Arid region through using integrated water technology in three conditions of rainfall. For this, nine underground dams were selected in producing areas, under three conditions of rainfall in the 250 to 350 mm ranges; 351 to 500 mm and 501 to 750 mm, in the states of Paraíba, Pernambuco and Bahia, respectively. The following actions were taken: implementation of soil tillage systems involving organic matter, charcoal and microorganisms, efficiency in using water; monitoring of water and soil characteristics; assessment of the potential of energy species; economic evaluation; use of supplementary irrigation. The source of the funds: Embrapa.

RESULTS

- The Project provided results related to the understanding of the productive system and training agents to multiply the knowledge. Among the results are:
- The characteristics of the soil are influenced by the management, and the quality of the organic matter varies according to the different environments;
- The quality of water in underground dams depends on management, because using chemical fertilizers in crops tends to increase the salt concentration in the water;
- Production systems in a consortium of cowpea, sunflower and sorghum in an underground dam are economically viable, and more productive when compared to single systems;
- Phytosanitary management in agroecological systems in underground dams they are controlled with the application of alternative products such as plant extract;
- The economic-ecological analysis of a family agroecosystem with the presence of an underground dam with water integration with a sidewalk cistern and a public dam contributed to the family's autonomy, food and nutritional security and monetary gains;
- Supplementary irrigation in orchards grown on underground dams is necessary for fruit production, requiring five liters of water three times a week in the period of summer;
- The cultivation of forage sorghum submitted to organic fertilization contributes to the colonization of N-fixing bacteria, which reduced the stresses caused by water deficits;
- The addition of three liters of manure as fertilizer in annual crops in agroecological systems contributes to increase crop productivity even in the smallest levels of rainfall;
- Training more than 500 family farming agents (farmers and technicians) on the selection, implementation and management of underground dams.

NEXT STEPS AND RECOMMENDATIONS

The execution of the Project made it possible to identify lines of research that need to be contemplated in new proposals so that agricultural systems are more resilient in the face of climate change. The following stand out:

- Integrating rainwater capture and storage technologies: the integration of technologies (cisterns, dams, underground dams, wells, weirs, in situ capture, etc.) is an alternative that allows the farmer to use various water resources to optimize food production during the year; and
- Gray water reuse: gray household water can be another source of water that favors the continuous production of food throughout the year, contributing to the family's food and nutritional security.

DATA PUBLISHED IN:

MELO. R. F. de; ANJOS. J. B. dos. Barragem subterrânea: alternativa de captação e armazenamento de água de chuva. Cadernos do Semiárido: Riquezas & Oportunidades. v. 11. n. 11. p. 27-31. mai./jun. 2017.

MELO. R. F. de; OLIVEIRA. A. R. de; SIMÕES. W. L.; SANTOS. M. L. de S. Desenvolvimento e produtividade do milho BRS Gorutuba sob diferentes lâminas de irrigação e adubação orgânica. Revista Científica Intelletto. v. 3. n. 1. p. 1-14. 2018.

OLIVEIRA. A. R.; MELO. R. F.; SANTOS. J. M. R. Sunflower consortium with cowpea productive performance in underground dam with irrigation supplementary. Journal of Engineering and Technology for Industrial Applications. v. 3. n. 10. p. 169-173. 2017.

SILVA. J. F. da; SILVA. T. R. da; ESCOBAR. I. E. C.; FRAIZ. A. C. R.; SANTOS. J. W. M. dos; NASCIMENTO. T. R. do; SANTOS. J. M. R. dos; PETERS. S. J. W.; MELO. R. F. de; SIGNOR. D.; FERNANDES JUNIOR. P. I. Screening of plant growth promotion ability among bacteria isolated from field-grown sorghum under different managements in Brazilian drylands. World Journal of Microbiology and Biotechnology. v. 34. n. 12. nov. 2018.

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Figure 1: Diversified crops in underground dam



Crédit: Roseli Freire de Melo.

DECISION MAKING SUPPORT SYSTEM FOR THE ADAPTATION AND COEXISTENCE OF EXTENSIVE LIVESTOCK FARMING IN THE DYNAMICS OF PANTANAL FLOODS AND DROUGHTS IN FACE OF CLIMATE CHANGE

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According to the Intergovernmental Panel on Climate Change, the extreme events that have been observed in recent decades and those predicted for the future are a consequence of climate change due to human activities. Regardless of the cause, be it climate change or natural climatic variability, extreme events eventually occur and cause societies to become concerned, due to the risk of loss of human life, property and economic losses. Measures for adapting to climate change are essential to minimize risks.

The Pantanal is an extensive sedimentary plain, with seasonal flooding and where extensive livestock farming is the main economic activity. Flood seasonality is a natural process in wetlands, it naturally fertilizes native pastures that occur in large areas in the Pantanal, being the basis of cattle feed. In regions that flood by overflowing rivers or those that flood directly because of rain, large areas of native pasture are submerged from time to time with critical depths and durations, and in extreme events, there may be a drastic reduction in the supply of food and even an increase of cattle mortality due to starvation or drowning. Over more than 200 years of coexisting with floods, management strategies such as the removal of cattle from low, floodable areas, to higher areas in the Pantanal or in the adjacent plateaus, allowed livestock to adapt to floods, being characterized as a very effective non-structural measure. In this context, the question that is asked every year is: what will the magnitude of the flood and flooded areas be and will the removal of cattle be necessary?

Because the Pantanal was considered an area of restricted use according to article 10 of the New Forest Code, structural measures to contain floods such as dikes and channels, are not recommended or are considered illegal, based on current legislation. Dykes, by changing the hydrological dynamics, can convert seasonally flooded environments into permanently flooded environments or generate water deficit, negatively impacting livestock and other system components. The channels drain the seasonally flooded areas, increasing the magnitude of drought events, which can generate water deficit in the soil, lowering the groundwater table, which then reduces the production of pastures, and can lead to losses in the areas.

severe and prolonged droughts. Therefore, coexisting with floods, based on non-structural measures, has been shown to be more effective and sustainable for Pantanal livestock and for the conservation of hydrological processes, biodiversity and distribution and abundance of native vegetation and wild fauna.

All these extrinsic and intrinsic factors point to the need for a decision-making system for adapting extensive livestock to floods and droughts in the Pantanal (Figure 1). The system will consist of three main components: 1 - Mapping and modeling the dynamics of flooding in the Pantanal using remote sensors, 2 - Flood risk modeling for the dissemination of an early warning system and 3 - Communication of flood alerts and flooded areas using Internet communication tools, in addition to media such as television and radio interviews.

RESULTS

- Flood alert system for the Pantanal rivers. Since 2013, we have been making forecast alerts on river levels available to the interested audiences. We are currently using statistical models of linear and non-linear regression with river level data in upstream and downstream stations, with a good margin of accuracy;
- Providing hydrometeorological information to all audiences from the Hydrological Information Portal for the Upper Paraguay-Pantanal basin on Facebook, since 2013;
- Interviews on television, radio and internet media, on the general aspects of each flood and flood event; and
- Preparing technical reports for the Civil Defense and Rural Unions in the event of above-average events.

NEXT STEPS AND RECOMMENDATIONS

We are developing and hope to achieve the following goals in the next two years:

- Improve current processing methods satellite images for flood detection and monitoring;

- Improve the current automation of processing large volumes of satellite imagery data in a computer cluster to accelerate the production of real time results;
- Evaluate new statistical methods for the treatment of time-stamped data of river flow and levels;
- Search for new precipitation data and other environmental variables, by satellite, on global and national data platforms; and
- Evaluate the Monitoring, Analysis and Alert Platform for Environmental Extremes - TerraMA to integrate environmental data, develop a model based on artificial intelligence to forecast floods and droughts in the Pantanal and make such information available to those interested on the internet and other communication platforms.

DATA PUBLISHED IN:

GEOHIDRO-PANTANAL (Brasil). Portal de informações hidrológicas da bacia do Alto Paraguai-Pantanal. Corumbá. MS. 01 jan. 2000. Facebook: geohidropantanal. Disponível em: <https://www.facebook.com/geohidropantanal>. Acesso em: 3 fev. 2020.

PADOVANI. C. R. Dinâmica espaço-temporal das inundações do Pantanal. 2010. Tese (Doutorado em Ecologia Aplicada) – Escola Superior de Agricultura “Luiz de Queiroz”. Centro de Energia Nuclear na Agricultura. Universidade de São Paulo. Piracicaba. 2010.

PADOVANI. C. R.; ESQUERDO. J. C. D. M.; ARAUJO. A. F.; ISHII. R. P.; MATSUBARA. E. T.; MINGOTI. R. Sistema de suporte à decisão frente às inundações do Pantanal. In: SEMINÁRIO DA REDE AGROHIDRO. 2016. Brasília-DF. Anais [...]. Planaltina: Embrapa Cerrados. 2016. p. 228-234.

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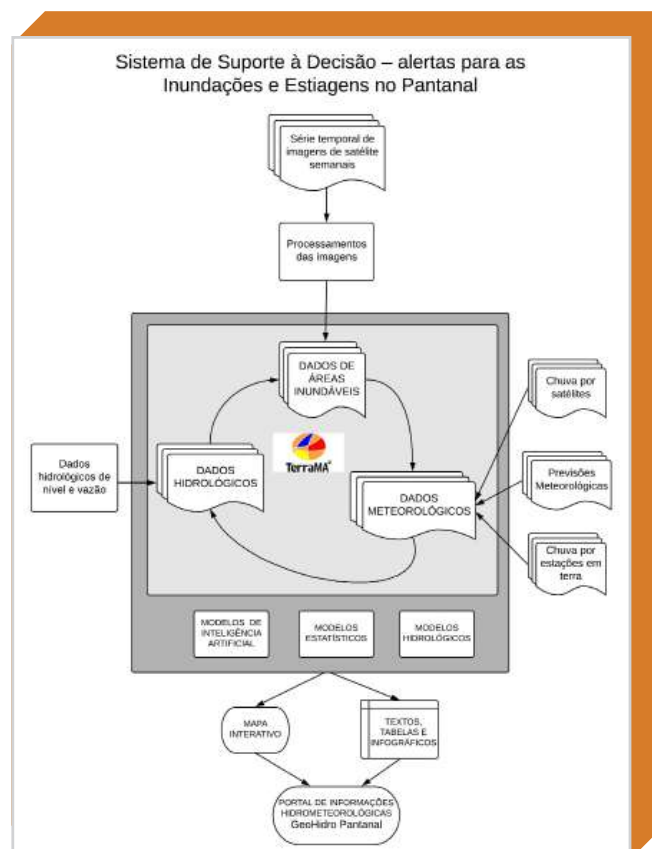
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Figure 1: Diagram of the compartments and processes of the Decision Support and Alert System for floods and drought in the Pantanal



Crédit: Carlos Padovani, Alex Araújo e Renato Ishii.

SUSTAINABILITY INDICATORS IN AGROECOSYSTEMS (ISA)

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In tropical regions, characterized by intense heat and heavy rains, systems with adequate productivity and resilience require permeable soils, with permanent and diversified vegetation cover and intense biological activity. Different soil management practices have been adopted in Brazil, however, there are some gaps for gauging the management of production systems and soil quality, as well as the integration of physical environment assessment with socioeconomic aspects, especially on the scale of the rural establishment, one of the main players in ensuring desired territorial management and development with a view to adapting to climate changes.

More integrated and diversified systems demand a higher degree of management complexity. For this, the producer will have to plan, reducing uncertainties, anticipating opportunities and challenges, and assessing his environmental and socioeconomic performance, allowing for more effective decision making in this dynamic context. Indicators can generate a diagnosis, as well as monitor possible transformations in progress, in addition to helping promote improvements in highly complex situations.

The system of Sustainability Indicators in Agroecosystems (ISA) was developed for this purpose (Figures 1 and 2). It consists of a questionnaire and several parameters that make up a set of 21 indicators, and aims to detect critical points, propose measures to correct the productive management that may be promoting negative impacts on the environment, and identify opportunities for generating income and practices aimed at adapting to climate change, such as joint actions for soil and water conservation, including revitalizing springs, adequate protection and management of aquifer recharge areas, and, in particular, providing better use of rainwater, from the maximization of the infiltration and, consequently, reduction of the runoff, ensuring that it remains on the land as long as possible. In this context we propose to equip rural producers, technicians, research and public managers, providing a new, more holistic vision and agenda.

Starting in 2008, a long journey of networking began, with the goal of elaborating and improving the ISA system. Since its institutionalization in the state of Minas Gerais, in 2012, the system was incorporated into the work of technical assistance and later expanded to other states.

RESULTS

- Training 750 technicians from Emater/MG and application of ISA in approximately 1,800 rural establishments;
- Application of ISA in approximately 700 rural establishments by SENAR/ ES;
- Forecast of application of ISA in approximately 400 rural establishments in the Rio Doce basin by Fundação Renova (2020); and
- Forecast of application of ISA in 4,000 rural establishments by SENAR in the FIP-Landscape project in the Cerrado Biome involving the states of MG, BA, MT, MS, RO, MA, GO and 10 hydrographic sub-basins (2020 to 2022).

NEXT STEPS AND RECOMMENDATIONS

- O sistema ISA é uma plataforma colaborativa. de domínio público. em processo de ampliação de parcerias. visando o aprimoramento contínuo do sistema;
- Indicadores relacionados à biologia do solo poderão ser integrados ao sistema. tendo como referência o trabalho de pesquisa da Embrapa. capitaneado pela pesquisadora leda de Carvalho Mendes. com as enzimas do solo Arilsulfatase e β -Glicosidase;
- Um dos fatores para prover maior resiliência aos sistemas de produção é uma adequada cobertura do solo durante o ano inteiro. O sensoriamento remoto com base em imagens de satélite pode também ser integrado ao ISA. permitindo monitorar a temperatura na superfície do solo. facilitando a avaliação e planejamento das estratégias para manter o solo coberto o ano inteiro; e
- Sistematização das informações das planilhas do ISA e elaboração de um menu de soluções técnicas disponíveis aos produtores rurais.

DATA PUBLISHED IN:

COSTA. A. M.; FERREIRA. J. M. L.; VIANA. J. H. M.; OLIVEIRA. A. R. Indicadores de Sustentabilidade em Agroecossistemas (ISA). In: CONGRESSO BRASILEIRO DE CIÊNCIA DO SOLO. 34.. 2013. Florianópolis. Anais [...]. Viçosa-MG: Sociedade Brasileira de Ciência do Solo. 2013. p. 1-4.

FERREIRA. J. M. L.; LOBO. L. M.; TEIXEIRA. H. M.; NOGUEIRA. R. S.; VELOSO. G. V.; VIANA. J. H. M. Avaliação da sustentabilidade de agroecossistemas agroecológicos e convencionais no município de Araçuaia. In: CONGRESSO BRASILEIRO DE AGROECOLOGIA. 7.. 2011. Fortaleza. Resumos[...]. Fortaleza: Cadernos de Agroecologia. 2011. v. 6. n. 2. dez. 2011.

FERREIRA. J. M. L.; MARTINS. M. R.; CABRAL. L. L. F. B.; TERRA. J. O. L. Gestão ambiental: o papel protagonista do produtor rural. Informe Agropecuário. Belo Horizonte. ed. especial. v. 35. p. 26-38. 2014.

Continued in Annex

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Figure 1: Set of ISA System Indicators.



Source: Authors.

Figura 2: Conservation management aiming to increase the resilience of production systems



Crédit: José Mário Lobo Ferreira.

FUTURE AGRICULTURAL SCENARIOS FOR PASTURES IN BRAZIL

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Livestock production plays an important environmental, economic and social role in Brazilian regions. Global climate change, environmental pressures, the expansion of agriculture and the need to produce energy from alternative sources indicate that there will continue to be a reduction in pasture areas in some regions, forcing their displacement to marginal areas, where there may be limitations of soil and climate to production.

The construction and analysis of future scenarios is strategic for Brazil, as it helps investors and public policy makers to make decisions and constitutes an important subsidy for livestock production planning, at the national, regional and local levels. The objective of the project was to generate and analyze future scenarios for livestock across the national territory, based on scenarios of global climate change and some of the main species used as cultivated pastures.

Cultivation scenarios for *Urochloa* pastures (*syn. brachiaria*) *brizantha* cv. Marandu (*brachiarão grass*, cv. Marandu) and cv. BRS Piatã (*BRS-Piatã-grass*), *Megathyrsus maximus* (*syn. Panicum maximum*) cv. Tanzania (*tanzania grass*), *Cenchrus ciliaris* (buffel grass), *Opuntia sp.* (forage palm) and *Lolium multiflorum* (annual ryegrass), used as cultivated pastures in Brazil, were generated with the help of simulation models and geographic information systems (Figure 1).

The project was financed by Embrapa and counted with postgraduate scholarships sponsored by FAPESP, CNPq and Capes.

RESULTS

The scenarios obtained suggest that climate change predicted by the regional climate models ETA-CPTEC and PRECIS for the different emission scenarios will have positive impacts on the total annual forage production from pastures made up of *Megathyrsus maximus* and *Urochloa brizantha* in the North, Midwest and Southeast. The area where such grasses can be grown is expected to increase. However, production seasonality

and the variability of annual production will also increase, causing climate risks.

Production systems must be adapted and new technologies must be generated to guarantee the competitiveness of the activity in an environment of greater climatic risk. The development of new cultivars and using adapted cultivars, supplementary feeding, forage conservation, the adequacy of pasture and soil management, the adoption of integrated production systems and using irrigation systems are some alternatives for adapting the production systems in the North, Midwest and Southeast regions.

In the Northeast region, especially in the semiarid area, pasture production is expected to be more vulnerable, and there may be a reduction in the area suitable for cultivating buffel grass. For the forage palm, the models used indicate an increase in the areas suitable for their cultivation for the scenarios of 2025 and 2055, with the emergence of suitable municipalities in regions beyond the Northeast of Brazil. On the other hand, areas that are currently suitable may become unfit, with the possibility of strong negative economic, social and environmental impacts on developing livestock in the region.

New genotypes of forage plants that are more tolerant to the intensification of drought conditions, associated with recommendations of management practices that reduce the effects of production seasonality, may contribute to alleviate the problems predicted by the results of this work. The large-scale breeding of small animals is also an alternative for adapting production systems in the region. In places where irrigation is possible, the cultivation of tropical grasses with high productive potential can be recommended as an alternative for adapting production systems.

Areas for cultivating temperate forage crops are expected to decrease in the South Region due to the forecast of increases in temperature. On the other hand, areas that are favorable to the cultivation of tropical forages are expected to increase, reducing the

vulnerability of regional animal production systems to global climate change. The production systems can be adapted both by replacing genetic resources with tropical forages and by developing temperate forage cultivars that are better adapted to future climate scenarios. There may be a major impact on native pastures that currently prevail in the Pampas region. The replacement of temperate native grassland areas with tropical grassland may increase. However, there are shallow soils in the Region, possibly resulting in drainage problems, to which many species of tropical grasses are not very tolerant.

NEXT STEPS AND RECOMMENDATIONS

Future pasture scenarios have been frequently updated. In the ongoing stage, in addition to improving the production models of forage plants, tools are being incorporated to estimate pasture support capacity and yield gap, in addition to assessing adaptation alternatives.

DATA PUBLISHED IN:

ANDRADE. A. S.; SANTOS. P. M.; PEZZOPANE. J. R. M.; ARAUJO. L. C.; PEDREIRA. B. C.; PEDREIRA. C. G. S.; MARIN. F. R.; LARA. M. A. S. Simulating tropical forage growth and biomass accumulation: an overview of model development and application. *Grass and Forage Science*. v. 71. n. 1. p. 54-65. June 2015.

ANDRADE. A. S.; SANTOS. P. M.; PEZZOPANE. J. R. M.; BETTIOL. G. M.; EVANGELISTA. S. R. M. Climate change and future scenarios for palisade grass production in the state of São Paulo. *Brazil. Pesquisa Agropecuária Brasileira*. Brasília. v. 49. n. 10. p. 745-753. Oct. 2014.

ARAUJO. L. C.; SANTOS. P. M.; RODRIGUEZ. D.; PEZZOPANE. J. R. M.; OLIVEIRA. P. P. A.; CRUZ. P. G. Simulating guinea grass production: empirical and mechanistic approaches. *Agronomy Journal*. v. 105. n. 1. p. 61-69. Jan. 2013.

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PROJECT COORDINATORS

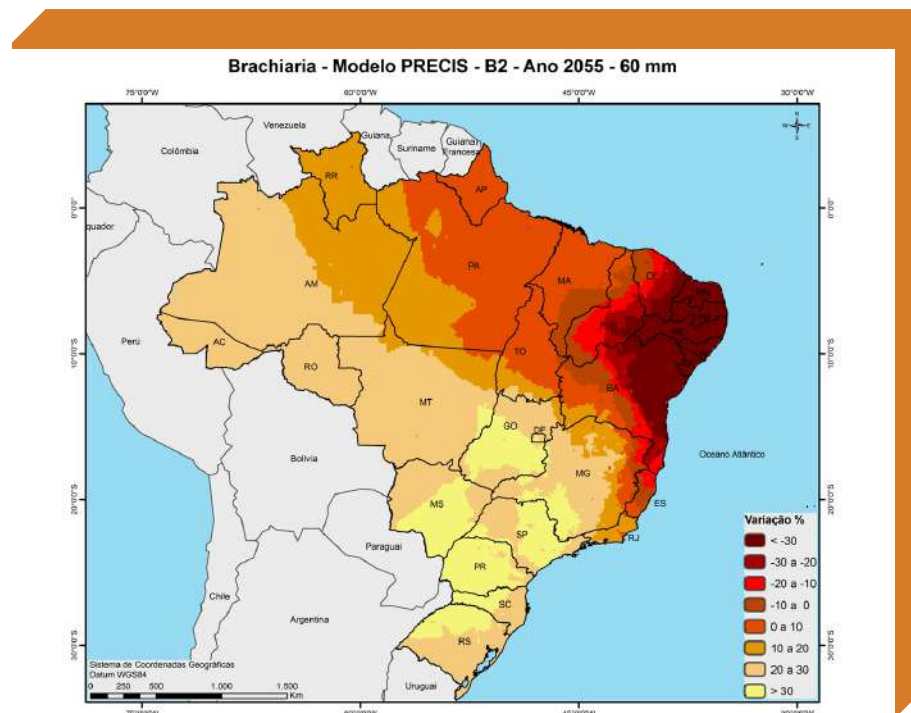
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Figure 1: Variation in annual production of *B. brizantha* cv. Marandu in B2 climate change scenarios of the PRECIS model compared to the current scenario for the years 2055 for medium textured soils



Source: Giovana Maranhão Bettiol.

COMPILATION AND RECOVERY OF TECHNICAL-SCIENTIFIC INFORMATION AND AN AGILE DEEP-DIVE INTO KNOWLEDGE ON THE AGRO HIDRO NETWORK- CRITIC@

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The CRITIC@ proposal, as a component of the project “Impacts of agricultural use and climate change on water resources in different Brazilian eco-regions: diagnosis and mitigating strategies” - AgroHidro, subsidized by Embrapa, was to concentrate the systematic analysis and organization of the information used and produced by the AgroHidro Network, made up of Brazilian researchers. The network sought to improve the management of technical-scientific knowledge in water resources and anticipating adaptation to climate change, providing an information assessment tool, which would facilitate not only identifying a body of literature and other sources of dissemination material, but also to provide information cross-referencing from several sources, in order to assess the path taken by the RD&I network and the methodologies with the greatest potential for adapting to the impacts of climate change (Figure 1). The proposal aimed to: 1) obtain analyses, considering past and present, in technological trends, research and development, in water resources in Brazil and locating the estimates obtained in time and space; 2) contribute with technological search and survey processes, with its own organization and retrieval of information, which requires cross-analysis of data; 3) specify and validate the organization of water resource knowledge in an ontological structure through a close partnership between researchers in the area of water resources and information; 4) provide an intelligent search environment for technical and scientific information used and produced by the AgroHidro Network; 5) generate a semi-automated methodology for organizing and providing technical-scientific information for similar network projects and for proposing adaptation actions.

RESULTS

- Based on the CRITIC @ tooling, it was possible to present a semi-automatic methodology to build technological portfolios, based on a large number of technical and scientific publications, illustrated in the publications, selected from the Open and Integrated System of Agriculture Information (SABIIA), which covers the entire area of interest. In order to build the portfolio, the following were adopted: some linguistic resources - such as dictionaries built by specialists in the field;

techniques for extracting information from texts by similarity; techniques of descriptive statistical analysis (percentiles, graphs); and, techniques for recognizing associative patterns (analysis of association rules). The experiment conducted showed the applicability of the methodology, resulting in a portfolio of technologies that adapt using water in agriculture. Based on this portfolio, association rules were generated to identify the relationship between technologies, locality and cultures in the regions of Brazil, in order to subsidize specialists in the field in verifying which technologies can be adapted to Brazilian biomes and adapt them to the impacts of climate change; and

- Based on this portfolio and the association rules to identify the relationship between technologies, locality and cultures, in the regions of Brazil, domain experts should check which technologies can be adapted for Brazilian biomes, or if the information presented is not sufficient for decision making, feed back into the process (increasing domain vocabulary, etc.) until the results presented are useful for this task.

NEXT STEPS AND RECOMMENDATIONS

There is no plan for maintenance or evolution of the Project. Since the results were very good, several of its components for extracting information, identifying and disambiguating place names, identifying topics in text collections and extracting item sets (formatted for use in association rules) have been used and evolved in other Embrapa Agriculture and Livestock Informatics or Embrapa Territorial.

DATA PUBLISHED IN:

MOURA. M. F.; TAKEMURA. C. M.; SILVA. I. L. C.; TÁPIAS. L. M.; OLIVEIRA. C. T. de; BASSOI. L. H.; OLIVEIRA. S. R. de M. Metodologia para a construção de portfólios tecnológicos agrícolas a partir de publicações técnico-científicas. In: CONGRESSO BRASILEIRO DE AGROINFORMÁTICA. 11.. 2017. Campinas. Anais [...]. Campinas: Editora da Unicamp; Embrapa Informática Agropecuária. 2017. p. 537-546.

PROJECT COORDINATORS

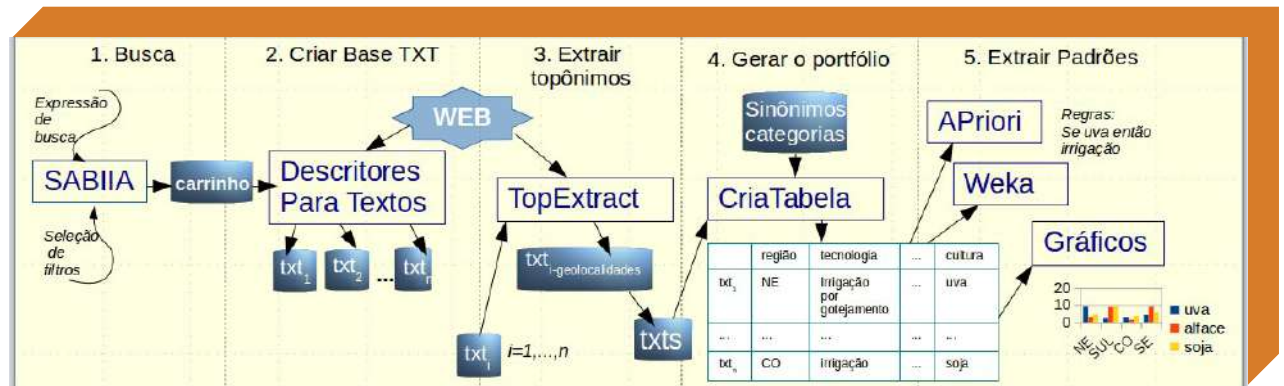
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Figure 1: Semi-automatic methodology for building technology portfolios



Source: Moura et. al. (2017).

AGROECOLOGICAL ZONING (ZAES)

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Agroecological Zonings (ZAES) are multi-thematic planning instruments whose main objective is to plan land use according to the sustainability criteria. They include information on soils, land use and coverage, climate, pedological crop potential, climate suitability by crop, soil potential for crops, land potential for irrigation, agroecological potential of land, water resources, among others. The theme that deserves to be highlighted is the soil survey, as it constitutes the “backbone” of the ZAES. It deals with pedological cartography individualizing mapping units and their environmental peculiarities. That is why, it is the theme that supports all the pedological interpretations that make up the ZAES. Integrated into a GIS, the set of themes allows quick consultations facilitating decision making by users. The ZAES make it possible, on the one hand, to reduce the risks inherent in agricultural production, and on the other, to increase crop productivity gains. Recent studies suggest that for every R\$ 1.00 invested in the ZAES, it is possible to recover R\$ 12.60 in benefits for society.

RESULTS

The main results of the ZAES, covering the Atlantic Forest, Caatinga and Cerrado biomes, are maps and explanatory texts, especially on the pedoclimatic potential and land for irrigation. Such results can enable strategic interventions aimed at developing the rural environment on a sustainable basis. An integrated notion of the Northeast region of Brazil, including the north of Minas Gerais, was obtained through the Northeast Agroecological Zoning (ZANE) (SILVA et al., 1993). At the state level, the main ZAES carried out on a scale of 1:100,000 were the Pernambuco Agroecological Zoning (ZAPE) (SILVA et al., 2001) and the Alagoas Agroecological Zoning (ZAAL) (SANTOS et al., 2013). On a municipal scale (1: 50,000), the Zoning of the Pedoclimatic Potential of the Area of Influence of the Coastal Lands of the Paraíba Channel (ZON-PB) (Table) In ZAPE, cotton crops were zoned, at two technological levels (medium and high technologies) and in three climatic scenarios (dry, regular and rainy years), cotton crops herbaceous, arabica coffee, sugar cane, common beans, cowpea beans, castor beans, cassava, corn and sorghum. ZAAL was similar to ZAPE, except coffee. An

example of the pedoclimatic potential for sugarcane can be seen in the Figure. In ZON-PB, the crops to be zoned will be corn, sorghum, sugar cane and pineapple. Recent studies carried out by Embrapa Solos indicate that the ZAES, if well used, bring a return of more than 10 times on the investments for their realization. In the specific case of ZAAL, it was estimated that for each R\$ 1.00 invested, R\$ 12.60 in benefits for society can be recovered. The ZAES also facilitate the implementation of agricultural technologies available according to the zoned environments, such as underground dams, ICLF, among others. By considering different climatic scenarios, the ZAES also make it possible to use land while taking climate change into account. The target public of the ZAES mainly covers users from the agricultural and environmental sectors.

NEXT STEPS AND RECOMMENDATIONS

- Update of the ZAES and publication in WebGis to facilitate public access; and
- Completion of the ZON-PB project.

REFERENCES:

- SANTOS. J. C. P.; ARAÚJO FILHO. J. C.; BARROS. A. H. C.; ACCIOLY. L. J. O.; TAVARES. S. C. C. H.; SILVA. A. B. Zoneamento agroecológico do estado de Alagoas. Recife: Embrapa Solos UEP Recife; Secretaria de Estado de Agricultura e do Desenvolvimento Agrário de Alagoas. 2013. u. 9. 11 p.
- SILVA. F. B. R.; RICHÉ. G. R.; TONNEAU. J. P.; SOUZA NETO. N. C.; BRITO. L. T. L.; CORREIA. R. C.; CAVALCANTI. A. C.; SILVA. F. H. B. B.; SILVA. A. B.; ARAÚJO FILHO. J. C.; LEITE. A. P. Zoneamento agroecológico do Nordeste: diagnóstico do quadro natural e agrossocioeconômico. Petrolina: Embrapa/CPATSA; Recife: Embrapa/CNPS. 1993. u. 2. (Documento 80).
- SILVA. F. B. R.; SANTOS. J. C. P.; SILVA. A. B.; CAVALCANTI. A. C.; SILVA. F. H. B. B.; BURGOS. N.; PARAHYBA. R. B. V.; OLIVEIRA NETO. M. B.; SOUSA NETO. N. C.; ARAÚJO FILHO. J. C.; LOPES. O. F.; LUZ. L. R. Q. P.; LEITE. A. P.; SOUZA. L. G. M. C.; SILVA. C. P.; VAREJÃO-SILVA. M. A.; BARROS. A. H. C. Zoneamento agroecológico do estado de Pernambuco. Recife: Embrapa Solos-UEP Recife; Governo do Estado de Pernambuco – Secretaria de Produção Rural e Reforma Agrária. 2001. (Documentos 35).

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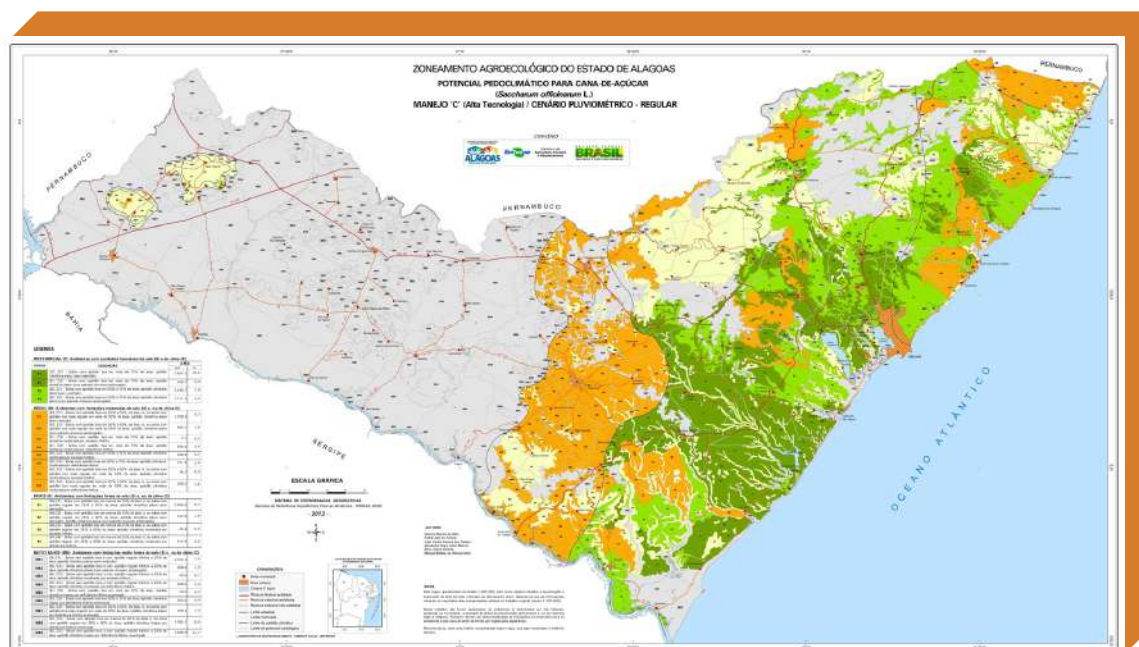
Table 1: Agroecological Zonings (ZAEs) in Northeast Brazil

Project (ZAE)1	Scale	Disclosure	Financing	Publication
ZANE	1:2,000,000	Books and CD-ROM	Embrapa/ Sudene	1993
ZAPE	1:100,000	CD-ROM	Government (PE)	2001
ZAAL	1:100,000	DVD	Government (AL)	2013
ZON-PB	1:50,000	WebGis	Government (PB)	In progress

Caption: 1ZANE: Agroecological Zoning of the Northeast; ZAPE: Pernambuco Agroecological Zoning; ZAAL: Alagoas Agroecological Zoning; ZON-PB: Zoning of the Pedoclimatic Potential of the Influence Area of the Coastal Strands Channel of Paraíba.

Source: Authors.

Figure 1: Pedoclimatic potential of sugarcane crop in the state of Alagoas in soil management with high technology and climatic scenario for regular years



Crédit: Santos et al. (2013).

AGRICULTURAL CLIMATE RISK ZONING (ZARC)

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Agricultural Climate Risk Zoning (ZARC) was implemented in 1996 with the objective of delineating municipalities and planting times based on agroclimatic risk. At its base is, a network of researchers and technicians from Embrapa and several other state institutions and an elaborate construction of agrometeorological data analysis systems and mathematical simulations, which quantify the production risk in the normal climatic conditions of each region, in order to allow an adequate assessment of the variability of each location, season and its consequences for agricultural crops (Figure 1).

The ZARC methodology is based on the determination of the water needs satisfaction index (ISNA) and, based on it, on the frequency of occurrence of adverse events that seriously affect or impede the development, growth or satisfactory productivity of agricultural crops.

ZARC provided relevant results for reducing crop losses, reducing deficit balances and fraud frequency at Proagro. It is estimated that the country will save approximately R\$ 1 billion per year.

Currently, the results of ZARC are used in the Program of Guarantees for Agricultural Activity (Proagro), in Proagro mais, aimed at small producers linked to the National Program for Strengthening Family Agriculture (Pronaf) and in the Subsidy Program for the Rural Insurance Premium (PSR) and also as conditions for the approval of agricultural credit for credit lines independent of the programs mentioned above.

In another way of using technological development promoted by ZARC, its mathematical models and databases are used in the simulation of future agricultural scenarios. These simulations are the basis for assessing vulnerability and alternatives for increasing the adaptive capacity and resilience of agricultural systems.

The ZARC also contributes to the adaptation of agricultural systems by imposing conditions for the approval of credit, inducing good practices and adaptive technologies that are adopted directly by the farmer during the harvest.

RESULTS

- ZARC itself, with its guidelines and use within the scope of national agricultural policy, as well as in the financial sector in the granting of credit, is the main result of the project. ZARC, coordinated by Embrapa in conjunction with MAPA, held, from 2016 to 2018, about fifteen national zonings, 70 validation meetings, in the various Brazilian states, with more than 1,400 participants. Latest developments and specific results:
- CONPREES System - Digital Platform for quality control, filling in the gaps and spatial meteorological data;
- Better spatial detailing of the results;
- More accurate estimates of atmospheric water demand, water consumption of crops and periods of water deficit and surplus;
- More detailed crop models with more simulation resources, including future scenarios of vulnerability;
- Better temporal consistency and larger sample universe, allowing a greater number of events to be evaluated;
- Better assessment of the level of associated uncertainty; and
- Less uncertainty in the results generated, an essential factor in making decisions about adaptation actions.

NEXT STEPS AND RECOMMENDATIONS

As next steps and/or challenges, we consider it necessary to:

- Increase the current execution scale, from 4 to 5 crops per year, to 15 to 20 crops per year;
- Expand zoning studies for crops and systems not yet covered;
- Develop and adapt modeling methodologies for the systematic quantification of risk by productivity range;
- Develop and apply methodologies for the evaluation of resilient production systems, that are less susceptible to adverse weather events;
- Develop a system for monitoring climate claims;
- Specific and predictable budget allocation for the maintenance of ZARC studies, or risk assessment and monitoring systems; and
- More appropriate resource management model.

DATA PUBLISHED IN:

CUNHA, G. R.; ASSAD, E. D. Uma visão geral do número especial da RBA sobre zoneamento agrícola no Brasil. Revista Brasileira de Agrometeorologia. Passo Fundo. v. 9. n. 3. p. 377-385. 2001.

MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO. Indicadores de Zoneamento Agrícola de Risco Climático. Portarias ministeriais no Diário Oficial da União. 2020. Disponível em: <http://indicadores.agricultura.gov.br/zarc/index.htm>.

SANTOS, W. G.; MARTINS, J. I. F. O Zoneamento Agrícola de Risco Climático e sua contribuição à agricultura brasileira. Política Agrícola. Ano XXV. n. 3. 2016.

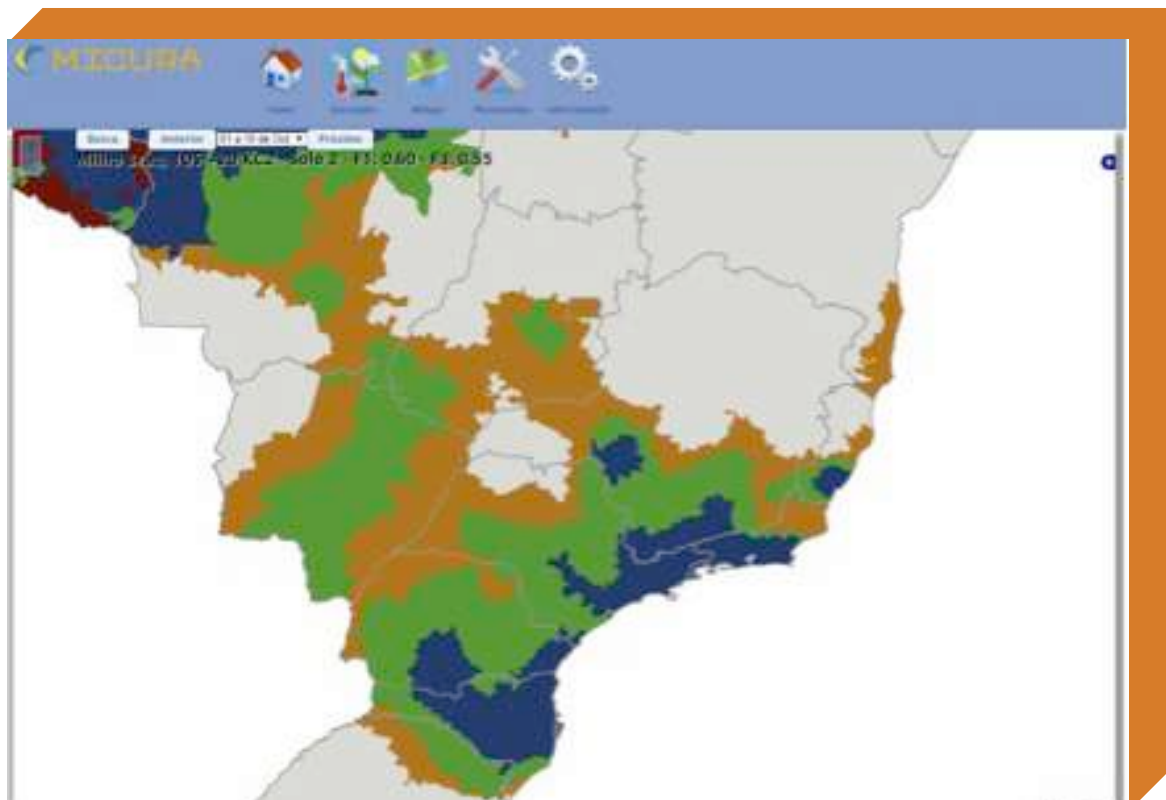
STEINMETZ, S.; SILVA, S. C. Início dos estudos sobre Zoneamento Agrícola de Risco Climático (ZARC) no Brasil. Santo Antônio de Goiás: Embrapa Arroz e Feijão. 2017. 27 p. (Documento 312).

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Figure 1: Climatic Risk Agricultural Zoning (ZARC) for corn cultivated in the Brachiaria corn system, early cycle cultivars and soils with medium water storage capacity, with sowing taking place in the first ten days of October



INFRARED THERMOGRAPHY TO DIAGNOSE BIOCLIMATIC CONDITIONS IN LIVESTOCK SYSTEMS IN THE AMAZON BIOME

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In Brazilian agriculture, the adoption of technologies capable of expanding the evaluation of variable-responses is being expanded, to consider processes in the soil-plant-animal-atmospheric system. Using infrared thermography makes it possible to diagnose, in real time, different thermal patterns regarding targets of technical and scientific interest. In livestock production system (McMANUS *et al.*, 2016), thermograms have supported evaluations capable of pointing out indicators of animal thermal comfort, herd health, quality standards in pastures (PILATO *et al.*, 2018b), animal behavior and thermoregulation associated with bioclimatic conditions (PERISSINOTTO *et al.*, 2006; MALAMA *et al.*, 2013; KOTRBA *et al.*, 2007; SOUZA *et al.*, 2008; MEDEIROS *et al.*, 2001; AGGARWAL; SINGH, 2008; MARAI; HAEED, 2010; SILVA *et al.*, 2010, MENEGASSI *et al.*, 2015). This is a non invasive method (ROBERTO; SOUZA, 2014) and has a high potential for use in rapid diagnostics in decision making, especially in strategies for improving thermal conditions, in open and controlled environments. Making it possible to measure the temperatures of buildings (PLEŞU *et al.*, 2012), including zootechnical installations.

RESULTS IN THE AMAZON BIOME

- Financial support for projects such as the PECUS Network, accessing funds to finance master's, doctoral and postdoctoral fellowship (CAPES/ Embrapa edital) and acquisition of equipment such as a thermographic camera (CTINFRA/CNPq) allowed the achievement of innovative research results. The availability of scholarships to support the training of new professionals in the region (undergraduate, master's, doctorate and post-doctorate) and the expansion of opportunities for new scientific investigations by the teams involved in these projects were decisive in achieving results such as:
 - Different anatomical regions showed thermal correlations with bioclimatological indexes of thermal comfort in buffaloes in the Eastern Amazon (BARROS *et al.*, 2015);
 - The maximum temperature of the eye orbit was the response variable most correlated to the rectal temperature. Temperature oscillations of the eye orbit, right flank, left flank and scrotum were measured in buffaloes, based on thermographic data (BARROS *et al.*, 2016);
- Climatic variables in the dry season on the Ilha de Marajó pointed out that buffaloes are prone to present thermal stress, especially between 10 am and 2 pm (JOSET *et al.*, 2018);
- The thermal comfort indexes for buffaloes indicated a high level of efficiency in evaluating the status of thermal comfort under environmental conditions in the research area (PANTOJA *et al.*, 2018);
- Thermal patterns were higher in areas with pastures undergoing degradation with exposed soil than in areas of secondary vegetation and targets in female adult bovines (PILATO *et al.*, 2018b);
- In a silvopastoral system in Belém-PA, it was observed that Murrah buffaloes with access to the shade of trees, whose microclimate presents lower values of air temperature, orbit temperature index and relative air humidity, were in better conditions of thermal comfort (SILVA *et al.*, 2011);
- The thermoregulation capacity, scrotal thermal patterns and the semen quality of male buffaloes were efficient in dissipating heat on days with high temperatures and high levels of humidity in the air (SILVA *et al.*, 2018);
- During the hottest periods of the day in an extensive livestock system, without trees in the pastures, the animals spent a long period in idleness (AMARAL JÚNIOR *et al.*, 2016), reinforcing the importance of thermal comfort for animals in production systems;
- Degraded pastures with extensive areas with exposed soil showed higher temperatures when compared to areas with secondary vegetation and animal targets at times of higher radiation intensity in western Pará (PILATO *et al.*, 2018b); and
- Thermal patterns in production systems pointed to successful responses that strengthen the wide application of near infrared thermography, in the

soil-plant-animal-atmosphere-system analyses (BARROS et al., 2016; BARROS et al., 2015; BRCKO et al., 2020; PANTOJA et al., 2018; PIRES et al., 2017; SANTOS et al., 2016a; SILVA et al., 2020; SILVA et al., 2018a; SILVA et al., 2018b; PIRES et al., 2019; SILVA et al., 2018; BARROS et al., 2015; MONTEIRO et al., 2016; ROCHA et al., 2018; SILVA et al., 2016; SANTOS et al., 2016b; SOUSA et al., 2016).

Results were also presented in a lecture at AMAZONVET and at the National Congress of Wild Animals (MARTORANO, 2019), at the invitation of the organizing committee. In Figure 1, it is possible to identify images of thermal patterns, based on thermographic diagnostics, in the Amazon biome.

NEXT STEPS AND RECOMMENDATIONS

The projects have all been completed. However, as the research networks have been consolidated over the period and duration of these projects, it is emphasized that new scientific investigations have been carried out due to the high potential of diagnosing thermal patterns in different targets with infrared thermography in the Amazon.

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DATA PUBLISHED IN:

AMARAL JUNIOR. J. M.; MORAIS. E.; CARMO. E. S. N.; SOUSA. M. A. P.; SILVA. B. A.; MARTORANO. L. G.; BERNDT. A.; SILVA. A. G. M. Enteric methane emission of female buffaloes supplemented with palm kernel cake in the Amazon biome. In: SIMPÓSIO INTERNACIONAL SOBRE GASES DE EFEITO ESTUFA NA AGROPECUÁRIA – SIGEE. 2.. [S. l.]. 2016. p. 53-57.

BARROS. D. V.; SILVA. L. K. X.; KAHWAGE. P. R.; SILVA. A. O. A.; SILVA. A. G. M.; FRANCO. I. M.; MARTORANO. L. G.; LOURENÇO JUNIOR. J. B.; ROMANELLO. N. Assessment of scrotal thermography and semen quality in buffalo bulls (*Bubalus bubalis*) raised under humid tropical environment. In: ANNUAL MEETING OF THE BRAZILIAN ERNBRYO TECHNOLOGY SOCIETY (SBTE). 29.. 2015. Gramado.

BARROS. D. V.; SILVA. L. K. X.; KAHWAGE. P. R.; LOURENÇO JUNIOR. J. B.; SOUSA. J. S.; SILVA. A. G. M.; FRANCO. I. M.; MARTORANO. L. G.; GARCIA. A. R. Assessment of surface temperatures of buffalo bulls (*Bubalus bubalis*) raised under tropical conditions using infrared thermography. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*. v. 68. p. 422-430. 2016.

Continued in Annex

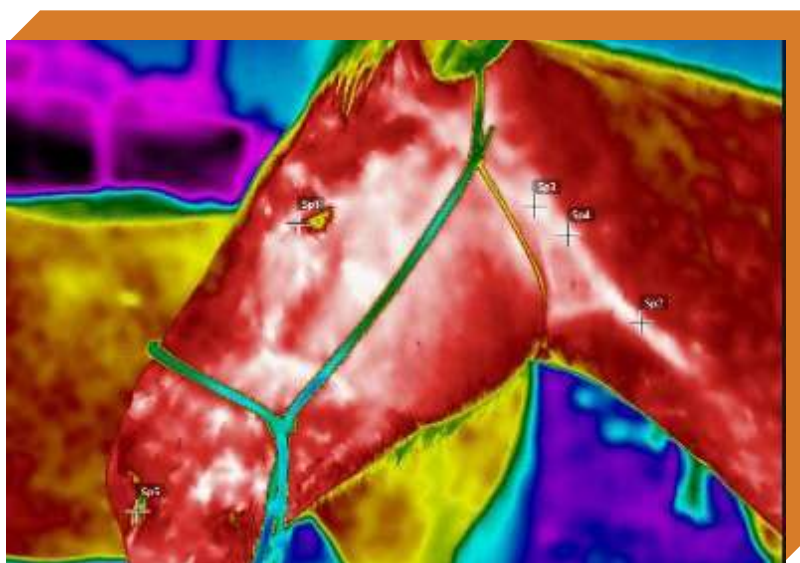
REFERENCES:

AGGARWAL. A.; SINGH. M. Changes in skin and rectal temperature in lactating buffaloes provided with showers and wallowing during hot-dry season. *Tropical Animal Health Production*. v. 40. p. 223-228. 2008.

JOSET. W. C. L.; SILVA. J. A. R. da; GODINHO. L. A.; BARBOSA. A. V. C.; MARTORANO. L. G. LOURENÇO JUNIOR. J. de B. Thermoregulatory responses of female buffaloes reared under direct sunlight and shaded areas in the dry season on Marajó Island, Brazil. *Acta Sci. Anim. Sci.* [Online]. v. 40. e37641. 2018.

Continued in Annex

Figure 1: Thermographic image in a livestock production system on a field monitoring date of 09/16/2017, in the Amazon



Crédit: Lucieta Martorano.

3

USE AND CONSERVATION OF BIODIVERSITY



Strategy for the Use and Conservation of Biodiversity in adapting Brazilian agriculture to climate change

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Biodiversity or biological diversity refers to a variety of life forms including flora, fauna, fungi and microorganisms (both native and domesticated) on our planet, comprising all genetic variability within and between populations of the same species, all the diversity of species and all the diversity of communities and ecosystems existing in the different biomes in continental and marine areas. Associated with the concept of biodiversity, we have the concept of ecosystem services that refer to the benefits resulting from the functioning of ecosystems, that is, the set of physiological and ecological processes of the different species that make up the ecosystems. The concepts of "Ecosystem Services", "Environmental Services" or "Nature's Contributions to Humanity" were well developed and scientifically explained in the "Millennium Ecosystem Assessment" launched by the UN in 2005, as a result from contributions from 1360 scientists between 2001 and 2005, and most recently in the "Global Biodiversity Assessment on Biodiversity and Ecosystem Services" launched in March 2019 by the Intergovernmental Platform for Science and Policies on Biodiversity and Ecosystem Services (IPBES). Currently, three major classes of ecosystem services are recognized: 1) Regulation (creation and maintenance of habitats, pollination and dispersion of seeds, air quality, climate, ocean acidification, fresh water quantity, water quality freshwater and coastal waters, formation and protection of soils, extreme events, etc.), 2) Material Supply (energy, food and fibers, building materials, medicines and biochemicals, genetic resources, etc.), 3) Non-material or cultural provision (physical and psychological experiences, learning and inspiration, support for identities, etc.).

Why do we have so much biodiversity on Planet Earth? The most accepted scientific explanation is that our planet is dynamic over time and spatially heterogeneous, which resulted in a process of natural selection that favored the development and the predominance of sexual reproduction over asexual reproduction. Sexual reproduction results in offspring who are genetically different from their parents and different from each other - this genetic variability increases the chances of individuals having characteristics that favor their adaptation and survival to the changes and environmental disturbances to which they are continually subjected. Therefore, biodiversity is nature's response to the unpredictability of environmental conditions on our planet over time and space (WILLIAMS, 1975). To some extent, species and ecosystems are able to adapt to climate change caused by the large increase in greenhouse gas (GHG) emissions resulting from the consumption of fossil fuels, deforestation and conversion of ecosystems.

Thus, in order to promote the capacity of agro-ecosystems to adapt to climate change, the first recommendation is to increase biological diversity at all levels of organization of life and at all geographical scales, including: 1) increasing the genetic variability of managed domesticated species (expanding the diversity of plant cultivars and animal breeds used, making use of native varieties and wild relatives in breeding programs); 2) expanding the diversity of managed species (within each rural property, each micro basin and each biome);

3) diversifying production systems and promoting diversified agroecosystems; 4) promoting conservation, sustainable use and the restoration of native ecosystems in the midst of productive landscapes; 5) reducing the genetic and domesticated species bottleneck used in agriculture and food at all scales, from local to global. Obviously, the reduction or loss of biodiversity and ecosystem services impacts and restricts our future options (DIAS, 2017; 2019).

Organisms and ecosystems adapt to environmental variations and disturbances in several ways, including developing strategies for: 1) resistance or tolerance (the ability of an individual, species or ecosystem to withstand and survive an event or a succession of events of disturbance without significant damage to its structures and functioning, such as Cerrado trees protected with thick cortical bark, which resist the impacts of fire); 2) resilience (capacity and speed of an individual, a species or an ecosystem to recover from an event or a succession of disturbing events by recomposing their structures and functions, such as the Cerrado herbaceous plants, which have well-developed underground structures with tubers and buds that make it possible to quickly reconstruct epigeal structures, above ground, destroyed by fire); 3) phenological or displacement response; and 4) replacement of species or communities and ecosystems.

Climate changes, in addition to changing temperature and rainfall, also change the duration and the beginning of the seasons, causing great impacts, such as the mismatch between the times of emergence and the flight of bees in spring and the flowering season of plants with consequent reduction in pollination and increase in pollination deficit. In this case, adaptation requires phenological changes to be selected over generations or the occurrence of displacements of populations along latitudinal or altitudinal gradients in search of adequate environmental conditions, with greater phenological synchronization, of temperature and humidity, both in the form of definitive geographical displacements and seasonal displacements, resulting in new patterns of migration and dispersion of species and ecosystems.

In studies concerning environmental impacts on organisms and ecosystems, it is useful to differentiate the concepts of disturbance and disruption: disturbance is any change in the environment and disruption refers to any disruption that extends beyond the normal limits of a system during a given period or that represents a novelty for the system, a new type of disturbance. However, not all ecologists consistently use the same definitions for disturbance, disruption and stress (BARRETT; ROSENBERG, 1981) and one option is to use the definitions adopted by the IPCC and the IPBES.

In the most severe cases of disturbance and change there is a natural species substitution process in ecosystems, with more vulnerable species migrate or become extinct and are replaced by more resistant species or by species from other ecosystems that are more adapted to new environmental stresses. At the end of this process, some types of habitats and ecosystems are reduced in area and others expand. In the case of agroecosystems, this process can result in the complete replacement of production systems and cultivated species.

It should also be noted that the impacts and solutions for adapting to climate change occur at different scales: in the field, pasture or agroforestry, in rural properties, in the microbasin, in the biome, on the continent and in the world. This applies to both biodiversity and ecosystem services. For example, on a global scale and across biomes, climate change in the African Sahara can affect the amount of nutrients transported in sandstorms to the Amazon Rainforest; the reduction in the extent of the Amazon Forest may affect the amount of rain in the Midwest, Southeast and South regions of Brazil, transported by the so-called "flying rivers"; the reduction in vegetation cover and the increase in the withdrawal of water for irrigation in agriculture and urban consumption in the Cerrado and Atlantic Forest biomes can cause the lowering of the water table and the drying up of springs, transforming streams and perennial rivers into intermittent ones; and deforestation of forests and drainage of wetlands reduces the capacity of ecosystems to buffer the impacts of scarcity and excess water caused by the greater frequency and intensity of extreme climatic events of droughts and rains.

The articles presented in this collection can be distributed according to the problems addressed, as proposed below.

1. Conservation and management of biodiverse systems and incorporation of new species to increase the biodiversity of agroecosystems

The management of systems of biodiversity and the incorporation of new species are divided into four groups: management of native ecosystems; establishment of agroforestry systems and biodiverse agricultural systems; enrichment of pastures and orchards; and underutilized native plants.

The first group deals with the management of native biodiverse ecosystems, especially the management of native pastures in the biomes of the Caatinga and Pantanal and the conservation and management of native fields with butia, the butiazais, in the Campos Sulinos. Native forests and fields/savannas are very abundant in Brazil, widely used for extractivism and present in the Legal Reserves required by the Law on the Protection of Native Vegetation (former Forestry Code), which are spaces of conservation (different from preservation) for the management of natural resources. Therefore, the absence in this collection of research, which exists in Brazil, on the management of other types of pastures and native forests represents a great gap.

The second group deals with the establishment and management of agroforestry systems and biodiverse agricultural systems in regions once covered by forests with agroforestry projects in São Paulo (Atlantic Forest), Rondônia (Amazon Forest) and Piauí (Caatinga) and by biodiverse agricultural systems in São Paulo (Mata Atlântica) and the sub-middle São Francisco (Caatinga). There is a great diversity of agroforestry systems in the country, as well as traditional systems of intercropping crops that deserve more attention in the context of promoting more biodiverse agricultural systems as a way of adapting to climate change. A line of research that does not yet exist in the country, but is already practiced in North America and Europe, is the restoration of belts of native biodiverse vegetation in the middle of extensive areas of monocultures to improve sustainability and adaptation to climate change (LIEBMAN; SCHULTE, 2015) (Figure 1).

Figure 1: Reconstructed and integrated prairie belt in a corn crop in Iowa, USA, in an experiment to test performance improvement and resilience



Source: Liebman; Schulte, 2015.

In Brazil, native vegetation belts on the riverside and on the slopes protected as Permanent Protection Areas (APPs), to a certain extent, play this role of breaking the continuity of extensive areas of monocultures, thus increasing their sustainability and adaptation to climate change, a subject that deserves more attention in research and that is absent in this set of articles.

The total area of Legal Reserves in Brazil, required by the Law on the Protection of Native Vegetation is estimated at about 1.33 million km² (15.6% of the Brazilian mainland), being that an unknown percentage is in need of restoration, and the total area occupied by APPs

is estimated at 1.97 million km² (23.2% of the Brazilian continental territory), with about 152 thousand km² in need of restoration based on studies by the Brazilian Foundation for Sustainable Development (FBDS) using high-resolution satellite imagery in the Cerrado and Atlantic Forest biomes.

The third group deals with the enrichment of pastures and orchards in the Caatinga and pastures in the Amazon, especially using native plants. The fourth group, on the other hand, deals with the identification of native plants from all underused Brazilian biomes, but with high nutritional value, species and varieties. It is a line of research with great potential in Brazil due to the richness of our biodiversity, the Creole varieties and the existing traditional knowledge. The large number of plant species that were domesticated by indigenous groups in the different biomes stands out. In the Amazon Forest alone, between 80 and 140 domesticated species are documented, at different levels of domestication (CLEMENT et al., 2010; CLEMENT et al., 2015; FAUSTO; NEVES, 2018).

2. Evaluation and selection of tolerance and resistance in cultivated plants

The evaluation and selection of tolerance, resistance and resilience in cultivated plants are divided into two groups: resistance or tolerance of cultivated plants and potential distribution of native trees.

The first group addresses the theme of resistance or tolerance of native and exotic cultivars grown in the Caatinga biome and in the Southeast. The stress factors evaluated were: drought/water stress (present in all articles), thermal stress (present in four articles) and increased CO₂ (present in two articles). The second group contains an article on the potential distribution of native trees.

3. Mutualism and parasitism/predation assessment

The evaluation of mutualisms and parasitism/predation can be better interpreted by dividing the work into two major approaches: I) phenological response or displacement (present in three articles, dealing with pollination systems of cultivated plants); and II) impacts on beneficial and harmful microorganisms, including those symbionts that assist in plant growth (an article dealing with bacteria), and those that are phytopathogenic (an article dealing with fungi and bacteria), both in the Caatinga.

Distribution by biome, themes and scales of the research articles reported in this chapter:

The articles presented research carried out in all biomes (11 in the Caatinga, 4 in the Atlantic Forest, 3 in the Amazon, 2 in the Cerrado, 1 in the Pantanal, 1 in the Pampa and 4 that cover all biomes). The biome with the highest concentration of articles was the Caatinga, which makes a lot of sense, since it is currently the biome that suffers from the greatest stresses and unpredictable weather and is the biome where the greatest impacts of climate change are expected in the coming decades.

Some topics covered in Chapter 3 are not covered in the articles received, such as resilience of cultivated plants, other mutualisms (herbivory, mycorrhiza, intestinal flora of ruminants etc.), other ecosystem services, in addition to pollination and recycling of nutrients in the soil, such as biological pest control, buffering effect of forests and wetlands, etc. Likewise, the articles in this Chapter did not deal with spatial scales of rural property, micro basins, biome, continent and world.

References

- BARRETT. G. W. ;R ROSENBERG. R. (eds.). Stress effects on natural ecosystems. New York: John Wiley & Sons. 1981.
- CLEMENT. C. R.; CRISTO-ARAÚJO. M. de; D'ECKENBRUGGE. G. C.; PEREIRA. A. A.; PICANÇO-RODRIGUES. D. Origin and domestication of native Amazonian crops. *Diversity*. v. 2. n. 1. p. 72-106. Mar. 2010.
- CLEMENT. C. R.; DENEVAN. W. M.; HECKENBERGER. M. J.; JUNQUEIRA. A. B.; NEVES. E. G.; TEIXEIRA. W. G.; WOODS. W. I. The domestication of Amazonia before European conquest. *Proceedings of the Royal Society Biological Sciences*. v. 282. n. 1812. p. 1-9. Aug. 2015.

Continued in Annex

TECHNOLOGICAL COMPLETION OF NATIVE AND EXOTIC FRUIT TREES FOR PRODUCTIVE SYSTEMS IN THE CERRADO

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There are more than 5 million producers who demand technological solutions for income generation in rural properties. Fruit growing is an important alternative and has great economic and social importance, generating employment and income, and it can be practiced by different types of producers (micro, small, medium and large) with different investment capacities. Regardless of the type of producer and the investment capacity, the business vision and the use of technology in the production system are fundamental to the success of this agribusiness. The use of technology involves the adoption of genetically improved cultivars and cultural practices appropriate to the production system. Embrapa Cerrados has been developing research and development actions with different native and exotic fruits since the 1990s, developing cultivars and adjusting production systems in the Cerrado (Figure 1). In this line of research, important results were obtained with mango, soursop, citrus, dragon fruit, pequi and araçá, including the selection and validation of elite genotypes in production systems. To make these elite genotypes available to society, some post-breeding actions need to be carried out highlighting the step of technological finishing. This project proposes actions to validate elite cultivars and genotypes under farm conditions and post-breeding actions so that the cultivars reach the farmer and benefit the entire production chain. The testing of genotypes in different production systems, studies of market trends and the dissemination and transfer of knowledge and technologies are also part of the Project's RD&I actions. As for the relationship between work and the adaptation of these species to climate change, there is still no scientific data to prove changes in physiology, productivity, incidence of diseases and pests in these species due to this event. Through experiments and observation units implemented in the early 1990s, in various locations in the country, there have been no abnormal changes so far. In general, tropical fruits have a wide range of adaptation to temperature variations. These species can be successfully cultivated in all regions of Brazil, where temperatures can vary from 10°C to 35°C and the relative humidity from 35% to 90%.

Target audience and beneficiaries: Fruit growers, juice, ice cream and sweets industries; Society that consumes fruits and derivatives; Use for restoring legal reserves and recovering degraded areas.

Funding Sources: Embrapa, CNPq, FAP-DF, CAPES, MAPA.

RESULTS

- Finishing technology for mango, soursop, pitaya, pequi and araçá cultivars;
- Transfer and dissemination of knowledge and technologies generated with a view to training technicians, workers and fruit growers.

NEXT STEPS AND RECOMMENDATIONS

- In order for technical-scientific projects to generate technological products that can be adopted and become innovation, continuity is essential. Thus, ensuring resources for the continuity of the project is our main challenge.

DATA PUBLISHED IN:

- As threats, the lack of resources for hiring labor is the most important, as it puts the continuity of research work at risk;
- As strengths, we can consider the domestication and development and release of cultivars of native species such as pequi, araçá, wild passion fruit and native dragon fruit, species from Brazilian biodiversity with high economic potential; generating more knowledge about the diversity of these Brazilian species; and the risks of threats of extinction and genetic erosion due to predatory extraction;
- Technological finishing and release of new mango cultivars adapted to low relative humidity during the flowering season.

DATA PUBLISHED IN:

AGOSTINI-COSTA. T. S.; GOMES. I. S.; PESSOA. G. K. A.; SILVA. J. P. D. B.; JUNQUEIRA. N. T. V. Avaliação do potencial nutricional de araçáçs procedentes da seleção CPAC-AR 1 da Embrapa Cerrados. In: CONGRESSO BRASILEIRO DE RECURSOS GENÉTICOS. 2.. 2012. Belém. Anais [...]. Belém: CBRG. 2012.

JUNQUEIRA. J. P.; FALEIRO. F. G. ; BELLON. G.; JUNQUEIRA. N. T. V.; FONSECA. K. G.; LIMA. C. A.; SANTOS. E. C. Variabilidade genética de acessos de pitaya com diferentes níveis de produção por meio de marcadores RAPD. Revista Brasileira de Fruticultura. v. 32. p. 840-846. 2010.

JUNQUEIRA. N. T. V.; REZENDE. D. V.; URBEN. A. F.; NASCIMENTO. A. C.; PEREIRA. A. V.; SILVA. J. A.; JUNQUEIRA. K. P. Doenças potencialmente importante para o cultivo do pequi no Cerrado. In: CONGRESSO BRASILEIRO DE FITOPATOLOGIA. 33.. 2000. Belém-PA. Anais [...]. Belém: [S. n.]. 2000. v. 1.

Continued in Annex

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Figure 1: Main fruit trees studied and grown at Embrapa – Cerrados in its 40 years of history: avocado, acerola, banana, Tahiti lemon and other citruses, coconut, soursop and other annonaceae, guava, mango, dragon fruit, passion fruit and other passionflowers, pequi, mangaba, araticum, baru, araçá, among other fruits native to the Cerrado



Crédit: Divulgação Embrapa.

TECHNOLOGICAL COMPLETION OF NATIVE AND EXOTIC FRUIT TREES FOR PRODUCTIVE SYSTEMS IN THE CERRADO

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Since the early 1990s, Embrapa and partners have been developing research and development actions with passion fruit in order to improve the production system and develop new cultivars through the genetic improvement of commercial and wild species for the Cerrado, Amazon, Caatinga and Atlantic Forest biomes (Figure 1). The Cerrado is one of the main centers of diversity of the *Passiflora* genus, from which genetic resources of great importance have been obtained, characterized and used in the genetic improvement program of sweet, ornamental and wild passion fruit. Part of this Program, is the project entitled “Characterization and use of germplasm and genetic improvement of passion fruit (*Passiflora* spp.) With the help of molecular markers” its first phase ran from 2005 to 2008, the second from 2008 to 2012 and the third from 2012 to 2016. In 2017, a new phase (phase IV) of the project was initiated, and is being financed by Embrapa. The *Passiflora* genus has wide genetic variability to be characterized and used in a practical way in the development of new varieties and hybrids of sour, sweet and wild passion fruit aiming at the diversification of productive systems from essentially Brazilian biodiversity. The cultivation of passion fruit on a commercial scale began in the 1970s, with sour passion fruit (maracujazeiro-azedo), with the average Brazilian productivity being around 13.4 t/ha/year being that the crop potential is greater than 50 t/ha/year. For this, it is essential to use hybrids and genetically improved varieties that are adapted to the different production systems and regions of Brazil. Regarding sweet, ornamental and wild passion fruit, despite the great potential, cultivation in Brazil is very small, which, is largely due to the lack of genetically improved varieties and hybrids. In view of this demand, Embrapa and partners have carried out programs for the characterization and use of germplasm and genetic improvement of commercial and wild passion fruit species. The current project contemplates a new phase of the Program with the general objective being to developing varieties and hybrids of sweet and wild passion fruit adapted to all regions of the country aiming at the diversification of production systems.

RESULTS OBTAINED UNTIL THE MOMENT

- Development of sour passion fruit cultivars BRS Gigante Amarelo, BRS Sol do Cerrado, BRS Rubi do Cerrado,;

- Development of sweet passion fruit cultivar BRS Mel do Cerrado;
- Development of wild passion fruit cultivars BRS Pérola do Cerrado and BRS Sertão Forte;
- Development of ornamental passion fruit cultivars BRS Estrela do Cerrado, BRS Rubiflora, BRS Roseflora, BRS Rósea Púrpura and BRS Céu do Cerrado;
- The cultivars developed are more productive, with better physical-chemical quality of fruits, more resistant to diseases and more well adapted to different regions and production systems in Brazil. The expansion of the genetic base of commercial crops with new varieties and hybrids has reduced the vulnerability of plantations to phytopathogens, and may increase their tolerance to climate change.

NEXT STEPS AND RECOMMENDATIONS

- For technical-scientific projects to generate technological products that can be adopted and become innovation, continuity is essential. Thus, ensuring resources for the continuity of the project is our main challenge.
- Technological finishing of rootstock cultivars to control fusariosis and improve tolerance to water stress;
- Technological finishing of new cultivars of sour, sweet and wild passion fruit, better adapted to different regions and Brazilian biomes;
- Finish the evaluations and agronomic characterization of 100 passion fruit species in order to identify materials with potentials such as resistance to pests and diseases, higher drought tolerance, greater productivity, ornamental, medicinal potential, better adaptations to different climates, domestication of new species and market potential.

THREATS, STRONG POINTS AND WEAK POINTS

- As threats, we can consider the lack of resources for hiring labor, the most important.
- As strengths, the development and release of new cultivars, the domestication of new species of Brazilian biodiversity and greater knowledge about the diversity of Brazilian passifloras, as well as the risk of extinction.

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DATA PUBLISHED IN:

FALEIRO, F. G.; JUNQUEIRA, N. T. V.; BRAGA, M. F.; PEIXOTO, J. R. Caracterização de germoplasma e melhoramento genético do maracujazeiro assistidos por marcadores moleculares: resultados de pesquisa 2005–2008. Planaltina-DF: Embrapa Cerrados. 2008. (Boletim de Pesquisa e Desenvolvimento 207).

FALEIRO, F. G.; JUNQUEIRA, N. T. V.; JESUS, O. N.; MACHADO, C. F.; FERREIRA, M. E.; JUNQUEIRA, K. P.; SCARANARI, C.; WRUCK, D. S. M.; HADDAD, F.; GUIMARÃES, T. G.; BRAGA, M. F. Caracterização de germoplasma e melhoramento genético do maracujazeiro assistidos por marcadores moleculares – fase III: resultados de pesquisa e desenvolvimento 2012–2016. Planaltina-DF: Embrapa Cerrados. 2017. (Documento 341).

FALEIRO, F. G.; JUNQUEIRA, N. T. V.; OLIVEIRA, E. J.; MACHADO, C. F.; PEIXOTO, J. R.; COSTA, A. M.; GUIMARÃES, T. G.; JUNQUEIRA, K. P. Caracterização de germoplasma e melhoramento genético do maracujazeiro assistidos por marcadores moleculares – fase II: resultados de pesquisa 2008–2012. Planaltina-DF: Embrapa Cerrados. 2014. (Documento 324).

EMBRAPA. Maracujá – Pesquisa e Desenvolvimento. Embrapa Cerrados. 8 abr. 2009. Disponível em: <http://maracuja.cpac.embrapa.br/>. Acesso em: 08 fev. 2020.

Figure 1: Sour, wild, ornamental and sweet passion fruit cultivars launched by Embrapa and partners



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BIODIVERSITY FOR FOOD AND NUTRITION

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In recent decades, agriculture and food systems have changed dramatically and there is a worldwide trend towards simplification, with the prevalence of monocultures and expansion of livestock, reinforcing practices that contribute to the destruction of natural habitats, loss of biodiversity and genetic erosion of local and traditional foods. This has a negative impact not only on the food security, nutrition and health of the population, but also on the resilience of agricultural systems.

The diversification of food is crucial for the supply of the necessary nutrients for a healthy life, since the consumption of little variety can lead to nutritional deficiencies, high consumption of “empty” calories and consequences such as overweight, obesity and chronic diseases. In addition, the diversification of agriculture increases its resistance to climate change and adverse conditions such as floods, droughts, soil impoverishment, pests and diseases.

Seeking to demonstrate the strong link between biodiversity, food and nutrition, in 2012 the Biodiversity Project for Food and Nutrition - BFN, was launched in Brazil by the Ministry of the Environment- MMA. The Project helped to recognize the value of native species, focusing on beneficiaries of public policies related to food and nutritional security.

The actions were based on 3 components:

Knowledge base - Demonstrate the nutritional value of biodiversity and the role it plays in promoting healthy food systems.

Political structure - Influence policies, programs and markets to support the conservation and sustainable use of biodiversity.

Awareness and training - Provide tools, knowledge and good practices to promote the use of biodiversity for food and nutrition.

The BFN prioritized 78 food species, selected by the Plants for the Future Initiative, which seeks to identify native species of Brazilian flora with current or potential use. As a way of expanding the reach and promoting regional research on native species, partnerships were signed with institutions in the five regions of the Country, involving more than one hundred teachers and students. The

researchers generated data on nutritional composition and developed culinary recipes, also acting as multipliers, when inserting and emphasizing native foods in teaching, research and extension of their institutions.

The activities had national reach, through partnerships with federal initiatives, such as the National School Feeding Program - PNAE; Food Acquisition Program - PAA; National Food and Nutrition Policy - PNAN; National Plan for Agroecology and Organic Production - PLANAPO; and Minimum Price Guarantee Policy for Sociobiodiversity Products - PGPMBio, in addition to interactions with the National Council for Food and Nutritional Security - CONSEA.

RESULTS

- Desenvolvimento da ferramenta “Biodiversidade · Development of the tool “Biodiversity and Nutrition: nutritional composition and recipes” (SiBBR, 2018). Native foods are as or more nutritious than others commonly consumed (Figure 1) and can contribute to diversify and enrich the diet.
- Launch of the book Brazilian Biodiversity: flavors and aromas with 335 recipes with native Brazilian ingredients.
- Publication of the list of species of Brazilian socio-biodiversity with nutritional value (MMA/MDS Decree nº 163/2016, updated by Decree nº 284/2018), which represents the recognition of the relevance of native species and contributes to expand the possibilities of cultivation and trade. An example of measures that aim to benefit producers is the Sociobiodiversity Seal (Ordinance No. 161/2019), which uses the list as a basis.
- Availability of the online course Biodiversity for Food and Nutrition with theoretical foundations and practical examples on the integration and sustainable use of biodiversity in areas such as education, health and agriculture.
- Publication of the series Notebooks of Good Practices for Sustainable Organic Extraction for 21 native species. Aimed at extractive communities and rural technicians, its goal is to guide the sustainable collection of products from socio-

biodiversity, aiming at organizing production and facilitating access to markets.

NEXT STEPS AND RECOMMENDATIONS

The results of the BFN are contributing to show that the food use of sociobiodiversity can be part of the solution to reduce the loss of biodiversity, contribute to the resilience of productive systems, improve the income and quality of life of rural producers and contribute to more nutritious and diverse diets.

For such benefits to be significant, it is necessary to stimulate the development of native species value chains, with incentives and training for rural producers, improvement of infrastructure, in addition to greater incentives for institutional purchasing programs such as PAA and PNAE. It is also necessary to continue the research and awareness work initiated by the BFN.

With such actions, sociobiodiversity gains importance and becomes better known in different sectors of society.

DATA PUBLISHED IN:

MINISTÉRIO DO MEIO AMBIENTE. Plantas para o Futuro. Brasília. Disponível em: <https://www.mma.gov.br/biodiversidade/conservacao-e-promocao-do-uso-da-diversidade-genetica/plantas-para-o-futuro.html>. Acesso em: 6 fev. 2020.

SISTEMA DE INFORMAÇÃO SOBRE A BIODIVERSIDADE BRASILEIRA (SiBBr). Ferramenta Biodiversidade e nutrição: composição nutricional e receitas. 2018. Disponível em: <https://ferramentas.sibbr.gov.br/ficha/bin/view/FN>. Acesso em: 6 fev. 2020.

SANTIAGO. R. de A. C.; CORADIN. L. (ed.). Biodiversidade brasileira: sabores e aromas. Brasília: MMA. 2018. (Série Biodiversidade/MMA. 52). Disponível em: <https://www.mma.gov.br/publicacoes/biodiversidade/category/54-agrobiodiversidade.html>. Acesso em: 6 fev. 2020.

Continued in Annex

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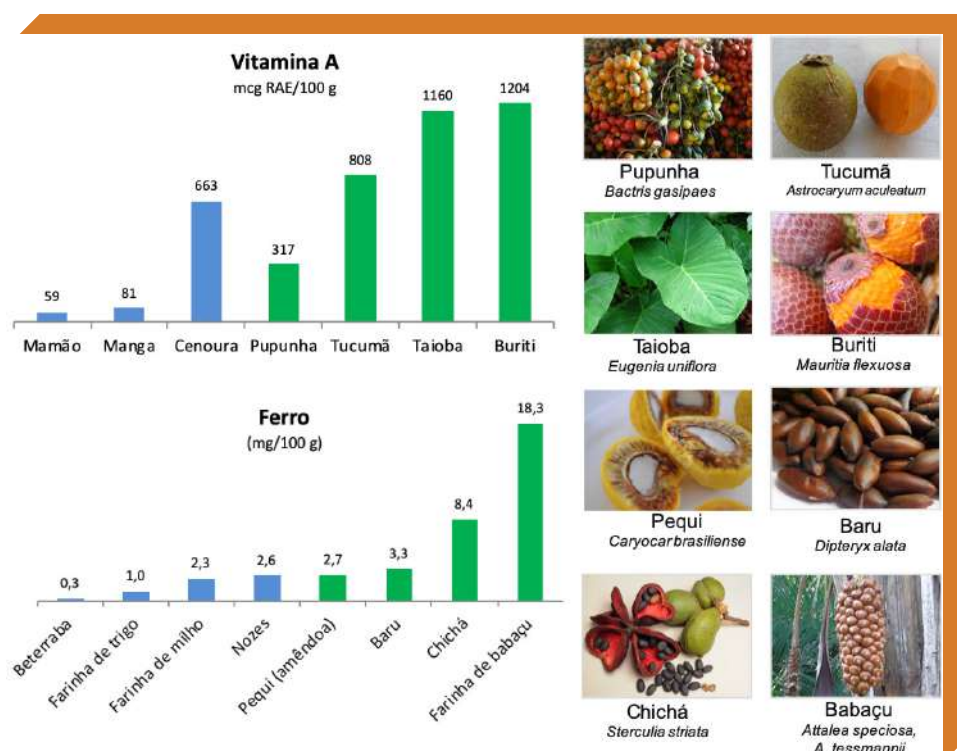
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Figure 1: Vitamin A and iron content in Brazilian sociobiodiversity foods (green) and in other foods (blue)



Source: SiBBr (2018) - Biodiversity Nutritional Composition Database, TACO (2011) - Brazilian Food Composition Table.

Credit: BFN Project.

INCREASING NATIVE SEEDLINGS AND SEED TOLERANCE TOWARDS GREATER RESILIENCE OF THE CAATINGA BIOME TO CLIMATE CHANGE

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The countryside of the Northeast is the Brazilian region most vulnerable to climate change, with a semiarid climate and xerophilic vegetation, corresponding to the Caatinga Biome. However, native species in this biome have a high tolerance for extreme conditions and the production of quality native seeds occurs throughout the year, even in periods of intense drought. The production and commercialization of seeds and forest seedlings native to the Caatinga can generate income for the farmer who has a preservation area on his rural property, as they can be produced at low cost and with a small amount of quality water.

In order to evaluate and increase the tolerance of these species to climate change in the Northeast of Brazil and promote the production of seeds and seedlings for the restoration of degraded areas of Caatinga, research was carried out on modeling the germination of native seeds and pretreatments that relieve stress and promote the production of more vigorous seedlings.

Three research projects (funded by CAPES, CNPq and Embrapa) were developed with the objective of assessing the tolerance of seeds and seedlings of native tree species in the Caatinga to environmental stresses; predict seedling germination and initial development in future climate; propose the discontinuous hydration technique of the seeds to induce greater tolerance to stresses and to guarantee the production of seedlings that are more resilient to field conditions.

The seeds germinated under different thermal conditions (temperatures from 5 to 50°C), water conditions (osmotic potentials of up to -1.8 MPa) or saline conditions (electrical conductivities of up to 40 dS m⁻¹). Germination requirements and limits were obtained in these conditions. Based on this information, germination modeling was performed for the year 2055, in the pessimistic climate scenario RCP 8.5, with the highest concentrations of greenhouse gases; an increase of up to 5°C in the average temperature of the Caatinga and a reduction in the volume of rain of up to 40%.

The seeds were submitted to the discontinuous hydration (HD) technique, with up to three cycles of HD, at specific hydration times for each species and, subsequently, submitted to the conditions of high temperatures, salinity or water deficiency.

RESULTS

Many Caatinga species germinate even under conditions of low water availability, showing high tolerance to water or osmotic stress during the early stages of development. The base (or minimum) osmotic potential varied around -0.8 MPa and was equivalent to 13.9% moisture in soils in the region where the seeds were harvested. From the minimum moisture in the soil (13.9%) for seed germination, the minimum precipitation (17.5 mm) required in one week for these seeds to germinate in the Caatinga was calculated. This water layer allowed the germination of angico seeds, as well as the adequate growth of seedlings in greenhouse.

According to RCP 8.5, the number of weeks with temperature and precipitation required for seed germination will decrease from 14 (historical data from 1970-2014) to four weeks in 2055. However, it remains to be seen whether this will be sufficient to guarantee the establishment of a new plant in the environment.

Due to the location of development and maturation of Caatinga seeds, these are naturally tolerant to the high temperatures to which they are subjected, with optimal germination temperature between 30 and 35 °C. The germination of these seeds is inhibited only at temperatures around 40 °C.

Caatinga seeds in general have a high tolerance to salinity. This means that, as long as there is water in the medium, they germinate and produce young plants (6 months) even in saline conditions. Native legumes germinate in electrical conductivities greater than 30 dS m⁻¹, and mulungu germinated in a salinity close to seawater. Other species such as aroeira, despite being less tolerant to soil salinity or irrigation water, still develop in brackish water with up to approximately 7 dS m⁻¹, enabling the production of seedlings with water reuse or use of brackish water and thus subsidize the restoration of the Caatinga, reduce greenhouse gas emissions and combat climate change.

The HD cycles showed positive effects on germination in the laboratory and seedling emergence in a greenhouse, indicating a physiological conditioning (hydroconditioning) of the seeds. In addition, with the exception of pereiro seeds, this technique increased seed tolerance to water deficit (Table).

NEXT STEPS AND RECOMMENDATIONS

Using the water memory of seeds, a natural phenomenon that occurs in the Caatinga, resulting from HD cycles, for the production of hydroconditioned seeds and more vigorous seedlings for reforesting the ecosystem is an accessible, low cost and viable technique, since one of problems in the production and planting of seedlings in the Caatinga is spending on irrigation due to limited rainfall.

Studies that prove the results of this research in reforestation areas and in agroforestry systems are in an initial phase.

DATA PUBLISHED IN:

DANTAS. B. F.; MOURA. M. S. B.; PELACANI. C. R.; ANGELOTTI. F.; TAURA. T. A.; OLIVEIRA. G. M.; BISPO. J. S.; MATIAS. J. R.; SILVA. F. F. S.; PRITCHARD. H. W.; SEAL. C. E. Rainfall. not soil temperature. will limit the seed germination of Caatinga dry forest species with climate change. *Oecologia*. v. 41. n. 1. p. 32-43. Feb. 2019.

DANTAS. B. F.; RIBEIRO. R. C.; MATIAS. J. R.; ARAÚJO. G. G. L. Germinative metabolism of Caatinga forest species in biosaline agriculture. *Journal of Seed Science*. v. 36. n. 2. p. 194-203. Apr./June 2014.

LIMA. A. T.; CUNHA. P. H. de J. da; DANTAS. B. F.; MEIADO. M. V. Does discontinuous hydration of *Senna spectabilis* (DC.) H. S. Irwin & Barneby var. *excelsa* (Schrad.) H. S. Irwin & Barneby (Fabaceae) seeds confer tolerance to water stress during seed germination? *Journal of Seed Science*. v. 40. n. 1. p. 36-43. Jan./Mar. 2018.

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Table 1: Tolerance limits of seeds of native Caatinga tree species subjected, during germination, to water restriction (low osmotic potential), to high temperatures and electrical conductivity with and without after discontinuous hydration

Species (FAMILY)	Common name	Without hydroconditioning			With hydroconditioning		
		Ø (MPa)	T (°C)	EC (dS.m ⁻¹)	Ø (MPa)	T (°C)	EC (dS.m ⁻¹)
<i>Anadenanthera colubrina</i> (Vell.) Brenan (FABACEAE)	angico	-0.7	48	30	< -0.9*	48*	30*
<i>Aspidosperma pyrifolium</i> Mart. & Zucc. (APOCYNACEAE)	pereiro	-0.7	40	18	-0.7	40	18
<i>Erythrina velutina</i> Willd. (FABACEAE)	mulungu	-0.6	40	48	-	-	-
<i>Astronium urundeuva</i> Allemão (ANACARDIACEAE)	aroeira	-0.8	> 40	18	-	-	-
<i>Cenostigma pyramidale</i> (Tul.) Gagnon & G. P. Lewis (FABACEAE)	catingueira	-0.8	45	29	-	-	-
<i>Senna spectabilis</i> (DC.) H. S. Irwin & Barneby (FABACEAE)	canafístula	-0.74	-	-	-1.8	-	-

Note: * maximum value evaluated with seed germination, higher values are needed to verify the tolerance limit

Source: Authors.

ECOPHYSIOLOGY OF NATIVE CAATINGA PLANTS AT EMBRAPA –SEMIARIDO

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Drought resistance is the focus of studies by the research team in ecophysiology of native Caatinga plants in the of Embrapa - Semiárido. In addition to elucidating the mechanisms involved, the group aims to develop technological and pre-technological assets aimed at agriculture. The projects may involve actions in specific regions of the Semiárido, through the prospecting of new accesses and new species, but their applications can normally extend to the border regions of this ecosystem. In addition to constituting demand for areas subject to drought across the northeastern hinterland characterized by its semiárido climate, results from this line of research also constitute solutions for mitigating the effects of climate change related to the intensification of droughts in other regions.

The results developed are intended both to subsidize other research programs in genetic improvement and product development, involving students and professionals from public and private institutions as their target audience, as well as for direct use by rural producers interested in the reintroduction and/or management of species with economic potential. In capacity building and training, the target audience is expanded to include rural development agents, technicians and public managers, aiming at training skills and creating conditions so that the technologies generated can be adopted by the productive sector.

The funding of these projects is carried out mainly through resources from the Union to Embrapa's budget, and also by state and federal research foundations, in the form of public editais.

The projects and actions related to the group's studies are duly registered in the National System for the Management of Genetic Heritage and Associated Traditional Knowledge - SisGen, under the codes A18C458, AD40331, A59AD05, AF44DE9, AF918EE, A98AA8D, AC7A21A, A3790D0, A1B41EA, A0FA681, A5C89E6.

RESULTS

The research results point to the occurrence of variable sets of resistance mechanisms in the studied species, in order to avoid dehydration, in the case of the deciduous *Poincianella microphylla* (Fabaceae) (REZENDE et al., 2016) and *Croton conduplicatus* (Euphorbiaceae), or maintain the continuity of water loss in the

evergreens *Colicodendron jacobinae* and *Colicodendron yco* (Capparidaceae). The desiccation tolerance strategy was demonstrated in *Selaginella convoluta* (Selaginellaceae) and *Tripogon spicatus* (Poaceae) (AIDAR et al., 2017; MORGANTE et al., 2018), in which genes responsible for the protection and physiological recovery mechanisms of whole plants that have been previously dehydrated to a relative water content of around 10%. In addition to genes, the study of the native microbiota associated with *T. spicatus* led to the identification of a set of nitrogen-fixing and growth-promoting bacteria potentially useful for improving the performance of grasses cultivated under water deficit conditions (FERNANDES-JÚNIOR et al., 2015).

As for the fruitful potential, the partnership between different lines of research and laboratories at Embrapa led to the registration of four cultivars in MAPA in 2017, under the names BRS 48, BRS 52, BRS 55 and BRS 68 (Figure), from the Active Germplasm Bank (BAG) from the Company's umbu trees (*Spondias tuberosa*), selected for their larger fruit size and sweeter pulp flavor (SANTOS et al., 1999). The umbuzeiro's extreme drought-resistant capacity allows its cultivation and that of other *Spondias* (umbu-cajá, umbuguela, among others) under rain dependence when grafted onto the native species, mainly due to the accumulation of water and nutrients in its tuberous roots. Another example of the use of native fruit potential applies to the study of accesses of passion fruit trees from the Caatinga (*Passiflora cincinnata*) from the Passion Fruit BAG (BGM) of Embrapa Semiárido, whose results contributed to the development and registration of the cultivar BRS Sertão Forte in 2016, and to identify differences in the capacity of resistance to dehydration among accesses in the collection for use in genetic improvement programs (MARÇAL et al., 2018).

NEXT STEPS AND RECOMMENDATIONS

As a focus of action, the group should direct efforts towards the development of agricultural practices and processes with high potential economic impacts.

DATA PUBLISHED IN:

AIDAR. S. de T.; CHAVES. A. R. de M.; FERNANDES JUNIOR. P. I.; OLIVEIRA. M. de S.; COSTA NETO. B. P. da; CALSA JUNIOR. T.; MORGANTE. C. V. Vegetative desiccation tolerance of *Tripogon spicatus* (Poaceae) from the tropical semiarid region of northeastern Brazil. *Functional Plant Biology*. v. 44. n. 11. p. 1124-1133. Nov. 2017.

FERNANDES JUNIOR. P. I.; AIDAR. S. de T.; MORGANTE. C. V.; GAVA. C. A. T.; ZILLI. J. E.; SOUZA. L. S. B. de; MARINHO. R. de C. N.; NÓBREGA. R. S. A.; BRASIL. M. da S.; SEIDO. S. L.; MARTINS. L. M. V. The resurrection plant *Tripogon spicatus* (Poaceae) harbors a diversity of plant growth promoting bacteria in Northeastern Brazilian Caatinga. *Revista Brasileira de Ciência do Solo*. Viçosa-MG. v. 39. p. 993-1002. July/Aug. 2015.

MARÇAL. K. L. G.; BEZERRA. W. H. F.; ARAÚJO. F. P. de; CHAVES. A. R. de M.; AIDAR. S. de T. Resistência à desidratação de diferentes acessos de *Passiflora cincinnata* Mast. (Passifloraceae). In: JORNADA DE INICIAÇÃO CIENTÍFICA DA EMBRAPA SEMIÁRIDO. 13.. 2018. Petrolina. Anais [...]. Petrolina: Embrapa Semiárido. 2018. p. 329-333.

Continued in Annex

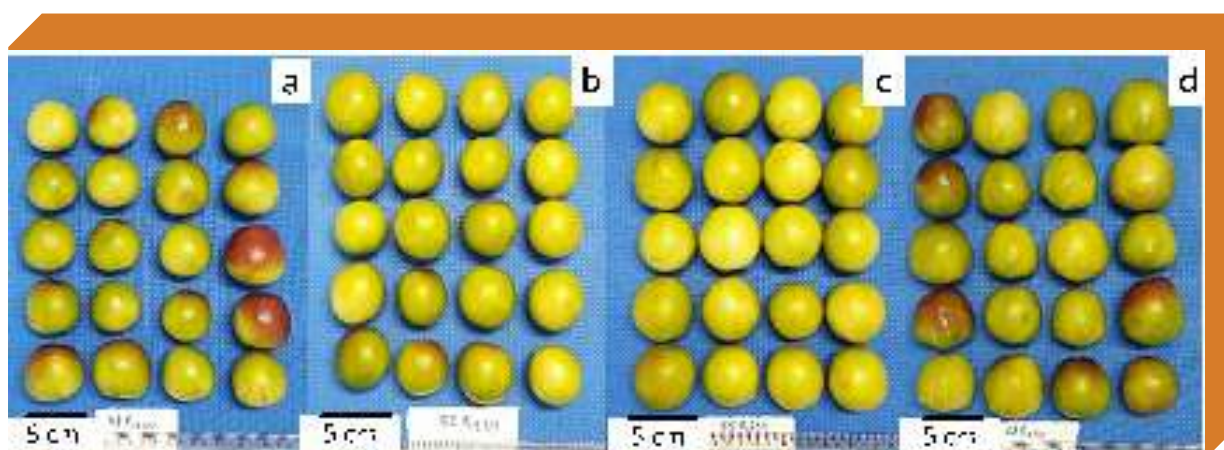
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Figure 1: Visual appearance of fruits from umbu trees (*Spondias tuberosa*) registered at MAPA under the names a) BRS 48, b) BRS 52, c) BRS 55 and d) BRS 68, selected for their larger size and pulp quality



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ARAUCAMATE – STUDY ON THE POTENTIAL DISTRIBUTION OF ARAUCÁRIA AND YERBA MATE FOR A GENETIC USE AND CONSERVATION PROGRAM

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Araucaria angustifolia (Bertol.) O. Kuntze (*Araucaria*) and *Ilex paraguariensis* St. Hil. (*yerba mate*) are forest species of great ecological importance, native to South America, whose exploitation and trade subsidized the economic and social development of the Center-South region of Brazil. The natural forests of these species occur in a diverse mosaic of soil conditions (MARCONDES et al., 2015; BOGNOLA et al., 2017), climate (FRITZSONS et al., 2018 a, b) and landscape, in most of the Atlantic Forest Biome. The intense anthropic pressure and deforestation have resulted in the reduction of the effective size of the populations of these two species, increasing the risks of inbreeding and loss of alleles due to the effect of genetic drift (SHIMIZU, 2000). Such vulnerability will be intensified in the face of global climate change scenarios. However, there is no information on how the species adapt to the new scenarios, nor are strategies defined for conservation under future habitat conditions.

Information on the location and geographical scope of natural populations can contribute significantly to rescuing genes still unknown to the scientific community. The combination of niche models with population genetic data of the species (see WREGE et al., 2016; 2017), in a GIS environment, can generate maps and information that can be used to select priority areas for the conservation of these species and which have greater potential for cultivation. To this end, since 2015, research actions have been developed in the project “Distribution of natural occurrence of *araucaria* and *yerba mate* populations for use in a genetic conservation program” - ARAUCAMATE, financed by Embrapa (Figure 1). The research focuses on identifying the environmental and genetic factors that influence the spatial distribution of natural populations of *araucaria* and *yerba mate* in the Center-South region of Brazil and also phenotypic parameters of commercial interest. In order to measure the impact of climate change projected by the IPCC, niche models of natural populations are also being developed until the year 2100, considering the projections of temperature increase in different scenarios.

Mapping and other information generated can be applied to genetic improvement and forestry programs, to subsidize the sustainable use of regional biodiversity and strengthen productive chains in the sectors of teas (*yerba mate*), pine nuts and wood (*araucaria*). They will also serve to define adaptation actions for these species in the face of climate change, such as the selection of areas for the conservation of genetic biodiversity, thus helping to define public policies aimed at maintaining the resilience of populations of both species, in the face of risks to survival in the coming decades.

NEXT STEPS AND RECOMMENDATIONS

1. Reached:

- Identification of limiting climatic factors for the distribution of *araucaria* and *yerba mate* in southern Brazil;
- Maps of the current potential distribution of the *araucaria* (base period: 1976-2005), and projected according to future climate scenarios (2011-2040; 2041-2070; 2071-2100).

2. Under development:

- Expansion of the climate and pedological information base about these two species;
- Maps with the potential distribution of *yerba mate* in Brazil - base period and future climatic scenarios;
- Growth models of *araucaria*, based on dendrochronology;
- Quantification of phytochemicals and nutrients in *yerba mate* leaves for characterization of populations and selection for silvicultural use;
- Genotyping of *araucaria* and *yerba mate* to differentiate natural populations;
- Growth models for *araucaria* and *yerba mate* associated with the genetic material of populations and the environment.

NEXT STEPS AND RECOMMENDATIONS

- Expansion of the number of populations characterized in the field;
- Improvement of field and laboratory methodology;
- Improvement of the mathematical modeling of the distribution of species including a greater number of environmental layers;
- Use of more advanced genotyping techniques for the genetic characterization of populations;
- Use of information to define priority areas for the conservation of the species' genetic biodiversity.

DATA PUBLISHED IN:

BOGNOLA. H. B.; BOGNOLA. I. A.; SOARES. M. T. S.; MATOS. M. D. F.; WREGE. M.; AGUIAR. A. V. de. Caracterização e classificação de solos sob populações naturais de erva-mate (*Ilex paraguariensis* St. Hill.) no Centro-Sul brasileiro. In: SIMPÓSIO MINEIRO DE CIÊNCIA DO SOLO. 4.. 2017. Viçosa-MG. Anais [...]. Viçosa-MG: UFV. 2017.

FRTZSONS. E.; MANTOVANI. L. E.; WREGE. M. S. Relação entre altitude e temperatura: uma contribuição ao zoneamento climático no estado de Santa Catarina. Brasil. Revista Brasileira de Climatologia. Curitiba. v. 18. n. 12. p. 80-92. jan./jun. 2016.

FRTZSONS. E.; WREGE. M. S.; MANTOVANI. L. E. A distribuição natural do pinheiro-do-paraná no estado do Rio Grande do Sul. Brasil: a influência de fatores climáticos e geomorfológicos. Revista Brasileira de Climatologia. Curitiba. v. 22. n. 14. p. 117-132. 2018b.

Continued in Annex

REFERENCES

FRTZSONS. E.; WREGE. M. S.; MANTOVANI. L. E. Climatic aspects related to the distribution of Brazilian Pine in the State of Santa Catarina. Floresta. Curitiba. v. 48. n. 4. p. 503-512. Oct./Dec. 2018a.

FRTZSONS. E.; WREGE. M. S.; MANTOVANI. L. E. Fatores climáticos limitantes para a distribuição natural da araucária no estado de São Paulo. Scientia Forestalis/Forest Sciences. Piracicaba. v. 45. n. 116. p. 663-672. dez. 2017.

SHIMIZU. J. Y.; JAEGER. P.; SOPCHAKI. S. A. Variabilidade genética em uma população remanescente de Araucária no Parque Nacional do Iguaçu. Brasil. Colombo: Embrapa Florestas. 2000. p. 18-36. (Boletim de Pesquisa Florestal 41).

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Figure 1: (A) Natural occurrence of araucaria in the Pampa biome, in the municipalities of Santana da Boa Vista-Canguçu-Pelotas, state of Rio Grande do Sul, representing the southern limit of occurrence of the species in Brazil. (B) Natural occurrence of yerba mate in the Pampa biome, in the municipalities of Santana da Boa Vista-Canguçu-Pelotas, state of Rio Grande do Sul.



Credit: Marcos Silveira Wrege.

CLIMATE CHANGE AND THE MISMATCH BETWEEN POLLINATORS AND AGRICULTURAL CROPS: THE CASE OF PASSION FRUIT AND XYLOCOPA FRONTALIS AND XYLOCOPA GRISESCENS CARPENTER BEES

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Pollination in agriculture has become vulnerable in different parts of the world, since the diversity of pollinators and their abundance are declining, directly affecting agricultural producers. Climate change is being pointed out as one of the reasons for the reduction of pollinators in these landscapes and studies suggest strong impacts by 2100. Thus, the Project aims to investigate the effects of climate change on the pollination of tropical agricultural crops in the near future. The study, with support from Capes and CNPq, sought to elect an important crop widely distributed in Brazil, and dependent on native wild pollinators, thus passion fruit. Therefore, we investigated how climate change for the Neotropical region may affect the suitability of current crop areas for the crop and the two most important pollinating bee species, *Xylocopa frontalis* (Figure 1) and *X. grisescens*.

The methodology consisted of systematic reviews of the literature and database for bee species and the passion fruit cultivated area in Brazil (BEZERRA et al., 2019). The effects of climate change on the crop and its pollinators were investigated considering two scenarios of the IPCC, RCP 4.5 and RCP 8.5 for the years 2060 and 2080. Models developed by the Hadley Center (HadGEM2-ES) and spatial distribution modeling through the MaxEnt algorithm were used to build future scenarios (PHILLIPS et al., 2006).

The models report that both the crop and the bees will be largely affected, with their suitability areas reduced, with a spatial change of areas suitable for the cultivation and presence of bees and a reduction in the overlapping areas of passion fruit with its pollinators. In addition, many areas may become unsuitable for passion fruit and/or for the existence of bees. However, even if new areas become suitable for one species, they may not be for both.

Strategies to mitigate the effects of climate change will include the selection of agricultural varieties adapted to the new ecological conditions in the current cultivation areas and/or the cultivation of current varieties in the new areas that will become suitable. As for pollinators, favorable conditions for nesting and feeding must be promoted through the management of agricultural areas and surrounding landscapes, as well as the breeding and management of these bees.

RESULTS

- *X. frontalis* bees will be affected especially in the RCP 8.5 scenario for 2060 and 2080. Which would result in an area change of 29.03 to 47.95% (Table);
- The *X. grisescens* bees, despite the loss of area (between 15.41 to 35.32%), are more adapted to the new climatic conditions, increasing the appropriate area between 20.33 to 115.02% (Table);
- Passion fruit will be affected in all scenarios, reducing its potential suitable area between 42.90 to 64.86%, which would reduce between 36.56 to 63.67% of the current cultivation area (Table);
- The appropriate areas of the crop overlapped with the suitable areas of the bees today, will reduce from 31.98 to 54.97% (Table);
- In addition to all the problems related to changing cultivation areas, this would result in higher costs for passion fruit producers who will need to hire more human labor for manual pollination.

NEXT STEPS AND RECOMMENDATIONS

- The possible solutions are to develop varieties of the crop adapted to the changes in the cultivation areas;
- Deploy cultivation in new suitable areas without causing environmental impacts;
- Mitigate the effects by means that favor the presence of pollinators in the crop areas;
- Provide food and nesting resources within or around plantations;
- Develop forms of rational bee breeding, enabling the introduction and removal in areas of future crops or reintroduction in formerly occupied areas that are undergoing a process of recovery.

DATA PUBLISHED IN:

BEZERRA. A. D. M. et al. Agricultural area losses and pollinator mismatch due to climate changes endanger passion fruit production in the Neotropics. *Agricultural systems*. v. 169. p. 49-57. 2019.

REFERENCES

PHILLIPS. S. J.; ANDERSON. R. P.; SCHAPIRE. R. E. Maximum entropy modeling of species geographic distributions. *Ecological Modelling*. v. 190. n. 3-4. p. 231-259. 2006.

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Table 1: Percentages of losses and changes in potential suitable areas for passion fruit (*Passiflora edulis*) and the presence of pollinators (*Xylocopa frontalis* and *Xylocopa grisescens*) in the Neotropics under the future scenarios of RCP 4.5 and RCP 8.5, for the years 2060 and 2080

Scenarios*	Passiflora edulis		Xylocopa frontalis		Xylocopa grisescens		Areas of bees overlapping with passion fruit crop
	Area loss (%)	Area change (%)	Area loss (%)	Area change (%)	Area loss (%)	Area change (%)	Area loss (%)
RCP 4.5 (2060)	44.91	- 39.03	27.34	8.34	15.41	115.02	- 34.17
RCP 4.5 (2080)	51.34	- 47.90	15.48	59.70	27.81	41.56	- 38.22
RCP 8.5 (2060)	42.90	- 36.56	57.71	- 47.95	23.52	45.59	- 31.98
RCP 8.5 (2080)	64.86	- 63.67	47.06	- 29.03	35.32	20.33	-54.97

Note: * Scenarios based on the IPCC; RCP 4.5 and RCP 8.5.
Source: Authors.

Note: * Scenarios based on the IPCC; RCP 4.5 and RCP 8.5

Source: Authors.

Figure 1: Carpenter bee *Xylocopa frontalis* pollinating the passion fruit (*Passiflora edulis*) flower.



Crédit: Breno Magalhães Freitas.

NORTH AND NORTHEAST FRUIT POLLINATION RESEARCH NETWORK

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Pollination is one of the most important environmental services, as it promotes plant genetic diversity, increasing the resilience of terrestrial ecosystems, in addition to providing benefits for the well-being of living beings (WOLOWSKI et al., 2019). Global climate change affects this balance, altering the timing of the flowering season with the activity of pollinators (GIANNINI et al., 2017).

The Amazon is the origin center of fruit species with high commercial potential, products of socio-biodiversity such as the Brazil nut (*Bertholletia excelsa*) and açai (*Euterpe oleracea*) that depend on the forest to provide pollinators. The Rede Castanha-do-brasil (CNPq Proc. 556406/2009- 5) showed that in cultivated areas close to forests in a good state of conservation, the wealth of pollinators is greater (CAVALCANTE et al. 2012; MAUÉS et al. 2015). The same was found in the pollination of the açazeiro in the estuary of the Amazon River (CAMPBELL et al. 2018, BEZERRA et al. 2020).

The PolinizaAÇAÍ project (CNPq Proc. 400568/2018-7) evaluates the potential of pollinator management (*Scaptotrigona* aff. *Postica*) to improve fruit yield and socioeconomic indexes for açai growers in different types of management (native açazais in the floodplains and plantations on dry land), as well as the impact of changes in the landscape adjacent to the plantations and native açai groves on the population of wild pollinators and açai fruit production. Açai is essential to Pará's economy and to the food security of local communities.

Little is known about the network of interactions between pollinators and fruit trees, and almost nothing about the potential for intercropping between them. The interactions between bees and fruit are the subject of studies of the PoliNet project (12.16.04.024.00 - SEG Embrapa), through the characterization of the interaction networks of floral açai visitors, camucamu, abricó-do-pará and guaraná, and of the plants surrounding the crops.

These projects seek to learn about the key pollinator species of Amazonian fruit trees, their relationship

with native forests, and to identify the ones that can be suggested as priorities for programs of management and rational raising. Improving agricultural productivity and, at the same time, minimizing environmental and climate change impacts, is one of the main challenges in the tropics, where natural habitats are rapidly being converted.

RESULTS

- More than 25 species of native solitary bees pollinate Brazil nuts;
- More than 100 species of insects (bees, flies, wasps and beetles) pollinate the açazeiro, especially stingless bees;
- Native bees are also effective pollinators of the camucamuzeiro and guaranazeiro (in this, the twilight solitary bees stand out) (Figure 1);
- The greater the integrity of the natural vegetation around the plantations or in the matrix where the fruit species grow, the greater the diversity and abundance of pollinators and the better the success of pollination;
- The standing forest is the best way to preserve the pollinators of brazil nut trees and açai;
- The management of native pollinators (stingless bees) can be an alternative to fill the deficit of pollination for the açai tree, when the forest surrounding the plantations is not sufficient to provide this input.

NEXT STEPS AND RECOMMENDATIONS

- Define stingless bee management recommendations *Scaptotrigona* aff. *postica* for pollination of the açazeiro, the socioeconomic and valuation indexes of the pollination service;
- Characterize the plant-pollinator interaction networks for the fruit trees and the alternative sources of floral resources;

- Expand knowledge sharing with society, mainly producers, extension workers, academia and the third sector, aiming at the adoption and validation of research results in the field;
- Increase awareness that agriculture depends on pollinators and the supply of pollinators, either naturally or through introduction and management, must be an agricultural input to be considered in the planning of productive systems;
- Strengthen the dialogue with decision makers, providing information to support laws and other instruments that can regulate the protection of pollinators, such as the Report on Pollination, Pollinators and Food Production (WOLOWSKI et al. 2019);
- Encourage the adoption of practices that are friendly to pollinators and restrict the use of pesticides, adoption of agroecological practices, biological control, planting in Agroforestry Systems, agriculture without fires, supply of substrate for nesting bees, recognition of pollination as an agricultural input, stimulate the training of farmers and extension workers in this area, among others;
- To reiterate the recommendations of the environmental legislation, through the fulfillment of the Brazilian Forest Code, which in the Amazon recommends the preservation of up to 50-80% of the native forest areas on rural property and the connectivity between these areas, so that they can be belt were pollinators will move and survive.

DATA PUBLISHED IN:

BEZERRA. L. A.; CAMPBELL. A. J.; BRITO. T. F.; MENEZES. C.; MAUÉS. M. M. Pollen loads of flower visitors to açai palm (*Euterpe oleracea*) and implications for management of pollination services. *Neotropical Entomology*. v. 49. p. 482-490. 2020.

CAMPBELL. A. J.; CARVALHEIRO. L. G.; MAUÉS. M. M.; JAFFÉ. R.; GIANNINI. T. C.; FREITAS. M. A. B.; COELHO. B. W. T.; MENEZES. C. Anthropogenic disturbance of tropical forests threatens pollination services to açai palm in the Amazon river delta. *Journal of Applied Ecology*. v. 55. n. 4. p. 1725-1736. Jan. 2018.

CAVALCANTE. M. C.; CAVALCANTE. M. C.; OLIVEIRA. F. F.; MAUÉS. M. M.; FREITAS. B. M.; FREITAS. B. M.; OLIVEIRA. F. F.; MAUÉS. M. M. Pollination requirements and the foraging behavior of potential pollinators of cultivated brazil nut (*Bertholletia excelsa* Bonpl.) trees in Central Amazon rainforest. *Psyche*. n. especial. p. 1-9. May 2012.

REFERENCES

GIANNINI. T. C.; COSTA. W. F.; CORDEIRO. G. D.; IMPERATRIZ-FONSECA. V. L.; SARAIVA. A. M.; BIESMEIJER. J.; GARIBALDI. L. A. Projected climate change threatens pollinators and crop production in Brazil. *PLoS ONE*. v. 12. n. 8. 2017.

MAUÉS. M. M.; KRUG. C.; WADT. L. H. O.; DRUMOND. P. M.; SANTOS. N. A. S. A castanheira-do-brasil: avanços no conhecimento das práticas amigáveis à polinização. Rio de Janeiro: Funbio. 2015.

WOLOWSKI. M.; AGOSTINI. K.; RECH. A. R.; VARASSIN. I. G.; MAUÉS. M.; FREITAS. L.; CARNEIRO. L. T.; BUENO. R. O.; CONSOLARO. H.; CARVALHEIRO. L.; SARAIVA. A. M.; SILVA. C. I. Relatório temático sobre polinização. polinizadores e produção de alimentos no Brasil. Brasília: Editora Cubo. 2019.

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Figure 1: Pollinators of Amazonian fruit trees. Uruçu-amarela (*Melipona flavolineata*) visiting the camu-camu flower (*Myrciaria dubia*)



Crédit: Márcia Maués.

IMPACT OF CLIMATE CHANGE ON BRAZILIAN CROPPOLLINATORS

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Agricultural production is mediated by species of fauna that act as pollinators, favoring the production of fruits and seeds. The main objective of this approach was to assess the vulnerability of production due to the impact of climate change on pollinators, with an emphasis on bees.

To assess the impact of climate change on pollinators and agricultural production, it was necessary to organize a database on interactions between agricultural crops and their pollinators (GIANNINI et al., 2015a; 2015b; 2020a). This step made it possible to identify the knowledge gaps, involving: [1] taxonomic impediment of bee species; [2] crops that have not yet been studied with regard to the degree of dependence on animal pollination and the determination of effective pollinators; [3] less studied regions; and [4] annual production of regional crops that are not included in public databases.

Next, Species Distribution Modeling was used, to analyze possible climate change scenarios and projects potential changes in habitat suitability and, consequently, in species distribution (GIANNINI et al., 2012; 2013b; 2017a; 2020b) (Figure 1). Therefore,

several scenarios were evaluated in order to determine possible pollinator losses, and how this could potentially affect agricultural production. To date, thirteen Brazilian crops have been further evaluated, involving more than 90 species of pollinators (GIANNINI et al., 2017a). We analyzed a variable associated with the potential loss of pollinators on a 10x10 km spatial scale, at the national level, which we called "probability of occurrence of pollinators", a number ranging from -1 (100% probability of pollinator loss) to +1 (100 % probability of pollinator gain) (GIANNINI et al., 2017a) (Table 1). This variable was determined for each of the thirteen crops analyzed and associated with the producing municipalities, which allows an economic estimate of the potential reduction in the production of each of the crops at the municipal level.

The next necessary steps are to increase knowledge about the interaction between pollinators and crops, as well as to study plants of regional economic interest. Possible proposals to solve the risk of loss of pollinators in agricultural production include: [1] restoration of habitats degraded by human activities; [2] conservation /restoration of areas of Legal Reserve within the cultivation areas; [3] determination of native and local pollinating bee species that can be managed in cultivated

areas; [4] increased knowledge about pollinator-Crop interactions.

The target audience of the research is composed of other researchers and public policy decision makers. The initiative also targeted the general public, as promotional materials have been produced throughout the project.

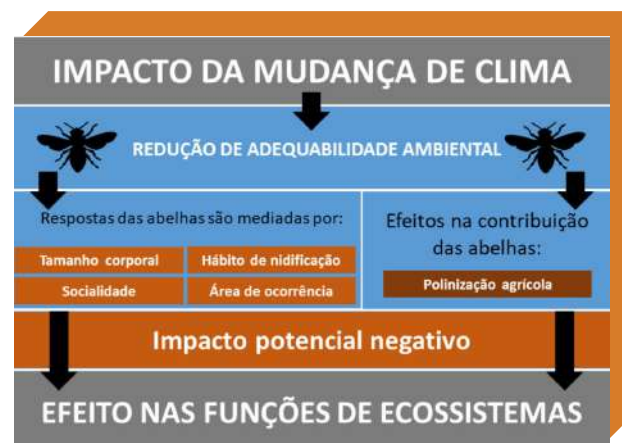
There was no specific funding source for the project, but other aid and infrastructure from ITV, USP, UFPA, UNISA, CAPES, CNPq, FAPESP and FAPESPA were essential.

RESULTS

Results achieved

- Database for Brazil on pollinators of agricultural crops and crop dependence on pollinators;
- Analysis of climate change impacts on pollinators of Brazilian agricultural crops;
- A list of plant species used for food by local and riverside communities in the Amazon was drawn up, and the pollination syndrome of these plants was analyzed.

Figure 1: Effects of the impact of climate change on bee species include reducing the environmental suitability of their areas of occurrence. Bees' responses to climate change can be complex, with potential negative effects on ecosystem functions and services, such as agricultural pollination



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The proposed initiatives expect to achieve

- Understanding of the vulnerability of agricultural production considering the impacts of climate change on their effective pollinators.

NEXT STEPS AND RECOMMENDATIONS

- Current stage: analysis of the vulnerability of agricultural production considering climate change and its effects on pollinators, with an emphasis on the Amazon region;
- Main challenge: data gap on interactions between animals and plants of economic interest for determining effective pollinator species;
- Solutions: field research aimed at the analysis of pollinators of flora species of economic interest;
- Next steps and/or perspectives: study on the management and introduction of bees in agricultural crops with high production value.

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DATA PUBLISHED IN:

GIANNINI. T. C.; BOFF. S.; CORDEIRO. G. D.; CARTOLANO. E. A.; VEIGA. A. K.; IMPERATRIZ-FONSECA. V. L.; SARAIVA. A. M. Crop pollinators in Brazil: a review of reported interactions. *Apidologie*. v. 46. n. 2. p. 209-223. 2015a.

GIANNINI. T. C.; CORDEIRO. G. D.; FREITAS. B. M.; SARAIVA. A. M.; IMPERATRIZ-FONSECA. V. L. The dependence of crops for pollinators and the economic value of pollination in Brazil. *Journal of Economic Entomology*. v. 108. n. 3. p. 849-857. 2015b.

GIANNINI. T. C.; COSTA. W. F.; CORDEIRO. G. D.; IMPERATRIZ-FONSECA. V. L.; SARAIVA. A. M.; BIESMEIJER. J.; GARIBALDI. L. A. Projected climate change threatens pollinators and crop production in Brazil. *PLoS ONE*. v. 12. n. 8. 2017.

REFERENCES

GIANNINI. T. C.; ALVES. D. A.; ALVES. R.; CORDEIRO. G. D.; CAMPBELL. A. J.; AWADE. M.; BENTO. J. M. S.; SARAIVA. A. M.; IMPERATRIZ-FONSECA. V. L. Unveiling the contribution of bee pollinators to Brazilian crops with implications for bee management. *Apidologie* v. 51. p. 406-421. 2020a.

GIANNINI. T. C.; COSTA. W. F.; BORGES. R. C.; MIRANDA. L.; COSTA. C. P. W.; SARAIVA. A. M.; IMPERATRIZ-FONSECA. V. L. Climate change in the Eastern Amazon: crop-pollinator and occurrence-restricted bees are potentially more affected. *Regional Environmental Change* 20. n. 9. 2020b.

PAZ. F. S.; PINTO. C. E.; BRITO. R. M.; IMPERATRIZ-FONSECA. V. L.; GIANNINI. T. C. Which are the main pollinators of edible plant species in the Brazilian Amazon Forest? *Journal of Economic Entomology*. 2021. <https://doi.org/10.1093/jee/toaa284>

Table 1: Potential impact of climate change on pollinators in each Crop analyzed, considering a decrease in the probability of occurrence of pollinators and the percentage of potentially affected municipalities.

Agricultural crop	Reduction in the average likelihood of ocorrência dos polinizadores (%)	Total number of municipalities that produce the crop	Percentage of potentially affected
Avocado	10.4	673	91.1
Acerola	14.0	201	74.6
Cotton	6.9	321	99.1
Coffee	15.3	1.708	95.5
Khaki	2.8	579	86.9
Coconut	5.6	1.753	86.8
Beans	9.9	4.188	84.2
Sunflower	17.7	101	100.0
Guava	16.0	838	94.6
Passion Fruit	10.8	1.155	84.2
Tangerine	15.1	13.645	9.3
Tomato	25.5	1.743	87.3
Annatto	14.7	258	85.3

Source: Giannini et al., 2017a.

SELECTION OF PLANT GROWTH PROMOTING BACTERIA FOR TRADITIONAL FOOD CROPS IN THE SEMI-ARID ENVIRONMENT

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The research on this subject was conducted with the objective of obtaining growth-promoting bacteria for different crops in the semiarid region, the Caatinga biome, aiming at increases in productivity and reduction in the demand for fertilizers, especially nitrogenous ones, as well as reducing the effects of these stresses on bacteria, benefiting mainly the small family-based producers in the hinterland. These actions are included in research projects for several important crops in family-based systems such as cowpea, peanuts and corn. In two projects, conducted between the years 2011 and 2015, we structured culture collections based on the isolation and characterization of bacterial isolates aiming at the selection of bacteria with the potential to promote plant growth, especially nitrogen fixers. As of 2015, we have been conducting projects with the objective of validating the agronomic efficiency of these previously selected isolates (Table 1). These results have pointed to the existence of bacteria with the potential to be used as commercial inoculants in the mentioned crops, which can increase productivity and reduce the use of fertilizers in the cultivation of corn, cowpea and peanuts. In addition to productive gains, these bacteria increase the resilience of crop productivity, in the face of a scenario of changes in the climate.

RESULTS

Selection of rhizobia strains for peanuts

- From a crop collection structured with approximately 150 rhizobial isolates, selection experiments highlighted the symbiotic performance of the ESA 123 strain of *Bradyrhizobium* sp. in harsh conditions (SANTOS et al., 2017; BARBOSA et al., 2018). Results in field trials in different field conditions in the Northeast confirmed the efficiency of this rhizobia strain (SIZENANDO et al., 2016). At the moment, network experiments are being carried out with the intention of evaluating the efficiency of this strain in experiments in the Northeast region, with the objective of validating its agronomic efficiency, according to the MAPA determinations for the recommendation of new bacteria for rhizobial inoculants (BRASIL, 2011).
- Selection of rhizobia strains for cowpea

- For the cowpea crop, some crop collections were structured by the team at Embrapa Semiárido and partner institutions, totaling more than 400 isolates. In preliminary selection tests, strains of *Bradyrhizobium* spp. ESA 17 and ESA 18 showed greater symbiotic efficiency in pot tests and agronomic efficiency in field experiments in the sub-medium conditions of the São Francisco Valley (MARINHO et al., 2017). These strains will be evaluated in network experiments to validate their efficiency.

Selection of strains of growth-promoting bacteria for corn

- Isolation and characterization of bacteria with the potential to promote plant growth was carried out with financial support from projects financed by CNPq and Embrapa between 2013 and 2017. These studies isolated more than 400 isolates using different approaches to isolation. The selection tests in several stages in the laboratory, greenhouse and field, pointed to the agronomic efficiency of the strains ESA 116 (*Agrobacterium* sp.), ESA 600 (*Bacillus* sp.) And ESA 601 (*Paenibacillus* sp.) (CAVALCANTI et al., 2020; NASCIMENTO, 2018). In seven experiments with MAPA determinations, strain ESA 601 showed statistical superiority compared to treatments without inoculation or fertilization in five trials and strain ESA 600 showed the same superiority in two trials. The results indicate that *Paenibacillus* sp. ESA 601 has the potential to produce inoculants for maize crops.

CHALLENGES

- Once network tests have been carried out with strains selected for other crops in semiarid conditions;
- Assess the ability of soil microorganisms to increase the resilience of species grown in family production systems to climate change scenarios;
- Understand the interactions between microbiology and plant physiology in stressful environments;

- Strengthen the technology transfer actions of inoculants already recommended for crops in family production systems in the Northeast;
- Find alternative sources of financing for research projects on crops that are essential for family farming systems in the semiarid region.

SOLUTIONS

- Structuring laboratories, institutions and research groups for the selection of strains of growth-promoting bacteria for crops that are essential in family farming systems in the Northeast;
- Obtaining funding for research on the development of new biotechnological products from soil microorganisms in order to reduce the impacts of climate change on annual crops in the semiarid environment;
- Provide the research results for formulating public policies.

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DATA PUBLISHED IN:

CAVALCANTE. M. C.; FREITAS. B. M.; MAUÉS. M. M. Polinização de algumas culturas agrícolas: polinização da castanheira-do-brasil (*Bertholletia excelsa*). Petrolina: Embrapa Semiárido. 2012. v. 249. p. 58-68. (Documentos/Embrapa Semiárido. Online).

CAVALCANTE. M. C.; GALETTO. L.; MAUÉS. M. M.; PACHECO FILHO. A. J. S.; BOMFIM. I. G. A.; FREITAS. B. M. Nectar production dynamics and daily pattern of pollinator visits in Brazil nut (*Bertholletia excelsa* Bonpl.) plantations in Central Amazon: implications for fruit production. *Apidologie*. v. 49. n. 4. p. 505-516. Aug. 2018.

CAVALCANTI. M. I. P.; NASCIMENTO. R. DE C.; RODRIGUES. D. R.; ESCOBAR. I. E. C.; FRAIZ. A. C. R.; SOUZA. A. P. DE; FREITAS. A. D. S. DE; NÓBREGA. R. S. A.; FERNANDES-JÚNIOR. P. I. Maize growth and yield promoting endophytes isolated into a legume root nodule by a cross-over approach. *Rhizosphere*. v.15. p.100211. 2020.

Continued in Annex

REFERENCES:

BARBOSA. D. D.; BRITO. S. L.; FERNANDES. P. D.; FERNANDES-JÚNIOR. P. I.; LIMA. L. M. de. Can Bradyrhizobium strains inoculation reduce water deficit effects on peanuts? *World Journal of Microbiology and Biotechnology*. v. 34. p. 87. 2018.

BRASIL. Ministério da Agricultura. Pecuária e Abastecimento. Instrução Normativa 13/2011 – Normas sobre especificações. garantias. registro. embalagem e rotulagem dos inoculantes destinados à agricultura. das especificações. garantias mínimas e tolerâncias dos produtos. Brasília: MAPA. 2011. Disponível em: <http://www.agricultura.gov.br/>.

Continued in Annex

Table 1: Summary of the results of the research actions achieved in the projects coordinated by Embrapa – Semiárido between 2011 and 2019

Crops	Experiments*	Results
Peanut	5	Agronomic efficiency of the ESA 123 strain of <i>Bradyrhizobium</i> sp. verified preliminary experiments and validation in accordance with the MAPA determinations being conducted.
Cowpea:	2	<i>Paenibacillus</i> sp. ESA 601 with agronomic efficiency superior to the uninoculated and unfertilized treatments in five out of seven experiments assessed in the Northeast Region.
Corn	7	<i>Paenibacillus</i> sp. ESA 601 with agronomic efficiency superior to the uninoculated and unfertilized treatments in five out of seven experiments assessed in the Northeast Region.

Note: * number of field experiments collected so far.

Caption: own authorship

THE PLANTS FOR THE FUTURE INITIATIVE: NATIVE SPECIES FROM THE BRAZILIAN FLORA WITH CURRENT OR POTENTIAL ECONOMIC VALUE

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In the 20th century, several estimates assessed the economic use of plants. In 1969, Mangelsdorf claimed that man had already used 3,000 species. Kunkel (1984), listed 12,500 species with food potential. Myers (1984) states that the man would have used 7,000 species. Wilson (1988) indicates 75,000 edible plants, many of which are superior to current crops. Rapoport and Drausal (2001), propose 27,000 species used as food. FAO cites 5,000 to 10,000 species (FAO/UN, 2005; 2008).

There is a consensus on the existence of 10 to 20% of potential food plants. But how many actually feed mankind? For Mangelsdorf, cited by Prescott-Allen (1990), there would be 15 species, which, according to Biazotto et al. (2019), account for 90% of the energy demanded by humans. For Solbrig (1992) 20 plants and 5 animals represent 90% of human sustenance and international food trade, a number considered to be very restricted.

With 15 to 20% of biodiversity, Brazil is the main megadiverse country (MITTERMEIER et al., 1997), which gives it an enormous comparative advantage. With climate change, population expansion and the succession of diseases and pests, the diversification of the use of these resources is strategic. In addition to being adapted and resilient, they have high nutritional value and can develop in adverse environments.

To expand the use of native species, improve perception and raise public concern, the Plants for the Future Initiative was created, with the purpose of: offering a clear assessment of the importance of these issues and actions to be taken; stimulate research and innovation to expand knowledge and add value; and warn of climate change and the importance of these species, varieties and cultivars adapted to local conditions (CORADIN et al., 2018).

The Initiative, developed in the five major regions of the country, involved governmental, non-governmental and private institutions. The species with the greatest potential for cultivation and investment were identified by the business sector and the main groups of use (food, aromatics, forage, medicinal, ornamental). Books from the South, Midwest and Northeast regions are available for consultation. Those in the North and Southeast are being finalized. Each species is presented in a portfolio.

The benefits extend to society as a whole, more directly to local communities; productive sector; technical-scientific community, research institutions and funding agencies; non-governmental organizations and social movements. The Initiative contributed to the Biodiversity, Food and Nutrition Project (BFN), with food and nutritional security actions, a partnership that generated the list of species of socio-biodiversity with food value Ordinance No. 284 (BRAZIL, 2018).

With new public policies and a rich diversity of species, the country can reorganize the agricultural matrix, the production base and minimize dependence on external genetic resources, creating more awareness in society regarding the importance of using local and regional biodiversity.

RESULTS

In the South Region, 149 species were prioritized, in seven use groups: food, aromatic, fibrous, forage, timber, medicinal and ornamental. The multifunctionality of the species was an important characteristic observed.

In the Midwest Region, 177 species were prioritized. There is consistency in the use of fruits and vegetables in people's diets. Exotic appearance, peculiar aroma and nutritional richness make the fruits attractive for cultivation, handling and trade.

In the Northeast, 154 species were prioritized, in ten groups. Many are already commercialized to some degree and can be found in regional markets and open markets.

For the North Region, 159 species were prioritized, in nine groups, with emphasis on the food category. Açaí is the most important Amazonian fruit. However, the production chain is vulnerable and depends on a solution from research institutions, in addition to public policies that regulate and stimulate activity.

The Southeast has 121 species, many of which were also prioritized in other regions. Some have some level of regional use and others are still little known, but have the potential for trade in fresh fruit or Industrialization Highlighting the aromatics, due to the oil and flavor industry.

NEXT STEPS AND RECOMMENDATIONS

The Plants for the Future series has become a reference in the use of native biodiversity and basic reading in the disciplines on the subject in Brazilian universities. Once the collection of publications is complete (Figure), it will provide a complete set of information, helping to value native biodiversity and generate gains for agriculture, the economy and environment. With these publications, there was a significant improvement in the Brazilian's perception of the importance of these species, their nutritional value and reasons for maintaining ecological systems. However, it will be necessary to expand the development of these valuable raw materials, diversify the species that are cultivated, strengthen the production chains and ensure that the prioritized species and their derived products reach the markets.

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DATA PUBLISHED IN:

CORADIN. L.; CAMILLO. J.; PAREYN. F. G. C. (ed.). Espécies nativas da flora brasileira de valor econômico atual ou potencial: plantas para o futuro: Região Nordeste. Brasília: MMA. 2018. Disponível em: <http://www.mma.gov.br/publicacoes/biodiversidade/category/142-serie-biodiversidade.html?download=1216:s%C3%A9rie-biodiversidade-biodiversidade-51>. Acesso em: 6 fev. 2020.

CORADIN. L.; SIMINSKI. A.; REIS. A. Espécies nativas da flora brasileira de valor econômico atual ou potencial: plantas para o futuro: Região Sul. Brasília: MMA. 2011. Disponível em: http://www.mma.gov.br/estruturas/sbf2008_dcbio/_ebooks/regiao_sul/Regiao_Sul.pdf. Acesso em: 6 fev. 2020.

FONTES. V. R.; CAMILLO. J.; CORADIN. L. (ed.). Espécies nativas da flora brasileira de valor econômico atual ou potencial: plantas para o futuro: Região Centro-Oeste. Brasília: MMA. 2018. Disponível em: <http://www.mma.gov.br/publicacoes/biodiversidade/category/142-serie-biodiversidade.html?download=996:serie-biodiversidade-biodiversidade-44>. Acesso em: 6 fev. 2020.

REFERENCES

BIAZOTTO. K. R.; MESQUITA. L. M. de S.; NEVES. B. V.; BRAGA. A. R. C.; TANGERINA. M. M. P.; VILEGAS. W.; MERCADANTE. A. Z.; DE ROSSO. V. V. Brazilian biodiversity fruits: discovering bioactive compounds from underexplored sources. *Journal of Agricultural and Food Chemistry*. v. 67. n. 7. p. 1860-1876. 2019.

BRASIL. Portaria Interministerial MMA e MDS Nº 284. de 30 de maio de 2018. Institui a lista de espécies da sociobiodiversidade, para fins de comercialização in natura ou de seus produtos derivados, no âmbito das operações realizadas pelo Programa de Aquisição de Alimentos-PAA. Brasília-DF: Diário Oficial da União. Seção 1. Nº 131. 10 de julho de 2018.

Continued in Annex

Figure 1: Books from the Plants for the Future series already completed and available for consultation (South, Midwest, Northeast and North regions) or in the process of being finalized (Southeast Region)



Credit: BRASIL, 2018.

AGROECOLOGICAL CASSAVA: A VIABLE ALTERNATIVE IN THE SEMIARID

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Food supply for the population and forage for animals in the semiarid region is unstable throughout the year, due to long periods of drought. This is one of the biggest challenges that research and agricultural extension face, as the scarcity of food affects the health and productive capacity of the population, leading to the impoverishment of these people who become dependent on food and forage from other regions of the country. In the last 19 years of research, several cassava planting areas were established in order to validate agroecological practices and support sustainable production in the semiarid region (figure 1, table 1). Research and development was carried out in production units of family farmers in the Caatinga biome using the participatory methodology, from the selection of varieties, monitoring of planting practices, crop treatments, to harvesting and processing. The main strategies for reducing vulnerability and increasing adaptive capacity are based on understanding the agro-ecosystem, in order to make adjustments in the production phases, from the correction of soil deficiencies to the choice of the best product for the market. Soil moisture was one of the variables monitored and represented the system's favorable response to water scarcity. The root harvest index was another indicator that made it possible to understand the productive efficiency of the varieties, making it easier to make choices about them when planting. The cassava plants were subjected to water deficit, most of them without any irrigation and a practice with excellent results was simultaneous cultivation. This practice allows the maintenance of moisture in the soil, reduces the occurrence of plagues and expands food and income options. Although the target audience is made up of family farmers, the practices were also adopted by farmers from medium-sized areas.

Financing: Embrapa Management System and Banco do Nordeste do Brasil.

RESULTS

- Phosphorus addition can increase between 24 and 87% of the content of the element in the soil and with liming, increase the efficiency of use of rainwater by 107.7% in the production of aerial parts and 121.1% in the production of cassava roots (Silva et al., 2014). This result reinforces the premise that the semiarid soil should be corrected and fertilized, even though it is a region with low rainfall;
- The use of residues, mulch, soil correction, fertilization and simultaneous cultivation are practices that need to be used continuously to increase the resilience of agroecological productive systems in the semiarid region;
- The production of cassava flour is responsible for 20% of the waste generation on production units that were monitored, but the largest production of waste occurs when rearing goats and other field crops (77.8 and 88.9%, respectively). This suggests that these residues are directed to the soil, as they are rich in calcium and nitrogen, important elements in plant nutrition (Silva, 2017);
- Aligning the production and processing of cassava to the market can bring significant gains to the farmer. An alternative is the aerial part that can be harvested up to three times from the same plant (Silva et al., 2009). The use of roots to prepare forage is also an alternative that reinvigorates the stock policy, which is highly necessary in the semiarid region.
- Agroecological practices must be adapted to each reality, as they have specificities and the aptitude and vocation of the land, the farmer and his family must be respected. Without meeting this requirement, these practices can be inefficient and burden the production system.

NEXT STEPS AND RECOMMENDATIONS

- Strengthen seed multiplication fields, enabling the connection between community seed banks and institutional genetic material banks;
- Encourage the adoption of agroecological practices, such as the reuse of organic waste, favoring the conservation and preservation of natural resources in the semiarid region;
- Understand the forms of fair trade and which markets are most appropriate to family farmers in the semiarid region, solving difficulties in accessing credit lines or subsidies for agroecological production systems;
- Increase the availability of seeds adapted to agroecological production systems, with easy access for communities in the semiarid region.

DATA PUBLISHED IN:

SILVA. A. F. Bases agroecológicas e resiliência de sistemas de produção em espaços geográficos Semiáridos. In: NÓBREGA. R. S.; SILVA. A. S. da; SILVA. A. K. de C.; COSTA. A. M. M. da; DANTAS. A. M. da S.; LIRA. D. V. de; MELO. E. E. de; BORGES. G. F. D. de. S.; SILVA. G. A. da; SOUZA. L. M. da S.; SENA. L. M. F. de; OLIVEIRA. T. N. de; ROSÁRIO. T. N. da S.; HOLANDA. T. F. de (Org.). Reflexões sobre o semiárido: obra do encontro do pensamento geográfico Ananindeua: Itacaiúnas. cap. 4. p. 52-66. 2017.

SILVA. A. F.; REGITANO NETO. A. As principais culturas anuais e bianuais na agricultura familiar. In: MELO. R. F. de; VOLTOLINI. T. V. (Org.). Agricultura familiar dependente de chuva no Semiárido. 1ed. Brasília-DF: Embrapa. 2019. v. 1. p. 45-83. 2019.

SILVA. A. F. PRÁTICAS AGROECOLÓGICAS PARA ENFRENTAR RISCOS NA AGROPECUÁRIA DO SEMIÁRIDO BRASILEIRO. In: JUNIOR. L. M.; FREITAS. C. M. F.; LOPES. E. S. S.; CASTRO. G. R. B.; Humberto Alves Barbosa BARBOSA. H. A.; Luciana Resende Londe LONDE. L. R.; Maria da Graça Mello Magnoni MAGNONI. M. G. M.; Rosicler Sasso Silua SILVA. R. S.; Tabita Teixeira TEIXEIRA. T. e Wellington dos S. Figueiredo FIGUEIREDO. W. S. (Org.). Redução do risco de desastres e a resiliência no meio rural e urbano [recurso eletrônico]. 2ed. São Paulo: CPS. 2020. v. 2. p. 200-222. 2020.

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REFERENCES

SILVA. A. F.. OLIVEIRA. D. S.. SANTOS. A. P. G. SANTANA. L. M. de. e OLIVEIRA. A. P. D. de. Comportamento de variedades de mandioca submetidas a fertilização em comunidades dependentes de chuva no semiárido brasileiro. Revista Brasileira De Agroecologia. 8(3). 2014.

SILVA. A. F. Uso de resíduo orgânico na produção de mandioca em transição agroecológica. no Projeto Pontal. Petrolina-PE. Tese (Doutorado em Desenvolvimento e Meio Ambiente) - Universidade Federal da Paraíba. João Pessoa. 194 f. 2017.

SILVA. A. F.; SANTANA. L. M. de; FRANÇA. C. R. R. S.; MAGALHÃES. C. A. de S.; ARAÚJO. C. R. de; AZEVEDO. S. G. de. Produção de diferentes variedades de mandioca em sistema agroecológico. Revista Brasileira de Engenharia Agrícola e Ambiental. Campinha Grande. v. 13. n. 1. p. 33-38. 2009.

Continued in Annex

Figure 1: Books from the Plants for the Future series already completed and available for consultation (South, Midwest, Northeast and North regions) or in the process of being finalized (Southeast Region)

Adapted Practices/Production Systems	Conventional production	Agroecological production system
Soil preparation	Plowing, harrowing	In sandy soil, no-till
Crop treatments	Various weeding	Mulch, simultaneous cultivation
Pest control	Agricultural pesticides	Bioinsecticides or plant extracts
Fertilization	Chemical fertilizers	Residues from the property, rock dust organics
Plants in the area	Only cassava, single	Diversified, Simultaneous crops
Market	Conventional	Alternative markets
Production decision	Market	Producer and his family
Production transformation	According to the market	Adapted to the demands of the community or property
High	Alto	Medium to low according to adaptation to the agroecological system

Figure 1: Cassava cultivation in an agroecological system. Petrolina, PE, 2013.



Crédit: Alineaurea Florentino Silva

4

INTEGRATED LANDSCAPE MANAGEMENT

Crédit: Joyce Monteiro



Human actions in the context of climate change risk: transition processes in the landscape

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ç It is becoming increasingly evident that the main causes and consequences of climate change are related to human actions, making it urgent to create alternatives for ecological management and institutional mechanisms that are capable of proposing ways of adapting and mitigating climate impacts, especially when considering the population groups most vulnerable to climate change. According to studies released by the Intergovernmental Panel on Climate Change (IPCC, 2019), greenhouse gas (GHG) emissions cause practically irreversible changes in the climate and landscape, causing changes in the patterns of wind, temperature, rain and circulation of oceans. The text emphasizes the importance of alternative proposals for land use changes and considers issues such as food security and threats to resilience, such as deforestation, soil degradation and desertification. Although it is extremely important to understand the causes and impacts of climate change, it is equally essential to understand them from a social perspective, since it is not just an ecological issue, but most consequences will have direct impacts on ways of life, including the consumption capacity of modern society and potential threats to the quality of life and economic development of society.

Thus, it is important to consider the dimension of human actions associated with the capacity or not of resilience, and equally, the economic and institutional dimensions that confer greater or lesser vulnerability to certain social groups. Such problems need to be addressed; otherwise, they may expand future challenges. This is one of the reasons why, in this article, the objective is to analyze a set of experiences developed mostly by Embrapa, in partnership with federal or state institutions, which expose behaviors, attitudes and manifestations of resilience and social prudence, in the face of the risk of climate change.

Climate change, drought, deforestation and soil impoverishment represent a long-term challenge for land and water management, locally and globally, and hamper efforts to reduce poverty and hunger. The work focused on social groups living in rural areas helps to strengthen technical and institutional capacities to improve the management of natural resources in climatic extremes.

Assessment of scientific work

This assessment points out the general aspects, the elements and the main characteristics of the works, as well as gaps of the theme in question, seeking to make decision-making recommendations to institutions directly involved with rural development. The works in this chapter are linked to the transition processes of agriculture, expressed in light of concrete situations in the field, the commitment to sustainable agriculture, attention to ecological processes, the improvement of local knowledge and interdisciplinarity. Therefore, they are approaches that are open to the integration of the economic, social, political and institutional dimensions that, in general, seek to transform agriculture, approaching it from the perspective of social players.

General aspects, elements and main characteristics

These are different initiatives to build new social relationships with natural resources, which are approached from changes in planning and in the integrated management of landscapes. These agricultural transition processes influence the way techniques are made available and implemented, the way resources are explored, the organization and management of territories, supported by the application of the constructivist approach to survey research problems and the construction of solutions pointed out by authors of participatory research. (ABREU, 2011).

Most works develop actions in relation to the management of natural resources (land, animals, forests and water) and adopt a participatory approach, which contributes to the growth of social awareness about the degradation of natural resources caused by inadequate agricultural practices, such as irrigation and excessive deforestation, especially in water ecosystems and scarce forests. Also these works creatively apply, to varying degrees, the principles of agroecology (ABREU et al., 2012).

The article by Fernanda Peruchi, a researcher at the São Paulo Forestry Institute, in partnership with technicians from the state's Secretariat for the Environment, called Agroforestry Systems: combining production and conservation in public policies in the state of São Paulo, strengthened the relationship between farmers, partners and technicians and carrying out joint tasks in the process of implantation and consolidation of SAFs systems, promoting changes in the landscape through the implementation of diversified production systems, including forests.

The technical and scientific work called Participatory construction of knowledge in biodiverse and resilient agricultural systems from the Embrapa - Meio Ambiente research team generated knowledge in partnership with family and settled farmers, especially in the state of São Paulo, but also in the Amazon, thanks to collective and participatory work. This took place in such a way that the experimental works within Reference Units were "tools" in the construction and social appropriation of knowledge in biodiverse agricultural systems. Finally, it is important to highlight that the actions consisted of a careful look at the functioning of nature and the design of biodiverse agroecological systems, aiming at social inclusion.

The work entitled Social resilience and food security in times of global ecological crisis in the southwestern Amazon, led by Lucimar Santiago de Abreu and Maria Aico Watanabe, reflected on the possibilities of reconciling economic and human development with the conservation of natural resources. The question posed by the work is linked to current concerns with seeking a harmonious relationship between environmental prudence and meeting fundamental human needs. It was assumed that agrobiodiversity associated with agroforestry systems contributes to food security and to the minimization of the global environmental crisis. The production model choice based on combining annual and perennial crops and livestock, undoubtedly expresses the importance of local populations in the construction and management of agrobiodiversity and local food security. It was concluded that family farmers, in general, agree and share amongst themselves global ecological societal principles of social development and ecological respect.

Octavio Rossi de Moraes, from Embrapa - Caprinos e Ovinos, and other researchers mentioned in the article and coordinators of the project called Rota do Cordeiro Program: initiative to strengthen livestock production in strategic sheep rearing territories developed a set of actions aimed at sustainable rural development, to strengthen initiatives of territorial organization in the states of Piauí, Rio Grande do Norte, Pernambuco and Bahia. There was institutional support from the government and local partners such as Codevasf, with a future perspective of focusing on valuing local traditional regional products (*savoir-faire*), through projects that

value goat and sheep products, countering the need to increase production as imperative for increasing producers' income. The project has undoubtedly contributed to increasing the resilience of rural populations in the face of an upsurge in climatic adversities.

In the work presented by Rosa Lía Barbieri and partners, the focus was on promoting actions to strengthen people's connection with their territory, by stimulating a new perspective of natural resources, seeking to value butiá as an element of socio-biodiversity. The study stimulated dynamism in the local economy (handicrafts, gastronomy, food and beverage production, tourism, urban landscaping) associated with the generation of environmental services in the remaining butiazais. The project called A Rota dos Butiazais (The Butiá Route): connecting people for the conservation and sustainable use of biodiversity, and encouraged actions for the conservation of butiazais and local culture, contributing to generating income, through strengthening regional identity, and favored processes of social inclusion and local development based on ecotourism, gastronomic tourism and the sale of handicrafts by local communities, in addition to contributing to the process of environmental education and training (extractivists, farmers, artisans and family agro-industries, in short cycles).

The project entitled Redesign of the Sustainable Animal Production System, coordinated by Salete Alves de Moraes of Embrapa - Semiárido developed in partnership with researchers from Embrapa - Caprinos e Ovinos, focused on finding solutions for water scarcity, temperature increase and adverse edaphic conditions, which are challenges for agriculture in the semiarid region. I believe that, this work on land, animal management and water is relevant to several dimensions of sustainable development: governance and management of food production systems; provision of essential ecosystem services; food security; human health; conservation of biodiversity; and mitigation and adaptation to climate change.

Sandra Santana de Lima, researcher at Embrapa - Agrobiologia, in partnership with colleagues from Embrapa - Meio-Norte and the Federal University of Piauí, presented the research called Impact of agroforestry management on nutrient dynamics and invertebrate soil macrofauna in a transition area in the north of Piauí. It is a joint assessment of the chemical attributes of the soil and the macrofauna, under the different management systems, demonstrating similarities between the agroforestry systems. In addition, it noted the environmental improvement in chemical characteristics and the enrichment of the invertebrate macrofauna. It concluded that the SAFs provided better chemical characteristics and increase in the abundance and richness of species of the invertebrate soil macrofaunal, reinforcing the assertion that these organisms can function as bioindicators of quality.

The research entitled Sustainable and intensive multifunctional agroecosystems Design, developed by the researcher Vanderlise Giongo from Embrapa - Semiárido and team, found that intensive multifunctional agroecosystems increase the adaptive capacity and ecological resilience of irrigated agricultural production systems of fruit and vegetables in the Brazilian Semiarid, mitigating the impacts of water and thermal stresses, intensified by climate change scenarios and GHG emissions. Drought represents a long-term challenge for land and water management, locally and globally, and hinders efforts to reduce poverty and hunger. The work helps to strengthen technical and institutional capacities to improve land and water management in extreme climates. Ethical coexistence with nature strengthened the local identity, representing a clear example of social resilience and success in building local agrobiodiversity.

The research work called Adaptations of riverside producers of the Amazonian floodplains in the context of climate change, by Julia Vieira da Cunha Ávila, from the Amazon Research Institute, and partners, found that in the current climate context, extreme weather phenomena are increasingly expected in the Amazon (BARICHIVICH et al., 2018). Therefore, dialogues between the social actors of the region (community, leaders, institutions and government agencies) were intensified as a strategy, aiming at the collective elaboration of an emergency plan that favors the traditional ways of life. The municipal government project, "Bolsa flood" (flood social transfer), allowed government agencies to directly support families in their needs and,

thus, was the government support program most appreciated by the riverside communities. However, researchers verified that it was only implemented once, at the beginning of this decade, and was discontinued.

The work entitled *Mata Atlântica Eco Markets*, by Gabriel Menezes and a team from the Auá Institute of Socioenvironmental Entrepreneurship, presented a set of results from the project's actions and emphasized that demand should value diversity and agroecological cultivation. This study points out the main challenge associated with expanding scientific knowledge about the management and characteristics of local species, as well as investments in production, processing and logistics infrastructures.

Some works in this collection, which are not directly part of chapter four, also contribute to sustainable or ecological management. Observed as a whole, there is simultaneous action to generate income alternatives and create alternatives for an ecologically-based economy. Financial subsidies are necessary to encourage the implementation of these projects, and roll back the current predatory situation, since the population involved in the activity considers that preservation is, above all, in their own interest. Sustainable management implies, by definition, social adherence, but adherence cannot be expected based on the desire to sacrifice the present for the benefit of the future, which is impossible in the current economic and social conditions, prevalent in the different regions of the case studies.

Conclusion

The general overview of the research work allows us to affirm that, in the process of operationalizing research activities, several techniques that favor the dialogue between producers, technicians and researchers are adopted. Thus, some characteristics can be inferred from this type of approach, which requires the exercise of interdisciplinarity and the view of the whole and of different scales of the territory, namely: local, state, national and international (in some cases it was necessary to consider elements of international agriculture and environmental development). These approaches are also especially marked by the effort of interaction between social actors (farmers and producers, researchers, extension workers and technicians from non-governmental organizations). Thus, the general characteristics of the set of research and development techniques are highlighted, and often called action-research. This compilation includes constructivist approach techniques, participant observation and the exchange of knowledge, applied in order to understand local problem, accessing, therefore, qualitative methods, but also, when necessary, tools and quantitative data specific to the research- action (consultations to IBGE socioeconomic data, geographic maps, etc.).

There are some elements, based on research experiences, that justify the relationship between farmers and the environment:

- 1) The experience with concrete environmental problems can create risk awareness and lead to taking a critical position in relation to the productivity-driven model of production;
 - 2) Market pressure for environmentally respectful and quality products can lead to choices of types of production systems that use ecologically based management and technologies. Thus, there is an economic hypothesis linked to the transition processes: the social construction of relationships with natural resources are determined by the productive strategies of farmers. In addition, the issue of the international market (globalization), more recently due to the environmental crisis, may favor sustainability, depending on the characteristics of the "agricultural business", the country and the population. In the case of exported products, for example, trade starts to be determined according to the environmental quality of the product,
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reversing the previous trend, in which the greater supply of the product was crucial and the actual costs of degradation and contamination are not effectively computed in current prices.

Some farmers who participated in the studies, and who were included in the “traditional” category, participate in the modern ecological economy, and are highly aware of environmental risk.

In this category of modern people who are aware and sensitive of environmental risk, there are farmers who seek to diversify their activities with tourism or ecotourism and organic agriculture, seeking new markets and geared towards associated values, such as product quality and landscape or environmental conservation. It is also paramount to note the importance of the presence of governmental and non-governmental institutions and their approach towards conservation.

The main characteristic of this set of studies is that they are marked by actions of social and agroecological resilience, having or not been prompted by the team responsible for conducting the work, but, without a doubt, positively impacting water, soil, forest, food security and agroecosystem and human health. It also ensures the economic reproduction of food production units. These initiatives are the result of several institutional projects that have helped producers and technicians to identify the relationships they establish with nature (soil, water, forests, etc.), questioning them and including the latent risk of actions that generate an environmental problem.

However, the knowledge and technologies produced by the scientific community are still insufficient to solve the problems posed by the environmental crisis and its implications for agriculture. Thus, current knowledge needs to be expanded, systematized and deepened, especially in relation to agroecological management practices. This accumulated knowledge already allows us to understand the economic and socio-cultural dynamics brought about by the environmental crisis. In general, the works are promoting coherent approaches to the sustainable management of land, water and landscape. One of the characteristics is that they involve a wide range of partnerships and collaborative ventures, often setting up sociotechnical networks. Through projects, and the dissemination of studies and information, many of the works developed by Embrapa and presented here help to increase the scientific understanding of the biophysical and socioeconomic relations between land and plant and water resources at the landscape scale and can be transformed into a guide for policies that aim to achieve greater coherence in agro-environmental management. The papers present practical, innovative and relevant options for decision-making policies on land, forest, water and landscape management.

The experiences developed contribute to greater coherence in policies and research on climate change and biodiversity. They present methodological “tools” that provide subsidies to improve the management of natural resources, but even so, in a country with a high inequality rate like Brazil, the main driver of the process of changing the management of natural and agricultural resources is institutional, that is, it depends heavily on public policies.

To what extent, do the transition processes in agriculture in high and low income countries really use agroecological principles, such as improving soil fertility, agroforestry, water quality, sustainable use of native forests, intercropping, composting, landscape, cultural heritage and economic resource enhancement? And what is the practical evidence that these methods are sufficient to guarantee resilient agricultural production?

However, we still must develop research and actions that enable us to distinguish these practices in a comparative way between different systems of agriculture in transition (from production units in the initial transition process and others already certified, organic).

Other relevant aspects

Sustainable or ecological management involves simultaneous action to generate alternative employment, income and create conditions for projects to achieve reduced costs for installation and implementation. Financial subsidies are necessary to encourage the implementation of these projects, and roll back the current predatory situation, since the population involved in the activity considers that preservation is, above all, in their own interest. Sustainable management implies social adherence, by definition, but adherence cannot be expected based on the desire to sacrifice the present for the benefit of the future, which is impossible in the current economic and social conditions, prevalent in the different regions of the case studies.

One of the major obstacles for State action, directed towards development and natural preservation is the disregard of specificities and differences within a municipality and between municipalities and regions. We can say that the population's global sensitivity to environmental issues can be strongly associated with socio-cultural variables, above all with the economic situation and, in this particular case, with family survival.

Finally, in its diversity, the set of studies analyzed proposes changes to the agri-food systems. In this regard, it is interesting to note that the systems transition proposition is being made evident in many parts of the world: Thus, it would be wrong to interpret the advance of the development of ecologically based agriculture experiences, as a response only to institutional policy, when it is also the result of a national and international socioeconomic demand. It is necessary to understand the current situation of natural resources that are rapidly depleted and the social and economic elements that accelerate actions and multiple transition processes, which are inscribed in controversies and in more or less strong interests in favor of agriculture. The ongoing transition process of ecologically based agriculture expresses a diversity of styles in networks of relations between agriculture and the environment, where different categories of players are organized to build sustainability commitments between agriculture, food security, the environment, scientific research and society.

References

- ABREU. L. S. de. Desenvolvimento de metodologias de interação das ciências sociais e agroambientais. In: MEDEIROS. C. A. B.; CARVALHO. F. L. C.; STRASSBURGER. A. S. (ed.). Transição agroecológica: construção participativa do conhecimento para a sustentabilidade. Pelotas: Embrapa Clima Temperado. 2011. p. 93-94.
- ABREU. L. S. de; BELLON S.; BRANDENBURG. A.; OLLIVIER. G.; LAMINE. C.; DAROLT. M. D.; AVENTURIER. P. Relações entre agricultura orgânica e agroecologia: desafios atuais em torno dos princípios da agroecologia. Desenvolvimento e Meio Ambiente. Curitiba. v. 26. p. 143-160. jul./dez. 2012.
- BARICHIVICH. J.; GLOOR. E.; PEYLIN. P.; BRIENEN. R. J. W.; SCHÖNGART. J.; ESPINOZA. J. C.; PATTNAYAK. J. C.; PATTNAYAK. K. C. Recent intensification of Amazon flooding extremes driven by strengthened Walker circulation. Science Advances. v. 4. n. 9. p. 1-7. Sep. 2018.

AGROFORESTRY SYSTEMS: ALIGNING PRODUCTION AND CONSERVATION IN PUBLIC POLICIES IN THE STATE OF SÃO PAULO

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The Sustainable Rural Development Project (PDRS) – Microbasins II – Market access was made possible by a loan agreement signed between the São Paulo government and the World Bank. It was executed by the Secretariat of Agriculture and Supply and by the Secretariat of the Environment (SMA), operated by the Coordination of Integral Technical Assistance (CATI) and the Coordination of Biodiversity and Natural Resources (CBRN), with the objective of increasing the competitiveness of family agriculture and improving their environmental sustainability, expanding employment and income opportunities, social inclusion, the preservation of natural resources and the well-being of rural communities.

SMA developed sustainable support schemes for natural resources (soil, water and biodiversity) that contributed to the mitigation and/or adaptation to climate change and strengthened the competitiveness of family farmers in the long term through 21 projects for the implementation or enrichment of Agroforestry Systems (SAFs) - which make it possible to combine conservation with production (Table 1).

The target audience was family farmers and agrarian reform settlers in the state of São Paulo. The projects were mainly developed in the Atlantic Forest Biome (Figure 1).

To overcome the initial difficulties for the implementation of SAFs, during the 2014/2015 rainy season we prepared the soil using, green manure, planting of annual agricultural crops, bananas, species of biomass production and some more rustic native forest species (SÃO PAULO, 2014), in addition to the suggestion of buying tree species. Due to the drought that occurred in 2014, in some projects the strategy of liming, harrowing and planting green manures was adopted in order to, later, at the end of the agreement (2015), plant seedlings, which proved to be quite satisfactory. According to farmers, the planting of green manures or other species for the production of organic matter, such as pioneer forest species, favored the control of ants and reduced attacks on grafted seedlings (SÃO PAULO, 2018).

The economic and financial analysis of the proposals was carried out, both at the time of selection and after the implementation and collection of data in the field.

RESULTS

- Deconstruction and reconstruction of language, methodologies and relationships for CBRN farmers, partners and technicians to work together to obtain the best and greatest possible advance in the implementation of biodiversity systems.
- Conversion of about 495 ha into SAFs.
- Diversification of agroecosystems, with the insertion of several exotic and native agricultural and tree species.
- Improvement of methodologies for monitoring SAFs and beginning the construction of a database to support public policy making (environmental and economic information).
- Development of a SAFs planning, monitoring and financial assessment tool (SAF São Paulo).
- Advances in commercialization, market access and stimulating interest and internalizing strategies to add value to production, such as organic certification and a system for participatory guarantees.

NEXT STEPS AND RECOMMENDATIONS

- Overcoming challenges imposed on family agriculture, such as: universalization of agroecological Technical Assistance and Rural Extension (ATER), adding value to the agroforestry product and conquering markets, access to public support policies, training farmers and involving young people.
- Consolidation of the implemented SAFs, transforming them into a network of demonstrative units that allow for visitation and training of family farmers by family farmers, in addition to continuity of socio-environmental and economic monitoring to better understand its impacts in order to disseminate them to other public policy makers, financiers and farmers.

- Consolidation and expansion of partnerships in a support network for the implementation of SAFs, given the perspective of the difficulties in making agroecological ATER feasible to all interested farmers.

DATA PUBLISHED IN:

SÃO PAULO (Estado). Secretaria de Infraestrutura e Meio Ambiente. Projeto Desenvolvimento Rural Sustentável. São Paulo. 7 fev. 2020. Disponível em: <https://sigam.ambiente.sp.gov.br/sigam3/Default.aspx?idPagina=13536>. Acesso em: 7 fev. 2020.

REFERENCES

SÃO PAULO (Estado). Secretaria do Meio Ambiente. Coordenadoria de Biodiversidade e Meio Ambiente. Relatório do intercâmbio de Subprojetos Ambientais apoiados pelo Projeto de Desenvolvimento Rural Sustentável/PDRS. Campinas: Secretaria do Meio Ambiente. 2014.

SÃO PAULO (Estado). Secretaria do Meio Ambiente. Coordenadoria de Biodiversidade e Meio Ambiente. Relatório do Workshop Avaliação Econômica Financeira de SAFs da Agricultura Familiar. São Paulo: Secretaria do Meio Ambiente. 2018.

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Table 1: Classification of indicators used in monitoring SAFs

Indicators	Management intensity	Environme	Transition agroecological	Social	Economic	Beginning of analysis
1	water infiltration into the ground	Presence of erosion	Origin of seeds and seedlings	Community opinion	Increase in income	Mortality rate
2	% of damage Leafs	Fauna	Use of varieties Native	Level of satisfaction	Level of satisfaction	Strata
3	Level of disturbance in the area	Species present in the SAF	Use of dead cover (mulch)	Youth participation in SAF	Youth participation in SAF	
4	% of soil with living cover		Planting of trees	Participation of women in production and activities		
5	% of soil with mulch		Agroecological functions of species	Women's participation in SAF		
6	Thickness of mulch on the line		Use of pesticides	joint efforts		
7	Thickness of mulch between the lines		Disease and pest control			
8	% of exposed soil					
Collection frequency	Quarterly	Annual	Annual	Annual	Annual	Single time

Source: Authors.

PARTICIPATORY KNOWLEDGE BUILDING IN BIODIVERSE AND RESILIENT AGRICULTURAL SYSTEMS

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The Embrapa Meio Ambiente Agroecology Team, through projects from different sources, has been working to support local and regional agroecological transition processes in several regions of the state of São Paulo, prioritizing family farmers and agrarian reform settlers. The most common problems identified by the Agroecology Team's studies can be summarized in: economic exclusion, limited financial resources, degrading natural resources, low social appropriation of agroecological knowledge, lack of basic development policies, lack of perspective for livelihoods on the field.

Diversified agricultural systems, being based more on processes than on inputs, more on internal than external resources, more on appropriate knowledge than on sophisticated and costly technologies, have the great potential of recovering resources, providing for families, generating income and ensuring that people be allowed to remain and generate their livelihood in rural environments.

The general objective of the work of the Embrapa Meio Ambiente Agroecology Team has been to build knowledge with family and settled farmers in the state of São Paulo, as an engine of ecological and social change. Biodiversified agriculture provides healthy products, food security, income and improved ecological and social conditions for families. The Reference Units (UR) were used as tools in the construction and social appropriation of knowledge in biodiverse agricultural systems, in the context of processes of transition to socially and ecologically resilient agriculture.

In the different regions where the team developed actions in the State, they focused on diversification through: home gardens, agroforestry yards, diversified orchards, agroforestry of different configurations, livestock systems and areas of environmental protection, among others. The most common technologies in practically all the reference units studied were soil conservation, organic fertilization, composting, vermicomposting, green winter and summer fertilization, foliar fertilization, irrigation, pruning of trees, selective weeding

clearing, garden beds and patches in agroforestry, windbreakers, pasture forestation, biological pest control, among many other technologies. The biomes covered in the studies were, from east to west, the Atlantic Forest, a transition region and the Cerrado.

Our team has focused on the dimension of knowledge, considered one of the main foundations of change. Biodiverse productive systems are designed based on transdisciplinary dialogue in the research area, as well as dialogue between the academy and popular knowledge. The work is developed in UR and Networks. The URs are plots of agricultural properties that serve for experimentation, validation, monitoring, exchange and dissemination of agroecological knowledge. URs have proven to be one of the most effective tools for the generation and wider use of knowledge. In them activities are developed that merge research, teaching and extension in a complex social laboratory. They allow a more fruitful exchange than classical scientific hermeticisms, providing a "natural" social appropriation of knowledge. In addition, this methodology has greater impact and is cheaper than standard extension methods.

Simplified production systems, which cause the destruction of the natural base and threaten the global ecological balance, must be replaced by more resilient ones. Biodiverse systems are inspired by natural forests. They mix native agricultural and forest species. They favor the transition to less ecological and socially vulnerable systems. Ecologically, because they protect the soil, recover springs, restore soil fertility, capture carbon and favor natural hydrological cycles. From a social point of view, biodiverse systems generate healthy food for consumers, food security, new market perspectives and social inclusion.

RESULTS

The technical results show a large number of techniques, processes, managements and practices that have been researched, adapted and appropriated by farmers in the course of the projects carried out. Methodological results can also be mentioned, such as innovation from

the perspective of participatory methodologies, based on field work. What is expected with such projects is to provide initial momentum, which in time will result in the dissemination of knowledge. This result is already observed in several regions, especially in agrarian reform settlements.

NEXT STEPS AND RECOMMENDATIONS

The hope is that the process will create autonomy among farmers, so that when projects are completed this does not determine the stagnation of the learning process. In any case, new investments to strengthen the involvement and expand the impact will be essential to keep the process alive.

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URCHEI, M. A.; CANUTO, J. C. (ed.). Trajetória das ações em agroecologia na Embrapa Meio Ambiente. Brasília: Embrapa. 2018.

DIVERSIFIED SYSTEMS AND FOOD SECURITY IN THE SOUTHEAST OF THE AMAZON: SOCIAL RESPONSE TO THE GLOBAL CRISIS

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The Amazon is of crucial importance in times of global ecological crisis, given its role in relation to the planet's climate. In this chapter, the research focuses on the southwestern Amazon, in the state of Rondônia, which has become known worldwide both for population growth, as a result of public policies to encourage immigration, and for the explosive rates of deforestation, making it a high-risk region socially, economically and ecologically.

Research activities financed by Embrapa Environment elected family farmers as the target audience, thus the investigation sought to understand the role of the rural population in the municipality of Ouro Preto do Oeste, in the state of Rondônia, regarding the conservation of biodiversity and the reduction of the effects of the global ecological crisis. The assumption of this type of research is that agrobiodiversity associated with agroforestry systems contributes to food security and to the minimization of the global environmental crisis. That said, the research aimed to investigate the possibility of reconciling environmental conservation with the expansion of family farming in the Amazon and consequently reduce the effects of the global ecological crisis.

It was found that family farmers, among which a group of women farmers stands out, implemented the commercial production of coffee or cocoa under SAF's. The cultivation of cocoa is generally conducted in SAF's. In this case, they diversified by introducing Amazonian crops such as açai, cupuaçu, rubber, pupunha and pepper, in the SAF's and faced challenges related to the cultivation of these species, but had the support of the Association of Alternative Producers (APA), EMATER, cooperatives and several NGOs. Almost all of the family farmers in Ouro Preto do Oeste, who were interviewed, have annual and perennial crops and livestock in their production units (UP). As annual crops, rice, beans, corn, cassava, pineapple and sugar cane plantations were identified. These crops are mainly intended for self-consumption, with the eventual sale of the surplus. As for the perennial fruit crops, they cultivated orchards of orange, mango, cashew, banana, papaya, avocado, pupunha, cupuaçu and coconut. These fruit trees are grown for self-consumption and the market via APA. Coffee and cocoa are grown with a view to predominantly serving the national market. The orange, mango, cashew and avocado fruit trees are grown exclusively for self-consumption. While the other fruit trees serve both self-consumption and the local and national market, in the case of commercial plantations

on a larger scale (> 50 plants).

Following are the animal species identified: beef and dairy cattle, poultry, pigs, horses, mules, sheep, bees and fish. These products are destined both for self-consumption and for the sale to cooperatives.

The methodology is characterized by its qualitative, participatory nature, favoring the construction of a script of questions that was applied to the selected sample of 27 producers from an APA.

In order to implement the strategies to increase resilience, it was of utmost importance to receive technical support for an ecologically-based transition, adding value to Amazon production, and helping get products to regional, state and national markets, and counting with international food networks committed to the production of healthy food.

RESULTS

Studies supported actions of governmental programs to strengthen family production in the southwestern Amazon and experiences of SAFs in the country.

The study documented annual and perennial crops associated, or not, with animal husbandry. It rescued the process of regional occupation of the state of Rondônia. Then, the main activities and strategies developed by APA family farmers were characterized, in order to add value to agricultural production (honey, liqueur, fruit pulp, jams, jams, canned hearts of palm) in order to ensure food security and supplement income.

The transition from conventional agricultural systems to ecologically based systems constitutes an important challenge for the environmental recovery associated with the economic strengthening of family farming. The highly diversified agroforestry production systems contribute to the reduction of deforestation and, consequently, it is a social response to the global ecological crisis. It was concluded that family farmers, in general, agree and share amongst themselves and with the global ecological society principles of social development and ecological respect. Ethical coexistence with nature strengthened the local identity, in this sense, this case is a clear example of social resilience and successful construction of local agrobiodiversity.

NEXT STEPS AND RECOMMENDATIONS

Public policies designed to encourage conservationist behavior are still precarious and discontinuous, it is necessary for the State to support local populations that have adhered to the alternative model based on SAFs, to increase the beneficial effects of reducing deforestation and fires, reconstructing devastated areas, protecting water resources, etc., since these populations are committed to ecological conservation and must be recognized by the State.

Such a recommendation based on concrete situations should add to the government's plan to Combat Global Climate Change, which aims to reduce and end, in the coming years, the current rate of deforestation in the Amazon, which has undergone significant reductions over the last decade.

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ABREU. L. S. de; SANTOS. A. da S. dos; WATANABE. M. A. A contribuição dos agricultores familiares da região sul da Amazônia brasileira à crise ecológica global. In: CANUTO. J. C. (ed.). Sistemas agroflorestais: experiências e reflexões. Brasília: Embrapa. 2017. p. 107-121

ABREU. L. S. de; WATANABE. M. A. Rede multiconectada envolvendo as mulheres agricultoras do sudoeste da Amazônia para a soberania alimentar. In: ARZABE. C.; COSTA. V. C. (ed.). Igualdade de gênero: contribuições da Embrapa. Brasília: Embrapa. 2018. p. 64-70. (Embrapa/Objetivos de Desenvolvimento Sustentável. 5).

WATANABE. M. A.; ABREU. L. S. de. Estudo agroecológico de agricultores familiares de base ecológica no sudoeste da Amazônia (Ouro Preto do Oeste, Rondônia). Jaguariúna: Embrapa Meio Ambiente. 2010. (Embrapa Meio Ambiente/Série Documentos. 81).

Figure 1: Family farmers, southern Amazon



Crédit: Maria Aico Watanabe.

Figure 2: Cupuaçu and fruit orchard in a family property in Ouro Preto do Oeste, southern Amazon



Crédit: Maria Aico Watanabe.

IMPACT OF AGROFORESTRY MANAGEMENT ON THE SOIL'S NUTRIENT DYNAMIC AND INVERTEBRATE MICROFAUNA IN A TRANSITION AREA IN THE NORTH OF PIAUÍ

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The intense use of natural resources, caused by the demand for areas for exponential food production and technological development, has resulted in the expansion of environmental degradation processes. In this context, the conversion of forest areas to agricultural cultivation, whether on a large or small scale, impacts the ecosystem. The agriculture model, based on intensive soil preparation and management with cutting and burning vegetation, which is still being used by farmers, guaranteeing the subsistence of many poor rural populations. Studies have been carried out in areas of slash and burn agriculture (ACQ) to understand its role in the release of carbon and other greenhouse gases (GHG) in the atmosphere and, consequently, its contribution to global warming. In this scenario, alternatives have been sought to reduce the impacts caused by ACQ. Thus, the role and importance of agroforestry systems (SAFs) in the stability of agricultural production and in the efficiency in recycling nutrients has been attracting the attention of many farmers in the region. As a way to understand this form of production advances sustainability and to subsidize public policies in favor of stimulating farmers, the impact of management both in ACQ and SAFs on the dynamics of nutrients and the soil invertebrate macrofauna was studied (Table 1). Soil fauna is an important bioindicator, which is closely related to edaphic processes, and therefore sensitive to changes that occur in the environment (Figure 1). The evaluation of land use systems, both in areas subjected to burning, and in areas with SAFs was carried out based on collections and analysis of soil and macrofauna, during the dry and rainy period. During the development of the project, there was a concern with publicizing the importance of soil conservation and management for the maintenance of soil fauna, in addition to the importance of organisms to the sustainability of the system, comparing the practice of slashing and burning vegetation with the management carried out in the SAFs. The research resulted in a Master's dissertation, in partnership with Embrapa Meio Norte, Embrapa Agrobiologia, the Federal University of Piauí and the collaboration of farmers from the Vereda dos Anacleto community, located in the municipality of Esperantina, in the north of Piauí. Also receiving the financial assistance of CAPES, EMBRAPA and CNPq.

RESULTS

Regardless of the evaluation period, the SAFs stood out with higher values, including in relation to the secondary forest, it can be attributed to the management of the areas, which even during the hottest period, favored the abundance and richness of the invertebrate macrofauna that promoted the best conditions for the development of fauna, from the practice of pruning of plant species, as well as the material from the clearings that was disposed on the soil, providing food and shelter. The rainy season in the region completely modifies all areas, and allows organisms to return, even in the area subjected to slashing and burning, however the values of the ecological indexes show that despite the damage after burning making the environment vulnerable, it is possible to discontinue the soil degradation from the adoption of less degrading management, a proven fact, considering that areas with SAF that 6 and 10 years earlier were managed with slash and burn practices. The joint evaluation between the chemical attributes of the soil and the macrofauna, under the different management systems, showed similarities between the agroforestry systems, and showed the relationship of the improvement in the chemical characteristics and the abundance and richness of the invertebrate macrofauna. In view of this, it is clear that ACQ management resulted in environmental simplification and the decline of the macrofauna, while the SAFs provided better chemical characteristics to the soil and increases in the abundance and richness of species of the invertebrate macrofauna in the soil, reinforcing the assertion that these organisms can function as bioindicators of soil quality.

NEXT STEPS AND RECOMMENDATIONS

Based on this innovative study in the State, more research has been carried out in the region and after the community got to know the results, other farmers joined the conservationist management.

DATA PUBLISHED IN:

LIMA, S. S. Impacto do manejo agroflorestal sobre a dinâmica de nutrientes e a macrofauna invertebrada nos compartimentos serapilheira-solo em área de transição no norte do Piauí. 2008. Dissertação (Mestrado em Desenvolvimento e Meio Ambiente) – Núcleo de Referência em Ciências Ambientais do Trópico Ecotonal do Nordeste. Universidade Federal do Piauí. Teresina. 2008.

LIMA, S. S.; AQUINO, A. M.; LEITE, L. F. C.; VELASQUEZ, E.; LAVELLE, P. Relação entre macrofauna edáfica e atributos químicos do solo, em diferentes agroecossistemas. Pesquisa Agropecuária Brasileira. Brasília. v. 45. n. 3. p. 322-331. mar. 2010.

LIMA, S. S.; LEITE, L. F. C.; OLIVEIRA, F. C.; COSTA, D. B. Atributos químicos e estoques de carbono e nitrogênio em argissolo vermelho-amarelo sob sistemas agroflorestais e agricultura de corte e queima no norte do Piauí. Revista Árvore. Viçosa. v. 35. n. 1. p. 51-60. ago. 2011.

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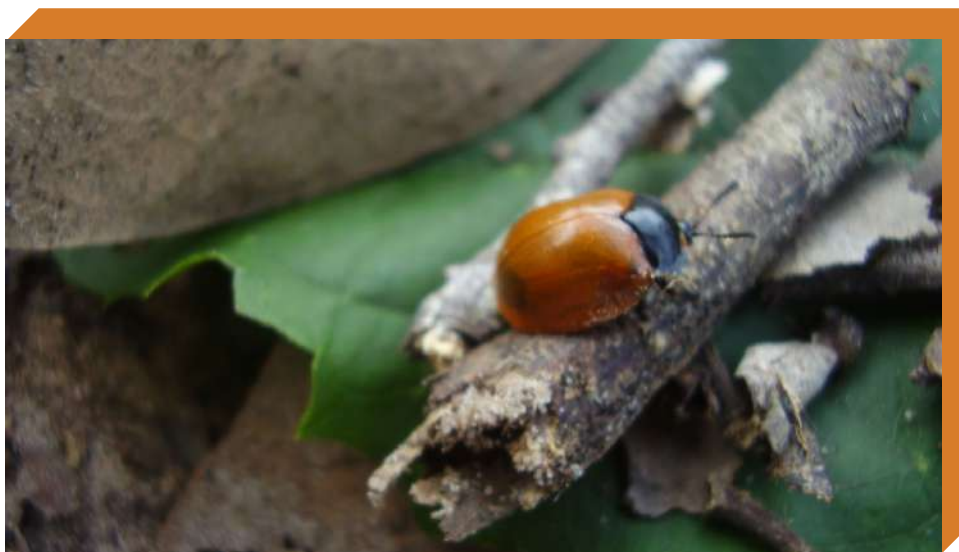
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Table 1: Ecological indexes related to soil macrofauna in agroforestry systems with six (SAF6) and ten years of adoption (SAF10), slash-and-burn agriculture (ACQ) and native forest (FN)

Systems	Collection Period:	Ind.m ²	Shannon Index	Pielou Index	Wealth
SAF6	Dry	150.40	3.30	0.92	12
	Rainy	1945.60	2.56	0.63	17
SAF10	Dry	64.00	2.38	0.85	7
	Rainy	1257.60	2.87	0.69	18
ACQ	Dry	16.00	0.27	0.17	3
	Rainy	384.00	1.99	0.63	9
FN	Dry	358.40	0.70	0.27	6
	Rainy	540.80	1.76	0.49	12

Source: Authors.

Figure 1: Coleoptera (Ladybug)



Crédit: Sandra Santana de Lima.

SUSTAINABLE AND INTENSIVE MULTIFUNCTIONAL AGROECOSYSTEM DESIGNS

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The current and predominant agricultural dynamics in the Caatinga Biome are unable to recover from the environmental impacts resulting from the change in land use and vegetation cover, much less are they structured to mitigate or adapt to climate change scenarios. This line of research comprises four basic actions: 1) creation of drawings of Agroecosystems with the proposal of multifunctionality, offering solutions for intensive irrigated fruit and vegetable systems in semiarid regions of Brazil and in the world; 2) systemic analysis of the anthroposphere, monitoring the dynamics of the impacts of the proposed models in the short, medium and long term; 3) use of predictive models and geotechnologies; 4) Actions to disseminate knowledge. In the first action, 12 models of agroecosystems were developed, six of them for annual crops and another six for perennial crops. These models are the result of pre-selection work on green manures/ cover crops. The second step, incorporated studies on mixtures of plants grown simultaneously. And finally, to compose the multifunction structures, two intensities of soil management were applied, concepts of population dynamics, as well as the valuation of native species as vegetation cover, incorporating them into the productive system, opposing the antagonistic view with that of synergies. The second axis, which concerns the systemic analysis of the anthroposphere to assess the impact of the proposed models, groups a multidisciplinary team integrating universities, research centers and novel actions with the private sector. Attributes and characteristics of soil, atmosphere and organisms (plants and edaphic fauna) are monitored. Among some indicators we highlight the carbon stock, nitrogen and phosphorus in the soil, greenhouse gas emissions, water footprint, carbon footprint, micronutrient dynamics, macro and micronutrient absorption curve, biological nitrogen fixation, mycorrhizal dynamics, dynamics of edaphic fauna, primary net productivity, productivity of commercial crops, economic analysis and environmental impact. On the third front, there are predictive models and geotechnologies advancing the development of models in time and space. Maps of soil, climate and vegetation are being incorporated into the obtained results enabling the prediction of the impacts of agroecosystems on a regional scale. The last, but not least important action, aims to socialize the knowledge generated and strengthen the role

of users of technologies, processes and information. Multifunctional agroecosystems co-depend on managers, opinion makers and agricultural multipliers at their forefront, in order to ensure a significant and positive impact on climate change (Figure 1). All actions aim, ultimately, to form the basis of sustainable and socially responsible agriculture as a business model that is competitively well positioned in the scenario of changes in the scope of consumption of a growing and nutritionally needy population.

RESULTS

- Intensive multifunctional agroecosystems increase the adaptive capacity and resilience of irrigated agricultural production systems for fruit and vegetables in the Brazilian semiarid region, mitigating the impacts of water and thermal stresses, which will be intensified by climate change scenarios.
- Benefits on biological nitrogen fixation, nutrient cycling, diversity of edaphic fauna, the relationship between mycorrhiza and phosphorus and increased water content in the soil.
- Reduction of nitrogen input through fertilizers, reduction of evapotranspiration, reduction of water and carbon footprints and other indicators of environmental impacts, in addition to promoting economic benefits for the farmer.

NEXT STEPS AND RECOMMENDATIONS

- The actions continue to be monitored in the field, in long-term experiments in the Brazilian semiarid region.
- The next challenges for the studies are:
 - » Reduce the input of synthetic fertilizers;
 - » Decrease water consumption and increase primary production and the contribution of carbon to the soil, on a regional scale;

- » Define the extent of the environmental and economic impacts of the adoption of sustainable multifunctional agroecosystemic models in relation to the productive models in force in different climate change scenarios on a regional scale;
 - » Implement geospatial models to monitor production systems ensuring efficiency and sustainability;
 - » Mitigate the impacts of water and thermal stress intensified by scenarios of climate change.
- Suggested solutions for facing the challenges:
 - Structure laboratories and experimental fields;
 - Register the experiments in the world bank of long-term experiments;
 - Strengthen national and international partnerships;
 - Provide results to guide the formulation of public policies.

DATA PUBLISHED IN:

BRANDÃO. S. da S.; SALVIANO. A. M.; OLSZEWSKIA. N.; GIONGO. V. Green manure contributing for nutrients cycling in irrigated environments of the Brazilian Semi-Arid. *Journal of Environmental Analysis and Progress*. v. 2. n. 4. p. 519-525. 2017.

CARNEIRO. J. M.; DIAS. A. F.; BARROS. V. da S.; GIONGO. V.; MATSUURA. M. I. da S. F.; FIGUEIREDO. M. C. B. de. Carbon and water footprints of Brazilian mango produced in the semiarid region. *The International Journal of Life Cycle Assessment*. v. 24. n. 4. p. 735-752. 2019.

FERREIRA NETO. R. A.; FREITAS. A. D. S. de; GIONGO. V.; CAMARGO. P. B.; MENEZES. R. S. C.; SAMPAIO. E. V. de S. B. Nitrogen fixation of Poaceae and Leguminosae in a green manure experiment in the Brazilian semiarid region. *Australian Journal of Crop Science*. v. 11. n. 11. p. 1474-1480. Nov. 2017.

Continued in Annex

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Figure 1: Agroecosystem with perennial cultivation



Credit: Vanderlise Giongo

ROTA DO CORDEIRO (SHEEP ROUTE) PROGRAM: INITIATIVE TO STRENGTHEN LIVESTOCK PRODUCTION IN STRATEGIC SHEEP FARMING TERRITORIES

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The Rota do Cordeiro (Sheep Route) program started in 2013, based on a demand from the Ministry of Integration (current Ministry of Regional Development - MDR) to Embrapa, for it to present proposals for technological support to goat and sheep producers in regions with the lowest development indexes. The program was developed to provide broad support to the entire environment surrounding the production of goats and sheep, encompassing producer organization, territorial intelligence, access to markets and institutional alignment (Table 1 and Figure 1). The objective of the program is to provide greater conditions for generating income for producers and those involved with processing and trade around goat and sheep farming, considering aspects of the environment, history, culture, fair trade and appreciating products.

Thus, directly or indirectly, the production environment is prepared for more severe conditions, such as prolonged droughts and reduced availability of natural forage or even the volume of water resources. This preparation begins with support for the farmers' organization, strengthening their cooperatives and associations, and then, favoring the relations between promotion agencies, research and technical assistance, within the territories. Fifteen territories with a concentration of goat and sheep production, social organization and tradition in this type of production were considered priorities for receiving the programs support. Of these fifteen territories, thirteen are in the semiarid region and two in the border region, in the south of the country. Technologies vary, depending on local demands, but include the capture and optimization of water use and the conservation of water sources, as well as the correct investment of financial resources in water infrastructure. As an example, the MDR can finance or suggest the financing of works to collect water, according to the demand of producers in a territory, but it will always do so through a study by the competent bodies to analyze and approve such investment in terms of environmental impacts and spring capacity. Technologies for enriching the caatinga, integrated-crop-livestock-forest, adjustment of the animal load with forage budgeting, also help to make the systems more sustainable and more resilient to the worsening of the situation of water scarcity or temperature increase. On the other hand, financing infrastructures meat processing,

for example, always considers the impact mitigation measures and the most appropriate technologies for each situation. Technologies such as composting carcass remains, reduce the need for water for settling ponds and assist in the production of natural fertilizers.

RESULTS

- Specialized technical advice and access to sustainable production technologies developed by Embrapa, in the territory of Inhamuns - CE;
- Collective acquisitions of inputs as a tool to reduce production costs in the territory of Inhamuns;
- Organizing fairs and markets to sell products, as an alternative to the informal goat and sheep market;
- Experimentation with collective animal finishing aiming at opening new markets and direct marketing with slaughterhouses eliminating middlemen;
- Scientific evidence from the Carrapateira region - PB as a potential indication of origin/geographical indication of sheep reared in this region.

NEXT STEPS AND RECOMMENDATIONS

- Appreciate and value products with regional characteristics, which also incorporate characteristics of local know-how, through projects that value goat and sheep products, countering the need to increase production as an imperative for increasing producers' income.
- Social construction of markets and shortening of chains as new opportunities for producers in regions most affected by climate change.
- Improve products in small local agro-industries, with all environmental and health requirements met, with support from MDR and partners, has been strengthened since 2019.
- Strengthening the territory to favor the population settling in the interior and increase the resilience of rural populations to the upsurge of climatic adversities.

DATA PUBLISHED IN:

COELHO, V. L. P.; NEMOTO, J. A.; MORAIS, O. R. de. Ambiente institucional e organizacional; Rota do Cordeiro. In: SORIO, A.; MAGALHÃES, L. A.; MARQUES, W. A. Carne ovina: o ontem, o hoje e o amanhã. Brasília: Escola Superior do Agronegócio Internacional. 2016. p. 173-185.

EMBRAPA CAPRINOS E OVINOS. Rota do Cordeiro. Sobral: Embrapa. 2011. Disponível em: <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/47362/1/FD-Rota-do-cordeiro.pdf>. Acesso em: 10 fev. 2020.

REFERENCES

BRASIL. Ministério da Integração Nacional. Secretaria de Desenvolvimento Regional. Bases para o plano nacional de desenvolvimento da Rota do Cordeiro. Brasília-DF: MI. 2017.

OLIVEIRA NETO, J. B. de. Estudos preliminares para caracterizar a contribuição da faveleira como possível fator para indicação geográfica da carne ovina. 2017. Tese (Doutorado) – Programa de Pós-Graduação em Zootecnia. Universidade Federal de Viçosa. Viçosa-MG. 2017.

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Table 1: Example of “project portfolio” for the Rota do Cordeiro hub. Rio das Contas hub -BA

Axis	Component	Project scope	Stakeholders
Inputs and production	Food	Implementation of confinement centers...	ABM Projects, Unirio, Municipal
	Genetic enhancement	Embrapa’s support in identifying the best types of industrial crossings ...	Unirio, Embrapa, UESB
		Expansion of the distribution of genetics that already exist at the hub	Unirio, Embrapa
Processing and adding value	Certified slaughter benefitting	Construction of rooms for cutting, and packaging	Unirio. Embrapa
	New products	Special cuts (training)	Manoel Vitorino Small Farmers Union
		Smoked meats and sausages (training)	

Source: Summary of the publication of the results of the workshops (BASES, 2017).

ROTA DOS BUTIAZAIS (BUTIAZAIS ROUTE): CONNECTING PEOPLE TO CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY

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The Rota dos Butiazais is a network that aims to articulate scientific and popular knowledge with the offer of ecosystem services and the generation of income in territories where there are still ecosystems of butiazais or where the historical and cultural value of the butiá stands out, in the Pampa biomes, Atlantic Forest and Cerrado (Figure 1). Butiazal ecosystems are groupings of butiazeiros, palm trees that produce edible fruits known as butiá (in the Pampa and Mata Atlântica Biomes) or sour coconut (in the Cerrado Biome). These palm trees are native to Brazil, Uruguay, Argentina and Paraguay, and having evolved over thousands of years in this environment, have great resilience and adaptive capacity to climate change. The fruits are used in the production of food and beverages, their leaves are raw material for handicrafts and the plants are valuable for landscaping. However, threatened by the advance of urbanization and the implantation of monocultures, butiazais are in danger of disappearing. A great challenge is to preserve the butiazais that still exist and, while also generating income and development for local communities. The Rota dos Butiazais associates the development of knowledge with actions for the conservation of butiazais, promoting income generation for the municipalities involved, strengthening regional identity and favoring social inclusion and local development. Making developed knowledge and technologies popular through workshops (of cooking, handicrafts, seedling production and environmental education), seminars, exhibitions, videos, scientific articles and articles in the media, are a fundamental part of the project to increase social awareness. Along with encouraging the use of the butiá, actions have been taken to restore the butiazais, either by managing cattle in native fields, allowing the development of young palm trees, or by introducing new seedlings. The beneficiaries of the Rota dos Butiazais are extractivists, farmers, ranchers, artisans, cooks, consumers, students, teachers, businessmen, public policy makers, municipal managers, agro-industries, civil society organizations and local companies. From 2015 to 2017 the funding source for the Rota dos Butiazais was the Ministry of the Environment (MMA). 2017 to 2020 the project has financial support from CNPq and the Ministry of Science,

Technology, Innovations and Communications (MCTIC).

RESULTS

The Butiazais Route has strengthened people's connection with their territory, by stimulating a new look at natural resources, seeking to value butiá as an element of socio-biodiversity, creating dynamics in the local economy (handicrafts, gastronomy, food and beverage production, tourism, urban landscaping) associated with the maintenance of important ecosystem services in the remaining butiazais. In addition, it has promoted actions for the conservation of butiazais and related culture, generating income for the municipalities involved, strengthening regional identity and favoring social inclusion and local development. The Rota dos Butiazais opened up possibilities for the strengthening of ecotourism, gastronomic tourism and the sale of handicrafts by local communities, generating income and work, in addition to contributing to the process of environmental education and citizen training. It has articulated the "know-how" from different places, valuing extractivists, farmers, artisans and family agro-industries (short circuits), which historically use butiás in a sustainable way, stimulating innovative entrepreneurship. Additionally, it contributes to leverage and stimulate the offer of other associated services, such as hotels, restaurants and local tourist guides.

NEXT STEPS AND RECOMMENDATIONS

The challenges of production and the market point to the improvement of the extractivist logistics for butiá, aiming to increase the quality of fruits and pulps, the development of new products with more access to the market and reduction of losses, and the organization of fair trade networks.

The challenges for the sustainability of ecosystems are the expansion of areas of butiazais that respect good management practices with monitoring of ecosystems as fundamental elements for their maintenance and regeneration of palm populations; building voluntary

certification standards for sustainable trade; and the monitoring and inspection of the degradation of remaining butiazeais. It is recommended to expand partnerships with landowners for the implementation of conservative management of remaining butiazeais; support SEMA, the Public Ministry and the municipalities where butiazeais occur by preparing ordinances and proposals for laws for the conservation and recovery of these ecosystems.

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DATA PUBLISHED IN:

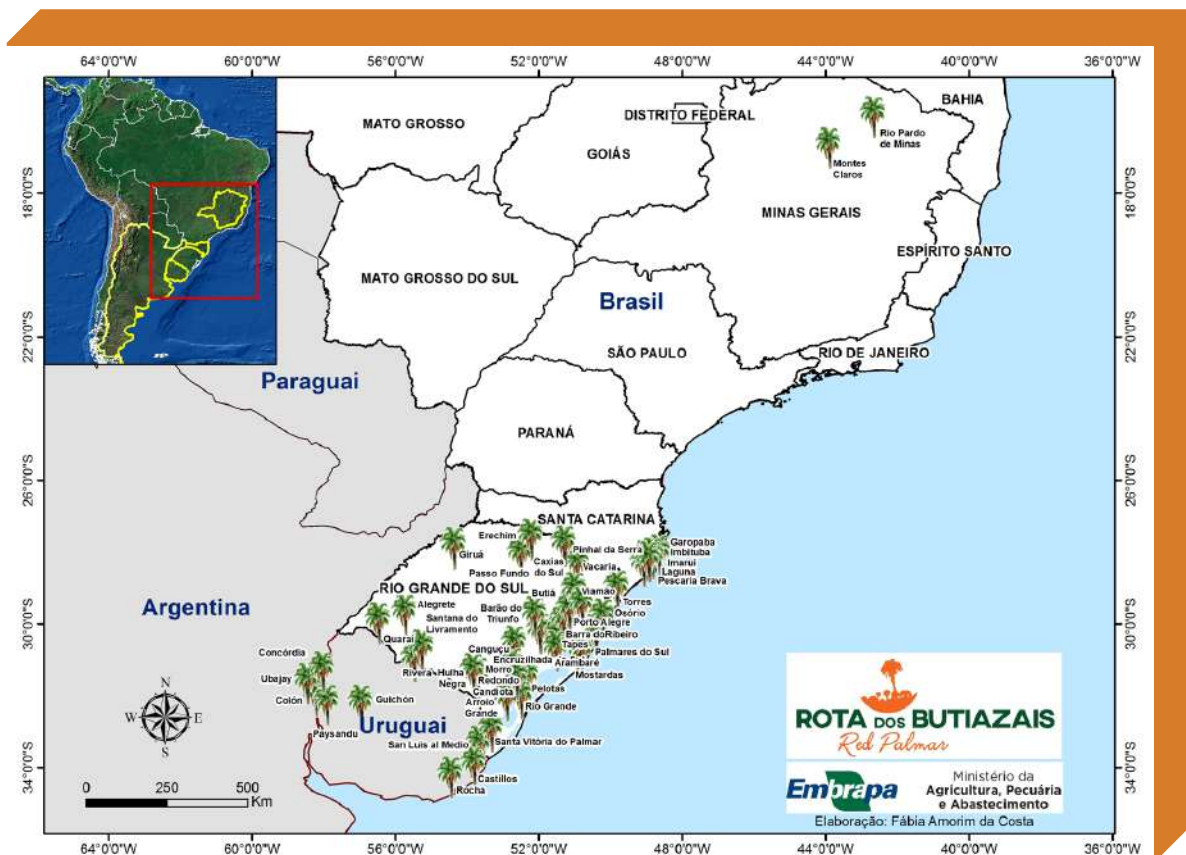
BARBIERI. R. L. (ed). Vida no butiazal. Pelotas: Embrapa Clima Temperado. 2015.

COSTA. F. A.; BARBIERI. R. L.; SOSINSKI JÚNIOR. E. E.; HEIDEN. G. Caracterização e discriminação espectral de butiazeiros (Butia odorata. Arecaceae) utilizando técnicas de sensoriamento remoto. Pelotas: Embrapa Clima Temperado. 2017. (Comunicado Técnico 355).

ESLABÃO. M. P.; PEREIRA. P. E. E.; BARBIERI. R. L.; HEIDEN. G. Mapeamento da distribuição geográfica de butiá como subsídio para a conservação de recursos genéticos. Pelotas: Embrapa Clima Temperado. 2016. (Boletim de Pesquisa e Desenvolvimento 252)

Continued in Annex

Figure 1: Map of the Butiazeais Route, where each palm tree indicates a location that participates in the project in Brazil, Uruguay and Argentina



Crédit: Fábila Amorim da Costa.

REDESIGN OF THE CBL (CAATINGA BUFFEL LEGUMINOUS) SUSTAINABLE ANIMAL PRODUCTION SYSTEM

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Water scarcity, high temperatures and adverse edaphic conditions are the major challenges facing agriculture in the semiarid region. The development of technologies aimed at increasing the resilience of production systems is a condition inherent to the adversities of this region. The actions aim to circumvent the difficulties mainly of climate, as well as others affecting the production systems.

The Animal Production Systems developed by Embrapa, as is the case with SAF Sobral; Sistema Glória and CBL - Caatinga Buffel Leguminosa, are receiving new attention in order to increase resilience and adaptive capacity to the challenges that have been even more accentuated by climate change.

The proposal for redesigning the semiarid production systems and the inclusion of integrated systems such as ICLF has been evaluated. The proposal "Production Models for the Sustainable Use of the Caatinga Aiming at Food Security in the Semiarid: New Paradigms for Agroforestry Production Systems in the Northeast", included redesigns of several agricultural production systems, and the CBL, designed by Embrapa Semiárido in the mid-2000s. 1990s was the system evaluated for areas with rainfall below 400 mm per year.

The CBL recommends the use of the Caatinga as a source of native pasture and the use of resistant species adapted to the climatic conditions of the semiarid region of the Northeast in the form of cultivated pasture and use as conserved forage.

Among the component activities, the following are evaluated:

- Forage budgeting throughout the year in the Embrapa Semiárido CBL system and in its rearrangement;
- Determination of the nutritional balance of protein and energy of small ruminants in the systems evaluated at Embrapa Semiárido;
- Implementation of the CBL system rearrangement;
- Evaluation of practices for the establishment of exotic crops in the CBL system and their rearrangement.

Strategies to reduce vulnerability and increase resilience are related to the identification and quantity of forage biomass in native pasture areas in dry and rainy seasons in order to allow subsidies for decision-making by researchers and even producers, with respect to support capacity for these pastures.

Besides this, the microhistological identification of the main plants consumed by the animals throughout the year in the native pasture was carried out, in order to enrich forage species and focus the direction of the studies related to them.

The diversity shown by the shrub/tree and herbaceous strata was very low compared to the plant diversity of the caatinga. This fact may be related to the low rainfall levels during the historical periods of drought, or even its level of use in the grazed form (table 1 and Figure 1).

The climatic events in the years in which the activities were carried out followed the lowest rainfall levels achieved in the last twenty years and reinforced the need to enrich the native pasture areas with the main plants consumed by animals and used for animal supplementation, specific to the different seasons of the year.

All actions were part of projects financed by Embrapa with the support of postgraduate programs from public universities. The results achieved are of interest to researchers, students and even producers in the semiarid region.

RESULTS

- Minimum levels of dietary supplementation were found in the order of 1.5% of body weight (BW) for adult female goats grazing in the Caatinga during the dry period of the year and in the order of 0.5%/ BW of supplementation without compromising body weight and diet digestibility.
- The most representative families found were Fabaceae, Euphorbiaceae and Anacardiaceae.

NEXT STEPS AND RECOMMENDATIONS

Studies are distributed in research portfolios and focus on assessing the resilience and adaptive capacity to the climate of the production systems described.

The production models have been constantly tested taking into account the results achieved with previous research.

The following steps include the application of sustainable intensification models and increased water intake for the system to be rationally and efficiently used. In addition, the models will be evaluated economically.

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DATA PUBLISHED IN:

LIMA, R. G. Microhistologia fecal na determinação da composição botânica da dieta de caprinos em pastejo na Caatinga. 2016. Dissertação (Mestrado em Zootecnia) – Universidade Federal do Vale do São Francisco. Petrolina-PE. 2016.

RIBEIRO, R. Suplementação concentrada para fêmeas caprinas em pastejo na Caatinga em diferentes períodos. 2018. Dissertação (Mestrado em Zootecnia) – Universidade Federal do Vale do São Francisco. Petrolina-PE. 2018.

Table 1: Nutrient intakes in supplemented female goats grazing in the Caatinga in the dry and rainy/transition periods

Variable	Level of Supplementation				ER	R2
	0.5%	1.0%	1.5%	2.0%		
Dry period						
CPB (g/day)	64.78b	83.23b	99.12b	116.35b	1*	0.99
CFDN (g/day)	303.90	308.70	295.20b	295.38b	-	-
CFDA (g/day)	185.00a	167.98a	138.30	118.79b	2*	0.99
Período chuvoso/ transição						
CPB (g/day)	154.57a	130.60a	152.06a	160.71a	-	-
CFDN (g/day)	321.10	349.68	366.20a	399.00a	3*	0.98
CFDA (g/day)	126.57b	136.85b	142.07	154.06a	4*	0.98

Caption: 1 * $Y = 48.22 + 34.12x$; 2* $Y = 209.6 - 45.622x$; 3* $Y = 296.44 + 50.044x$; 4* $Y = 117.97 + 17.538x$; CPB - p Crude protein; CFDN - neutral detergent fiber; CFDA - fiber in acid detergent.

Note: Different letters for the same variable in the same column show a significant difference ($P < 0.05$).

Source: Ribeiro (2018).

ATLANTIC FOREST ECOMARKET NETWORK

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The Auá Institute has been promoting local sustainable development in São Paulo for 22 years and, since 2009, it has been coordinating the Cambuci Route. The movement formed by farmers, artisanal processors, gastronomic establishments, retail, touristic establishments, industries, governments and scientific researchers, for the conservation of Cambuci (*Campomanesia phaea*) in its biome, the Southeast Atlantic Forest, valuing the local culture, agroecology, fair trade and sustainable tourism. As shown in the Figure, we verified the evolution of deforestation in SP, mainly due to the cultivation of coffee, sugar cane, orange, eucalyptus and cattle raising.

The Cambuci Route emerged spontaneously, from fruit promotion initiatives in municipalities surrounding Serra do Mar, between 2005 and 2009, with Gastronomic Festivals, seeking to enhance the local identity and its cultural traditions using the fruit. In early 2009, the 1st Gastronomic Route of Cambuci was formed, bringing together municipal festivals with the participation of artisanal producers of jellies, liquors, cachaças, juices, antipasti, etc.

In 2013, the Cambuci Route also brought together farmers with their plants and, on this occasion, it was remodeled, ceasing to be just an annual itinerary of Gastronomic Festivals, to become a Program of sustainable regional development, integrating culture, gastronomy, agriculture, industry, education, tourism and economy, based on the region's identity, linked to the fruit and natural assets of the Biome. Thus, other actions were launched such as the Local Sustainable Productive Arrangement, the Cambuci Tourist Route and the Network of Scientific Researchers.

In 2014, we began organizing farmers for market insertion, bringing together 12 main producers and 7 tons of frozen Cambuci. At this moment, we have defined the seals of the Productive Arrangement and the value of the product at each link of the productive chain, leaving producers with R\$ 5.00/kg, 250% more than what it was normally sold for. This increase made the potential profitability of Cambuci's culture greater than that of exotic species, thus making it more attractive to the farmer. In 2019 we already have more than 100 producers and we expect a harvest of approximately 120 tons of the fruit by 2020.

To ensure it had the power to lead the agroecological model of production, the Auá Institute invested in market structures, such as a store, a distributor with a 500 m² warehouse and a commercial brand called Empório Mata Atlântica. We conquered several clients, from restaurants, retail, industries and school meals and, with that, we were able to bring to the Productive Arrangement a methodology of Agroforestry System with native fruits, called Pomares Mata Atlântica. The severe droughts and frosts that occurred between 2015 and 2017 also contributed to strengthening the agroecological model, as it can be seen empirically that those who planted only Cambuci lost 80% more of their production compared to those who diversified their planting.

Since 2014, the Auá Institute has made it possible to purchase more than R\$ 500,000.00 of Cambuci and other native species from small farmers, mainly Juçara and Uvaia. For 2020, we expect a revenue from the productive arrangement of more than R\$ 1,200,000.00, both with the sale of fruits and their derivatives for industries, retail and restaurants. We also hope that this demand will provide an increase of at least 20% per year in the diversity of cultivated species.

RESULTS

- Access to knowledge about Cambuci and São Paulo's native fruits, through media, press, events and food, for more than 15 million people;
- More than 30 thousand native fruit trees planted by 80 farmers in Agroforestry Systems and 100 hectares with a Management Plan prepared in the Pomares Mata Atlântica methodology, awaiting resources for planting.
- Influence on public policies in 20 municipalities in the state of São Paulo
- More than 100 Cambuci festivals held, with an audience of 1 million people (only in 2019, 18 events and 100 thousand people) and R\$ 1,000,000.00 transacted in the region thanks to events where products were purchased and also involving gastronomy and tourism.

- More than R\$ 1,500,000.00 raised with Public and Private Funds for projects to train 150 farmers and structure production and the market.

NEXT STEPS AND RECOMMENDATIONS

Certainly, our main challenge in the coming years is to structure a market that demands native species from the Southeast Atlantic Forest at an equal speed, or higher than the growth that should occur with the supply. This demand must be qualified to value biodiversity and agroecological cultivation. As a result, consequently, it is a challenge to expand scientific knowledge about the management and characteristics of these species, as well as investments in production, processing and logistics infrastructures.

The following steps include the application of sustainable intensification models and increased water intake for the system to be rationally and efficiently used. In addition, the models will be evaluated economically.

DATA PUBLISHED IN:

ANDRADE. B. A. G. de F.; FONSECA. P. Y. G. da; LEMOS. F. (org.). Cambuci o fruto. o bairro. a rota: história. cultura. sustentabilidade e gastronomia. São Paulo: Ourivesaria da Palavra. 2011. Disponível em: <http://institutoaua.org.br/portfolio/cambuci-o-fruto-o-bairro-a-rota-2/>. Acesso em: 10 fev. 2020.

INSTITUTO AUÁ DE EMPREENDEDORISMO SOCIOAMBIENTAL. Pomares Mata Atlântica – Orientações para o cultivo agroecológico de pomares de Mata Atlântica. Osasco: Auá. 2018. Disponível em: <http://institutoaua.org.br/portfolio/pomares-mata-atlantica-orientacoes-para-o-cultivo-agroecologico-de-pomares-de-mata-atlantica/>. Acesso em: 10 fev. 2020.

SATO. G. S. (org.). Turismo rural. indicação geográfica. gastronomia e sustentabilidade. São Paulo: SAA-IEA. 2016. Disponível em: <http://institutoaua.org.br/portfolio/turismo-rural-indicacao-geografica-gastronomia-e-sustentabilidade/>. Acesso em: 10 fev. 2020.

PROJECT COORDINATORS

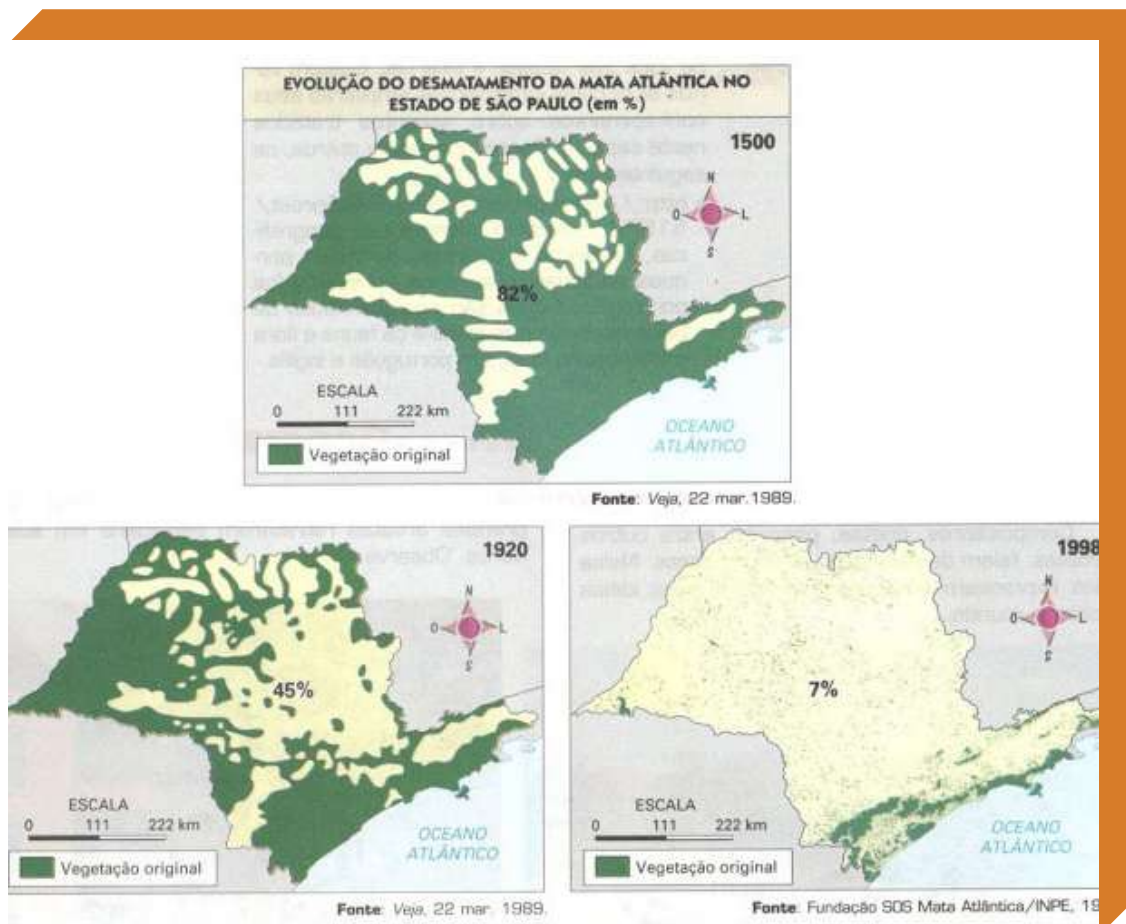
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Figure 1: Evolution of deforestation in the Atlantic Forest in the state of São Paulo



Crédit: <http://profwladimir.blogspot.com/2014/09/atividade-sobre-mata-atlantica.html>.

ADAPTATION TO CLIMATE CHANGE BY RIVERSIDE LOWLAND AND PALEOVÁRZEA PRODUCERS IN THE AMAZON

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In the Amazon, numerous extreme climatic phenomena are observed due to climate change. In floodplains and paleovárzea ecosystems, large floods are the ones that most affect livelihoods. We conducted semi-structured interviews to understand how the riverside of the Middle Rio Solimões was affected and adapted to extreme climatic situations. The main effects of large floods are: 1) the cultivation areas are flooded suddenly and concomitantly; 2) many flour-roasting houses flooded; 3) in the floodplain, 45% of the crops are affected; 4) fish spread in the vast volume of water, making fishing difficult and 5) increasing the mortality of farm animals. We also describe the adaptation actions found and highlight the need for greater dialogue between different social actors, aiming at the collective elaboration of strategies and an emergency plan that favors traditional ways of life. The research is carried out at the National Institute for Research in the Amazon (INPA) and at the Mamirauá Sustainable Development Institute (IDSM). We have funding from the Amazon Fund, CNPq and FAPESAM.

RESULTS

- Floods: an extreme flood occurred per decade; since 2009, there have been four. Traditional strategies are adapted and new strategies are developed.
- Climate predictability: the riverside inhabitants have vast traditional knowledge about the climate. However, indicators of seasonal cycles are no longer reliable, causing loss and instability in production. New indicators are being tested.
- Cassava: During common flooding, agricultural management is done through *ajuris* (joint efforts). During large floods, crops are flooded suddenly and concomitantly, making it difficult to raise them. There may not be time for cassava to ripen completely, which generates poor quality flour or makes its production unfeasible.
- Flour houses: some riverside communities build floating flour houses, because of annual flooding. During extreme flooding, not everyone can find a place to make flour. The most experienced are familiar with pre-Columbian adaptation techniques for storing cassava dough for preparing flour during the rivers low periods.
- Planting: traditionally they build suspended flower beds for vegetables, and plant more cassava/manioc varieties and short cycle species in the fields. The waters may rise earlier than expected, generating intense mortality of non-adapted plants. During the largest recorded flooding, 45% of the floodplain crops were affected. As an adaptation, they prioritize the cultivation of plants that have demonstrated greater survival or cultivate temporarily on land areas.
- Causes of crop losses: in addition to not surviving when they come in contact with little or a lot of water at different stages of development, the movement of water in root systems can kill plants. When puddles of water become heated by the sunlight they can "cook" the roots. To protect the roots, they do not harvest fruit by climbing the flooded trees.
- Cultivation in soil piles: in communities of high floodplain, they create piles of soil in backyards (circular terrace about 1m high) to plant trees above the maximum water level.
- Seeds: annually set aside seeds and seedlings. However, in extreme flooding some plants die before producing them. Researchers and young people from the Technological Vocational Center of the Mamirauá Institute started organizing annual fairs to exchange branches and seeds.
- Fire: *cauxi* is a (cf. *Tubella reticulata* and cf. *Betesil parnula*) highly combustible sponge that grows on the trunk of trees. When water levels rise, the *cauxi* spreads in the water and in the ebb is deposited/hangs onto the vegetation. After major floods, experienced producers are more cautious with the use of fire in open agricultural areas.
- Fishing: at the beginning of the annual flood, fish are scattered throughout the vast volume of water. When

the water reaches the backyards, the fruit attracts some fish, minimizing the difficulty in fishing. When there are extreme levels of water, schools come out of the lakes (including ponds for the preservation of fishery management stocks), increasing the availability of fish.

- Animal breeding: during extreme floods they present more diseases, drown, bog down or are attacked by wild animals. They place the animals in marombas (rafts), and sell or eat the animals. They also resort to solid ground or temporarily change their source of income, increasing fishing.

NEXT STEPS AND RECOMMENDATIONS

Extreme climatic phenomena are increasingly expected in the Amazon (BARICHIVICH et al. 2018). Greater dialogues are needed between social players in the region (community, institutions and government agencies) for the collective elaboration of strategies and an emergency plan that favors traditional ways of life.

Increasing the exchange of local strategies that favor the resilience of these populations in the current scenario should take place. For example, techniques for storing cassava mass and the more careful use of fire due to cauxi need be disseminated and planned.

REFERENCES

BARICHIVICH. J.; GLOOR. E.; PEYLIN. P.; BRIENEN. R. J. W.; SCHÖNGART. J.; ESPINOZA. J. C.; PATTNAYAK. J. C.; PATTNAYAK. K. C. Recent intensification of Amazon flooding extremes driven by strengthened Walker circulation. *Science Advances*. v. 4. n. 9. p. 1-7. Sep. 2018.

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Tabela 1: Summary of the contexts in the floodplain and paleovarzea of the middle Rio Solimões that are affected by extreme weather events, mainly floods, and the strategies adopted by riverside dwellers to adapt to these events

Context	Extreme situation	Adaptation
Floods	There have been three times as many floods in the past decade.	New strategies and adaptations of the previous ones are being developed.
Local traditional knowledge about the climate	Indicators for seasonal cycles are not applicable.	The lack of climate predictability generates losses and instability in production.
Cassava	Difficulty in performing ajuri (joint effort). Some cassava trees are unable to complete their maturation when the water level rises.	They plant as family units. The green cassava produces poor quality flour or makes its production unviable.
Flour production	Flour houses flood.	Researchers and young people from the Vocational Center Technological Institute of Mamirauá started organizing fairs and seed exchanges.
Planting	45% of crops are affected in the floodplain, which is sometimes totally lost.	Pesquisadores e jovens do Centro Vocacional Tecnológico do Instituto Mamirauá iniciaram a mobilização de feiras e trocas de sementes.
Fishing	Fish are scattered in the vast volume of water.	Fruit from backyards and other growing areas attracts some fish, minimizing the problem.
Farm animals	More diseases and risks for animals more (drowning, getting bogged down, being attacked by wild animals).	They sell or feed on animals. Appeal to firmer land. They adapt their sources of income, increasing fishing.

STRATEGIES FOR ADAPTATION OF BRAZILIAN AGRICULTURAL SYSTEMS TO CLIMATE CHANGE

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The studies sent by the researchers cover a wide variety of themes, perspectives, problems, considerations on vulnerabilities and proposals for adaptation strategies for Brazilian agricultural systems, throughout the national territory. The dedication of researchers, and the consequent excellence of Brazilian agricultural research, give the country a huge differential in the possibilities of adapting agricultural systems to climate change. However, in this wide range of approaches, there is ambiguity and some confusion between the impacts of climate change and those arising from land use changes or inadequate agricultural systems management. As efforts to adapt to climate change must seek the sustainable production of agricultural systems (FAO, 2017), it is natural that the vulnerability pointed out by researchers is strongly based on the assessment of the sustainability of productive processes. In this sense, the organization of the researchers' work in strategic adaptation axes allows the identification of variations and trends on the type of problem and the vulnerabilities faced, as well as the approaches developed.

The vulnerability to water and thermal stress, although present in all axes, is massively addressed in the strategic axis "Use of genetic resources". It is notorious and expected that many studies focused on problems with drought and high temperature in the Semiarid Region, where the greatest impacts of climate change in Brazil forecasted. As a result of these stresses, there is considerable concern in this axis with several vulnerabilities and the resulting reductions in productivity, nutritional quality, changes in the agroclimatic aptitude of cultivars and in the intensity and geographical and temporal distribution of their pathogens. Therefore, the objective of several studies in this axis focus on the genetic improvement of cultivars so that they are more resistant and tolerant to climatic stresses, in addition to investigating the effects of these stresses for different pathosystems, eliminating the seasonality of production and improving inadequate productive managements.

The works presented in the strategic axis "Infrastructure, production technologies and equipment", in addition to addressing vulnerabilities related to the climate stress mentioned above, also focus on issues of degradation and intensive soil management and gaps in gauging the management of production systems. For this reason, the work on this axis aims to contribute to solving the problems by developing tools and technologies for diagnosis, planning and intervention in the management of agricultural systems in various approaches.

The work on the strategic axis "Use and conservation of biodiversity" is concerned with the increasing vulnerability of productive systems resulting from the destruction or degradation of natural ecosystems and the loss of biodiversity caused by both climate change, as well as inadequate and unsustainable land use practices. There is strong concern in this group about the genetic erosion of local and traditional food crops and a reduction in ecosystem services (such as pollination), which are among the greatest assets for the adaptation of agricultural systems to climate change. Therefore, the objectives of the work on this axis seek to understand the effects of climate change on native species, pollinators and bacteria beneficial to agriculture, the importance of biodiversity and agrobiodiversity for human food and nutrition, proposing, among others, the development of native cultivars.

The work in the strategic axis "Integrated landscape management", in addition to being concerned with the vulnerability of agricultural systems in relation to climate change, adds stronger and broader criticism than previous efforts on the predominant management in these systems. Criticism ranges from the degradation of natural resources, to the advance of urbanization, economic exclusion, the lack of financial resources and basic development policies. Consequently, the objective of these works is to understand complex problems, using technical-scientific and traditional knowledge to develop and apply participatory sustainability solutions, in a context of social inclusion, conservation of natural resources and the well-being of people.

Some works incorporate characteristics of more than one of the above axes. However, the strategic axes show a trend that allows them to be grouped according to the way they perceive the problems and vulnerabilities to be discussed and faced and their proposed solutions. This more or less subtle trend, according to each work, shows a gradient that begins in the strategic axis "Use of genetic resources", passing through the axes "Infrastructure, technologies and agricultural equipment" and "Use and conservation of biodiversity", ending on the "Integrated landscape management" axis. Permeated by the strong overlapping and confusion between the impacts caused by climate change or production practices, there is a gradient that on the one hand focuses on specific vulnerabilities of cultivars and soil management; and on the other, the resilience of complex systems and land use changes. Even incorporating one or another element from the other extreme, this gradient presents at the end of the axis "Use of genetic resources" a more local approach, with specific objectives, strongly based on knowledge and technical-scientific solutions, aiming primarily at maintaining or increasing the productivity and the simplification of agricultural systems. At the other end of the gradient, the "Integrated landscape planning and management" axis brings a more landscape and regional development oriented approach, with broader objectives, based on the participatory use and construction of technical-scientific and traditional knowledge, aiming at social well-being and the conservation of natural resources in complex agricultural systems. In summary, there is a tendency with greater or lesser intensity, for the work to adopt an approach in relation to climate change, in a gradient that goes from the resistance of simplified agricultural systems to the resilience of complex agricultural systems.

Although there are important advances in national and international research on adaptation, both lack the same need for development, that is, the consolidation of a theoretical and methodological framework to support the theme. Without a definition or clear parameters that allow a deeper analysis of the types and needs of existing adaptation, it becomes more difficult to make a decision on which are the appropriate adaptation strategies, or even the effectiveness of any strategies already applied.

It is known that agricultural systems with practices that lead to greater sustainability tend to reduce vulnerability and strengthen the resilience of the system in relation to the impacts arising from climate change. Specifically, strategies that guide the establishment of agricultural production systems based on conservation agriculture, involving adequate management of soil and water, the conservation and sustainable use of biodiversity and the maintenance of ecosystem services, are strategies that are among the greater assurances of future possibilities for adaptation to climate change. In this sense, the proposals and results that the ABC Plan has achieved, by establishing strategies and technologies that lead to greater sustainability of agricultural systems, contribute in some way to the capacity to adapt to climate changes. However, the magnitude of the impacts of the ABC Plan on strengthening resilience and the capacity to adapt agricultural systems is not yet clear. Although all the research in this collection and in Brazil is extremely relevant for advancing the theme, the evaluation of the information presented in this publication, both through the review of national and international documents and ongoing initiatives, shows that there is no clarity regarding the definitions and the related concepts are still confusing. Without clear concepts, methodologies for assessing adaptive capacity are not possible, reinforcing the uncertainty that can be observed when discussing adaptation.

Based on this observation, this collection recommends promoting the advancement of public policies beyond the efficiency of their application, focusing mainly on the effectiveness of their results. Efficiency refers to the correct implementation of processes, that is, to implement policies for adapting to climate change, such as developing a national adaptation plan, making financial resources available, among others, and is related to process indicators. Knowing how and if climate change adaptation policies and initiatives are effective and sufficient requires another level of understanding and effort. Effectiveness refers to doing the right thing, that is, in addition to efficiently implementing policies and initiatives to adapt to climate change, they demonstrably have to increase resilience and reduce the vulnerability of agricultural systems to climate change. Effectiveness is related to results or impact indicators, such as available ecosystem services, food security for the population, maintenance of productive capacity, among others.

Some effects and impacts of climate change in agriculture are already recognized and reported in the studies received from Brazilian researchers working on the topic, in the literature and in the reports disseminating national experiences in different countries. The subject of adaptation to climate change is strongly incorporated in the scientific agenda and in national and international politics. However, there is still a lot of uncertainty related to this topic. To face the conceptual and methodological uncertainty, the path to be followed to understand and advance the effectiveness of adapting agricultural systems to climate change in Brazil is the construction of a conceptual framework, with clear and viable definitions, objectives and evaluation methodologies, which include technical, institutional and procedural strategies that can effectively give the agricultural producers the necessary security in their decision-making process, in an increasingly uncertain environment, with regard to the ability to predict favorable climatic conditions for Brazilian agricultural production. This compilation is an important step in that direction.

Reference

United Nations Food and Agriculture Organization– FAO. Tracking adaptation in agricultural sectors: Climate change adaptation indicators. 2017. Available at: <http://www.fao.org/3/a-i8145e.pdf>. Accessed on: jul. 09 2020.

Annex - Bibliographic continuation

Intercropping grasses and legumes for pasture diversification and sustainable intensification of livestock in the Amazon

Data published in:

VALENTIM. J. F.; ANDRADE. C. M. S. de. Forage peanut (*Arachis pintoi*): a high yielding and high quality tropical legume for sustainable cattle production systems in the western Brazilian Amazon. *Tropical Grasslands*. Australia. v. 39. n. 4. p. 222. Dec. 2005b.

VALENTIM. J. F.; ANDRADE. C. M. S. de. Perspectives of grass-legume pastures for sustainable animal production in the tropics. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA. 41.. 2004. Campo Grande. Tema: A produção animal e segurança alimentar. Anais [...]. Campo Grande: Sociedade Brasileira de Zootecnia; Embrapa Gado de Corte. 2004.

VALENTIM. J. F.; ANDRADE. C. M. S. de. Tropical kudzu (*Pueraria phaseoloides*): successful adoption in sustainable cattle production systems in the western Brazilian Amazon. *Tropical Grasslands*. Australia. v. 39. n. 4. p. 221. Dec. 2005a.

References

IBGE. Censo Agropecuário 2017. Tabela 6722: Número de estabelecimentos agropecuários e Área dos estabelecimentos. por utilização das terras. condição legal do produtor. direção dos trabalhos do estabelecimento agropecuário e grupos de área total – resultados preliminares 2017. Rio de Janeiro: IBGE. 2017. Disponível em: <https://sidra.ibge.gov.br/tabela/6722#resultado>. Acesso em: 8 jan. 2020.

INPE; EMBRAPA. Projeto TerraClass: levantamento de informações de uso e cobertura da terra na Amazônia Legal brasileira – 2004-2014. São José dos Campos: INPE. 2016. Disponível em: http://www.inpe.br/cra/projetos_pesquisas/dados_terraclass.php. Acesso em: 25 jul. 2016.

STRASSBURG. B. B. N.; LATAWIEC. A. E.; BARIONI. L. G.; NOBRE. C. A.; SILVA. V. P.; VALENTIM. J. F.; VIANNA. M.; ASSAD. E. D. When enough should be enough: Improving the use of current agricultural lands could meet production demands and spare natural habitats in Brazil. *Global Environmental Change*. Netherlands. v. 28. p. 84-97. Sep. 2014.

Ruminant hologenome - characterization of microorganism population in ruminants' digestive tract and their impact on the host's functional genome performance, product quality and environmental impact

References

CESAR. A. S. M.; REGITANO. L. C. A.; REECY. J. M.; POLETI. M. D.; OLIVEIRA. P. S. N.; OLIVEIRA. G. B. de; MOREIRA. G. C. M.; MUDADU. M. A.; TIZIOTO. P. C.; KOLTES. J. E.; FRITZ-WATERS. E.; KRAMER. L.; GARRICK. D.; BEIKI. H.; GEISTLINGER. L.; MOURÃO. G. B.; ZERLOTINI. A.; COUTINHO. L. L. Identification of putative regulatory regions and transcription factors associated with intramuscular fat content traits. *BMC Genomics*. v. 19. p. 1-20. June 2018.

CESAR. A. S. M.; REGITANO. L. C. A.; TULLIO. R. R.; LANNA. D. P. D.; NASSU. R. T.; MUDADO. M. A.; OLIVEIRA. P. S. N.; NASCIMENTO. M. L. do; CHAVES. A. S.; ALENCAR. M. M.; SONSTEGARD. T. S.; GARRICK. D. J.; REECY. J. M.; COUTINHO. L. L. Genome-wide association study for intramuscular fat deposition and composition in Nelore cattle. *BMC Genetics*. v. 15. p. 2-10. Mar. 2014.

DINIZ. W. J. S.; COUTINHO. L. L.; TIZIOTO. P. C.; CESAR. A. S. M.; GROMBONI. C. F.; NOGUEIRA. A. R. A.; OLIVEIRA. P. S. N.; M. M.; REGITANO. L. C. A.; SOUZA. M. M. Iron content affects lipogenic gene expression in the muscle of Nelore beef cattle. *PLoS ONE*. v. 11. n. 8. p. 1-19. Aug. 2016.

DINIZ. W. J. S.; ROSA. K. O.; COUTINHO. L. L.; TIZIOTO. P. C.; OLIVEIRA. P. S. N. de; SOUZA. MARCELA M. de; CHAVES. A.

S.; LANNA. D. P. D.; MOURÃO. G. B.; REGITANO. L. C. A. KCNJ11 gene expression is associated to feed consumption and growth traits in Nelore beef cattle. *Agri Gene*. v. 9. p. 1-4. Sep. 2018.

GEISTLINGER. L.; SILVA. V. H. da; CESAR. A. S. M.; TIZIOTO. P. C.; WALDRON. L.; ZIMMER. R.; REGITANO. L. C. de A.; COUTINHO. L. L. Widespread modulation of gene expression by copy number variation in skeletal muscle. *Scientific Reports*. v. 8. p. 1-11. Jan. 2018.

GONÇALVES. T. M.; REGITANO. L. C. de A.; KOLTES. J. E.; CESAR. A. S. M.; ANDRADE. S. C. da S.; MOURÃO. G. B.; GASPARIN. G.; MOREIRA. G. C. M.; FRITZ-WATERS. E.; REECY. J. M.; COUTINHO. L. L. Gene co-expression analysis indicates potential pathways and regulators of beef tenderness in Nelore cattle. *Frontiers in Genetics*. v. 9. p. 1-18. Oct. 2018.

KASARAPU. P.; PORTO-NETO. L. R.; FORTES. M. R. S.; LEHNERT. S. A.; MUDADU. M. A.; COUTINHO. L. L.; REGITANO. L. C. A.; GEORGE. A.; REVERTER. A. The *Bos taurus*–*Bos indicus* balance in fertility and milk related genes. *PLoS ONE*. v. 12. n. 8. p. 1-20. Aug. 2017.

MUDADU. M. A.; PORTO-NETO. L. R.; MOKRY. F. B.; TIZIOTO. P. C.; OLIVEIRA. P. S. N.; TULLIO. R. R.; NASSU. R. T.; NICIURA. S. C. M.; THOLON. P.; ALENCAR. M. M.; HIGA. R. H.; ROSA. A. N.; FEIJÓ. G. L. D.; FERRAZ. A. L.; SILVA. L. O.; MEDEIROS. S. R.; LANNA. D. P.; NASCIMENTO. M. L.; CHAVES. A. S.; SOUZA. A. R.; PACKER. I. U.; TORRES. R. A. Jr.; SIQUEIRA. F.; MOURÃO. G. B.; COUTINHO. L. L.; REVERTER. A.; REGITANO. L. C. Genomic structure and marker-derived gene networks for growth and meat quality traits of Brazilian Nelore beef cattle. *BMC Genomics*. 2016;17(1) : 235.

OLIVEIRA. G. B.; REGITANO. L. C. A.; CESAR. A. S. M.; REECY. J. M.; DEGAKI. K. Y.; POLETI. M. D.; FELÍCIO. A. M.; KOLTES. J. E.; COUTINHO. L. L. Integrative analysis of microRNAs and mRNAs revealed regulation of composition and metabolism in Nelore cattle. *BMC Genomics*. v. 19. p. 1-16. Feb. 2018.

OLIVEIRA. P. S. N.; CESAR. A. S. M.; NASCIMENTO. M. L.; CHAVES. A. S.; TIZIOTO. P. C.; TULLIO. R. R.; LANNA. D. P. D.; ROSA. A. N.; SONSTEGARD. T.; MOURÃO. G. B.; REECY. J. M.; GARRICK. D. J.; MUDADU. M. A.; COUTINHO. L. L.; REGITANO. L. C. A. Identification of genomic regions associated with feed efficiency in Nelore cattle. *BMC Genetics*. v. 15. p. 2-10. Sep. 2014.

OLIVEIRA. P. S. N.; TIZIOTO. P. C.; MALAGO JUNIOR. W.; NASCIMENTO. M. L.; CESAR. A. S. M.; DINIZ. W. J. da S.; SOUZA. M. M.; LANNA. D. P. D.; TULLIO. R. R.; MOURAO. G. B.; MUDADU. M. A.; COUTINHO. L. L.; REGITANO. L. C. A. A single nucleotide polymorphism in *NEUROD1* is associated with production traits in Nelore beef cattle. *Genetics and Molecular Research*. v. 15. n. 2. p. 1-8. July 2016.

POLETI. M. D.; REGITANO. L. C. A.; SOUZA. G. H. M. F.; CESAR. A. S. M.; SIMAS. R. C.; SILVA-VIGNATO. B.; OLIVEIRA. G. B.; ANDRADE. S. C. S.; CAMERON. L. C.; COUTINHO. L. L. Data from proteomic analysis of bovine *Longissimus dorsi* muscle associated with intramuscular fat content. *Data in Brief*. v. 19. p. 1314-1317. Aug. 2018.

POLETI. M. D.; REGITANO. L. C. A.; SOUZA. G. H. M. F.; CESAR. A. S. M.; SIMAS. R. C.; SILVA-VIGNATO. B.; OLIVEIRA. G. B.; ANDRADE. S. C. S.; CAMERON. L. C.; COUTINHO. L. L. *Longissimus dorsi* muscle label-free quantitative proteomic reveals biological mechanisms associated with intramuscular fat deposition. *Journal of Proteomics*. v. 179. p. 30-41. May 2018.

SILVA. V. H. da; REGITANO. L. C. de A.; GEISTLINGER. L.; PÉRTILLE. F.; GIACHETTO. P. F.; BRASSALOTI. R. A.; MOROSINI. N. S.; ZIMMER. R.; COUTINHO. L. L. Genome-wide detection of CNVs and their association with meat tenderness in Nelore cattle. *PLoS ONE*. v. 11. n. 6. p. 1-22. June 2016.

SILVA-VIGNATO. B.; COUTINHO. L. L.; CESAR. A. S. M.; POLETI. M. D.; REGITANO. L. C. A.; BALIEIRO. J. C. C. Comparative muscle transcriptome associated with carcass traits of Nelore cattle. *BMC Genomics*. v. 18. p. 2-13. July 2017.

SILVA-VIGNATO. B.; COUTINHO. L. L.; POLETI. M. D.; CESAR. A. S. M.; MONCAU. C. T.; REGITANO. L. C. A.; CARVALHO. J.

C. de B. Gene co-expression networks associated with carcass traits reveal new pathways for muscle and fat deposition in Nelore cattle. *BMC Genomics*. v. 20. p. 1-13. Jan. 2019.

SOMAVILLA. A. L.; REGITANO. L. C.; ROSA. G. J.; MOKRY. F. B.; MUDADU. M. A.; TIZIOTO. P. C.; OLIVEIRA. P. S. N.; SOUZA. M. M.; COUTINHO. L. L.; MUNARI. D. P. Genome-Enabled prediction of breeding values for feedlot average daily weight gain in Nelore cattle. *G3: Genes. Genomes. Genetics*. v. 7. n. 6. p. 1855-1859. June 2017.

SOMAVILLA. A. L.; SONSTEGARD. T. S.; HIGA. R. H.; ROSA. A. N.; SIQUEIRA. F.; SILVA. L. O. C.; TORRES JÚNIOR. R. A. A.; COUTINHO. L. L.; MUDADU. M. A.; ALENCAR. M. M.; REGITANO. L. C. A. A genome-wide scan for selection signatures in Nelore cattle. *Animal Genetics*. v. 45. n. 6. p. 771-781. Sep. 2014.

SOUZA. M. M. de; NICIURA. S. C. M.; TIZIOTO. P. C.; IBELLI. A. M. G.; GASPARIN. G.; ROCHA. M. I. P.; BRESSANI. F. A.; MALAGÓ-JR.. W.; DINIZ. W. J. S.; OLIVEIRA. P. S. N.; LIMA. A. O.; MUDADU. M. A.; BARIONI JUNIOR. W.; COUTINHO. L. L.; ZERLOTINI. A.; REGITANO. L. C. A. Allele- and parent-of-origin-specific effects on expression of the KCNJ11 gene: a candidate for meat tenderness in cattle. *Genetics and Molecular Research*. v. 15. n. 3. p. 2-10. Aug. 2016.

SOUZA. M. M. de; ZERLOTINI. A.; GEISTLINGER. L.; TIZIOTO. P. C.; TAYLOR. J. F.; ROCHA. M. I. P.; DINIZ. W. J. S.; COUTINHO. L. L.; REGITANO. L. C. A. A comprehensive manually-curated compendium of bovine transcription factors. *Scientific Reports*. v. 8. p. 1-12. Sep. 2018.

TIZIOTO. P. C.; COUTINHO. L. L.; DECKER. J. E.; SCHNABEL. R. D.; ROSA. K. O.; OLIVEIRA. P. S.; SOUZA. M. M.; MOURÃO. G. B.; TULLIO. R. R.; CHAVES. A. S.; LANNA. D. P.; ZERLOTINI-NETO. A.; MUDADU. M. A.; TAYLOR. J. F.; REGITANO. L. C. A. Global liver gene expression differences in Nelore steers with divergent residual feed intake phenotypes. *BMC Genomics*. v. 16. p. 1-14. Mar. 2015.

TIZIOTO. P. C.; COUTINHO. L. L.; MOURÃO. G. B.; GASPARIN. G.; SOUZA. M. M.; MALAGÓ-JR. W.; BRESSANI. F. A.; TULLIO. R. R.; NASSU. R. T.; TAYLOR. J. F.; REGITANO. L. C. A. Variation in myogenic differentiation 1 mRNA abundance is associated with beef tenderness in Nelore cattle. *Animal Genetics*. v. 47. n. 4. p. 491-494. Aug. 2016.

TIZIOTO. P. C.; COUTINHO. L. L.; OLIVEIRA. P. S. N.; CESAR. A. S. M.; DINIZ. W. J. S.; LIMA. A. O.; ROCHA. M. I.; DECKER. J. E.; SCHNABEL. R. D.; MOURÃO. G. B.; TULLIO. R. R.; ZERLOTINI. A.; TAYLOR. J. F.; REGITANO. L. C. A. Gene expression differences in Longissimus muscle of Nelore steers genetically divergent for residual feed intake. *Scientific Reports*. v. 6. p. 1-15. Dec. 2016.

TIZIOTO. P. C.; DECKER. J. E.; TAYLOR. J. F.; SCHNABEL. R. D.; MUDADU. M. A.; SILVA. F. L.; MOURAO. G. B.; COUTINHO. L. L.; THOLON. P.; SONSTEGARD. T.; ROSA. A. N.; ALENCAR. M. M.; TULLIO. R. R.; MEDEIROS. S. R.; NASSU. R. T.; FEIJÓ. G. L. D.; SILVA. L. O. C.; TORRES. R. A. A.; SIQUEIRA. F.; HIGA. R. H.; REGITANO. L. C. A. A genome scan for meat quality traits in Nelore beef cattle. *Physiological Genomics*. v. 45. n. 21. p. 1012-1020. Nov. 2013.

TIZIOTO. P. C.; GASPARIN. G.; SOUZA. M. M.; MUDADU. M. A.; COUTINHO. L. L.; MOURÃO. G. B.; THOLON. P.; MEIRELLES. S. L.; TULLIO. R. R.; ROSA. A. N.; ALENCAR. M. M.; MEDEIROS. S. R.; SIQUEIRA. F.; FEIJÓ. G. L. D.; NASSU. R. T.; REGITANO. L. C. A. Identification of KCNJ11 as a functional candidate gene for bovine meat tenderness. *Physiological Genomics*. v. 45. n. 24. p. 1215-1221. Dec. 2013.

TIZIOTO. P. C.; GROMBONI. C. F.; NOGUEIRA. A. R. A.; SOUZA. M. M.; MUDADU. M. A.; THOLON. P.; ROSA. A. N.; TULLIO. R. R.; MEDEIROS. S. R.; NASSU. R. T.; REGITANO. L. C. A. Calcium and potassium content in beef: influences on tenderness and associations with molecular markers in Nelore cattle. *Meat Science*. v. 96. n. 1. p. 436-440. Jan. 2014.

TIZIOTO. P. C.; TAYLOR. J. F.; DECKER. J. E.; GROMBONI. C. F.; MUDADU. M. A.; SCHNABEL. R. D.; COUTINHO. L. L.; MOURÃO. G. B.; OLIVEIRA. P. S. N.; NASSU. R. T.; DONATONI. F. A. B.; THOLON. P.; SONSTEGARD. T. S.; ALENCAR. M. M.; TULLIO. R. R.; REECY. J. M.; NOGUEIRA. A. R. A.; REGITANO. L. C. A. Detection of effects of quantitative trait loci on mineral content of bovine longissimus dorsi muscle. *Genetics Selection Evolution*. v. 47. p. 1-9. Mar. 2015.

Impact of climate change on physiological, productive performance and forage quality of the *Panicum maximum* cv Mombaça grass

Data published in:

PRADO. C. H.; HAIK L.; CASTRO. É.; MARTINEZ. C. A. Leaf dynamics of *Panicum maximum* under future climatic changes. PLoS ONE. v. 11. n. 2. e0149620. 2016.

VENTURA. R. B.; ALVES. L.; OLIVEIRA. R. de; MARTÍNEZ. C. A.; GRATÃO. P. Impacts of warming and water deficit on antioxidant responses in *Panicum maximum* Jacq. *Physiologia Plantarum*. v. 165. p. 413-426. 2019.

VICIEDO. D. O.; PRADO. R. de. M.; MARTÍNEZ. C. A.; HABERMANN. E.; PICCOLO. M. Short-term warming and water stress affect *Panicum maximum* Jacq. stoichiometric homeostasis and biomass production. *Science of The Total Environment*. v. 681. p. 267-274. 2019.

Links to interviews and published articles::

AGENCIA FAPESP/DICYT. El cambio climático puede perjudicar la calidad de las pasturas. Agencia Iberoamericana para la Difusión de la Ciencia y la Tecnología. Meio Ambiente Brasi. 20 maio 2019. Disponível em: <https://www.dicyt.com/noticias/el-cambio-climatico-puede-perjudicar-la-calidad-de-las-pasturas>.

AGRO RECORD. Aquecimento pode prejudicar pasto. Record TV Interior SP. 12 maio 2019. Disponível em: <https://pt-br.facebook.com/recordtvinteriorsp/videos/316454155695237/UzpfSTE0NDIxODg3NDYwNDEyNjA6MjI3MTAxNjY2MzE1ODQ2MA/>.

ARAGAKI. Caroline. Rádio USP. Produção pecuária já é afetada por mudanças climáticas. Jornal da USP no Ar. 16 abr. 2019. Disponível em: <https://jornal.usp.br/?p=238051>

MOON. Peter. A study shows climate change may lead to a decline in pasture quality. Agência FAPESP. 15 maio 2019. Disponível em: <https://agencia.fapesp.br/a-study-shows-climate-change-may-lead-to-a-decline-in-pasture-quality/30495/>.

MOON. Peter. Mudança climática pode piorar a qualidade das pastagens. Agência FAPESP. 28 mar. 2019. Disponível em: <https://agencia.fapesp.br/mudanca-climatica-pode-piorar-a-qualidade-das-pastagens/30119/>.

MOON. Peter; AGÊNCIA FAPESP. Mudança climática pode piorar a qualidade das pastagens. Jornal da USP. 3 abr. 2019. Disponível em: <https://jornal.usp.br/?p=233514>.

RÁDIO NACIONAL. Programa No AR. Mudança climática interfere na qualidade das pastagens? Brasil Rural. 9 abr. 2019. Disponível em: <https://radios.ebc.com.br/brasil-rural/2019/04/sera-que-mudancas-climatica-interfere-na-qualidade-das-pastagens>.

Melhoramento genético de eucaliptos para desenvolvimento de cultivares destinadas a múltiplos usos da madeira e de populações com potencial para superar possíveis adversidades ocasionadas por mudanças climáticas

References

REIS. C. A. F.; ASSIS. T. F. de; SANTOS. A. M.; PALUDZYSZYN FILHO. E. *Corymbia maculata*: estado da arte de pesquisas no Brasil. Colombo: Embrapa Florestas. 2014. 52 p. (Documento 263).

REIS. C. A. F.; ASSIS. T. F. de; SANTOS. A. M.; PALUDZYSZYN FILHO. E. *Corymbia torelliana*: estado da arte de pesquisas no Brasil. Colombo: Embrapa Florestas. 2014. 48 p. (Documento 261).

REIS. C. A. F.; SANTOS. P. E. T. dos; PALUDZYSZYN FILHO. E.; SANTOS. A. M. Avaliação de banco de conservação de *Corymbia maculata* para uso em melhoramento genético. In: ENCONTRO BRASILEIRO DE SILVICULTURA. 3.. 2014. Campinas. Anais: resumos expandidos [...]. Curitiba: Malinowski. 2014. p. 62-65.

REIS. C. A. F.; SANTOS. P. E. T. dos; PALUDZYSZYN FILHO. E.; SANTOS. A. M.; REIS. B. S. Avaliação de progênies de *Eucalyptus crebra* no norte do Estado de Goiás. In: ENCONTRO BRASILEIRO DE SILVICULTURA. 3.. 2014. Campinas. Anais: resumos expandidos [...]. Curitiba: Malinowski. 2014. p. 75-77.

REIS. C. A. F.; SANTOS. P. E. T. dos; PALUDZYSZYN FILHO. E. Avaliação de clones de eucalipto em Ponta Porã. Mato Grosso do Sul. Pesquisa Florestal Brasileira. Colombo. v. 34. n. 80. p. 263-269. out./dez. 2014.

SANTOS. P. E. T. dos; PALUDZYSZYN FILHO. E.; MAGALHÃES. W. L. E.; VANDRESEN. P. B. Melhoramento genético de eucaliptos subtropicais: contribuições para a espécie *Eucalyptus badjensis*. Colombo: Embrapa Florestas. 2018. 95 p. (Documento 325.).

SANTOS. P. E. T. dos; PALUDZYSZYN FILHO. E.; RIBASKI. J.; DRUMOND. M. A.; OLIVEIRA. V. R. Melhoramento e lançamento de material genético. In: EMBRAPA. O eucalipto e a Embrapa: 40 anos de pesquisa e desenvolvimento. Colombo: Embrapa Florestas. 2019. No prelo.

SANTOS. P. E. T. dos; PALUDZYSZYN FILHO. E.; SILVA. L. T. de M. da; VANDRESEN. P. B. Genetic variation for growth and selection in adult plants of *Eucalyptus badjensis*. Genetics and Molecular Biology. v. 38. n. 4. p. 457-464. Oct./Dec. 2015.

O cafeeiro no contexto das mudanças climáticas globais

Data Published in::

DAMATTA. F. M.; GODOY. A. G.; MENEZES-SILVA. P. E.; MARTINS. S. C. V.; SANGLARD. L. M. V. P.; MORAIS. L. E.; TORRE-NETO. A.; GHINI. R. Sustained enhancement of photosynthesis in coffee trees grown under free-air CO₂ enrichment conditions: disentangling the contributions of stomatal, mesophyll, and biochemical limitations. Journal of Experimental Botany. v. 167. n. 1. p. 341-352. Oct. 2016.

DAMATTA. F. M.; RAHN. E.; LÄDERACH. P.; GHINI. R.; RAMALHO. J. C. Why could the coffee crop endure climate change and global warming to a greater extent than previously estimated? Climatic Change. v. 152. n. 1. p. 167-178. Feb. 2018.

DUBBERSTEIN. D.; RODRIGUES. W. P.; SEMEDO. J. N.; RODRIGUES. A. P.; PAIS. I. P.; LEITÃO. A. E.; PARTELLI. F. L.; CAMPOSTRINI. E.; REBOREDO. F.; SCOTTI-CAMPOS. P.; LIDON. F. C.; RIBEIRO-BARROS. A. I.; DAMATTA. F. M.; RAMALHO. J. C. Mitigation of the negative impact of warming on the coffee crop: The role of increased air [CO₂] and management strategies. In: SRINIVASARAO. C.; SHANKER. A. K.; SHANKER. C. (eds.). Climate resilient agriculture: strategies and perspectives. Rijeka. Croatia: Intech. 2018. p. 57-85.

FORTUNATO. A.; LIDON. F. C.; BATISTA-SANTOS. P.; LEITÃO. A. E.; PAIS. I. P.; RIBEIRO. A. I.; RAMALHO. J. C. Biochemical and molecular characterization of the antioxidative system of *Coffea* sp. under cold conditions in genotypes with contrasting tolerance. Journal of Plant Physiology. v. 167. n. 5. p. 333-342. Mar. 2010.

GILES. J. A. D.; FERREIRA. A. D.; PARTELLI. F. L.; AOYAMA. E. M.; RAMALHO. J. C.; FERREIRA. A.; FALQUETO. A. R. Divergence and genetic parameters between *Coffea* sp. genotypes based in foliar morpho-anatomical traits. Scientia Horticulturae. v. 245. p. 231-236. Feb. 2019.

GHINI. R.; TORRE-NETO. A.; DENTZIEN. A. F. M.; GUERREIRO-FILHO. O.; IOST. R.; PATRÍCIO. F. R. A.; PRADO. J. S. M.; THOMAZIELLO. R. A.; BETTIOL. W.; DAMATTA. F. M. Coffee growth, pest and yield responses to free-air CO₂ enrichment. Climatic Change. v. 132. p. 307-320. May 2015.

- GOULAO, L. F.; FORTUNATO, A. S.; RAMALHO, J. C. Selection of reference genes for normalizing quantitative real-time PCR gene expression data with multiple variables in *Coffea* spp. *Plant Molecular Biology Reporter*. v. 30. p. 741-759. Dec. 2012.
- MARTINS, L. D.; RODRIGUES, W. P.; DAMATA, F. M.; RAMALHO, J. C.; PARTELLI, F. L. O cafeeiro no contexto de alterações climáticas. In: ADÉSEIO, F.; PARTELLI, F. L.; AMARAL, J. A. T. do; DALI, L. P.; CALDEIRA, M. V. W.; COELHO, R. I. (org.). Tópicos especiais em genética e melhoramento. Rio Branco: Suprema. 2016. p. 263-288.
- MARTINS, L. D.; TOMAZ, M. A.; LIDON, F. C.; DAMATA, F. M.; RAMALHO, J. C. Combined effects of elevated [CO₂] and high temperature on leaf mineral balance in *Coffea* spp. plants. *Climatic Change*. v. 126. n. 3-4. p. 365-379. Oct. 2014.
- MARTINS, M. Q.; FORTUNATO, A. S.; RODRIGUES, W. P.; PARTELLI, F. L.; CAMPOSTRINI, E.; LIDON, F. C.; DAMATA, F. M.; RAMALHO, J. C.; RIBEIRO-BARROS, A. I. Selection and validation of reference genes for accurate RT-qPCR data normalization in *Coffea* spp. under a climate changes context of interacting elevated [CO₂] and temperature. *Frontiers in Plant Science*. v. 8. p. 1-11. Mar. 2017.
- MARTINS, M. Q.; PARTELLI, F. L.; GOLYNSKI, A.; PIMENTEL, N. V.; FERREIRA, A.; BERNARDES, C. O.; RIBEIRO-BARROS, A. I.; RAMALHO, J. C. Adaptability and stability of *Coffea canephora* genotypes cultivated at high altitude and subjected to low temperature during the winter. *Scientia Horticulturae*. v. 252. p. 238-242. June 2019.
- MARTINS, M. Q.; RODRIGUES, W. P.; FORTUNATO, A. S.; LEITÃO, A. E.; RODRIGUES, A. P.; PAIS, I.; MARTINS, L. D.; SILVA, M. J.; REBOREDO, F. H.; PARTELLI, F. L.; CAMPOSTRINI, E.; TOMAZ, M. A.; SCOTTI-CAMPOS, P.; RIBEIRO-BARROS, A. I.; LIDON, F. C.; DAMATA, F. M.; RAMALHO, J. C. Protective response mechanisms to heat stress in interaction with high [CO₂] conditions in *Coffea* spp. *Frontiers in Plant Science*. v. 7. p. 1-18. June 2016.
- OLIOSI, G.; GILES, J. A. D.; RODRIGUES, W. P.; RAMALHO, J. C.; PARTELLI, L. F. Microclimate and development of *Coffea canephora* cv. Conilon under different shading levels promoted by Australian cedar (*Toona ciliata* M. Roem. var. *Australis*). *Australian Journal of Crop Science*. v. 10. n. 4. p. 528-538. Apr. 2016.
- PARTELLI, L.; ARAÚJO, A. V.; VIEIRA, H. D.; DIAS, J. R. M.; MENEZES, L. F. T.; RAMALHO, J. C. Microclimate and development of 'Conilon' coffee intercropped with rubber trees. *Pesquisa Agropecuária Brasileira*. Brasília. v. 49. n. 11. p. 872-881. nov. 2014.
- PARTELLI, F. L.; BATISTA-SANTOS, P.; CAMPOS, P. S.; PAIS, I. P.; QUARTIN, V. L.; VIEIRA, H. D.; RAMALHO, J. C. Characterization of the main lipid components of chloroplast membranes and cold induced changes in *Coffea* spp. *Environmental and Experimental Botany*. v. 74. p. 194-204. Dec. 2011.
- RAKOCEVIC, M.; MATSUNAGA, F. T. Variations in leaf growth parameters within the tree structure of adult *Coffea arabica* in relation to seasonal growth, water availability and air carbon dioxide concentration. *Annals of Botany*. v. 122. n. 1. p. 117-131. July 2018.
- RAKOCEVIC, M.; RIBEIRO, R. V.; MARCHIORI, P. E. R.; FILIZOLA, H. F.; BATISTA, E. R. Structural and functional changes in coffee trees after 4 years under free air CO₂ enrichment. *Annals of Botany*. v. 121. n. 5. p. 1065-1078. Apr. 2018.
- RAMALHO, J. C.; DAMATTA, F. M.; RODRIGUES, A. P.; SCOTTI-CAMPOS, P.; PAIS, I.; BATISTA-SANTOS, P.; PARTELLI, F. L.; RIBEIRO, A.; LIDON, F. C.; LEITÃO, A. E. Cold impact and acclimation response of *Coffea* spp. plants. *Theoretical and Experimental Plant Physiology*. v. 26. p. 5-18. Feb. 2014.
- RAMALHO, J. C.; FORTUNATO, A. S.; GOULAO, L. F.; LIDON, F. C. Cold-Induced changes in mineral content in leaves of *Coffea* spp. identification of descriptors for tolerance assessment. *Biologia Plantarum*. v. 57. n. 3. p. 495-506. Sep. 2013.

RAMALHO. J. C.; FORTUNATO. A. S.; RODRIGUES. A. P.; MARTINS. M. Q.; RODRIGUES. W. P.; COLWELL. F.; SEMEDO. J. N.; PAIS. I. P.; BATISTA-SANTOS. P.; LEITÃO. A. E.; PARTELLI. F. L.; CAMPOSTRINI. E.; SCOTTI-CAMPOS. P.; RIBEIRO-BARROS. A. I.; LIDON. F. C.; DAMATTA. F. M. Can enhanced CO₂ help to mitigate the global warming impact in the tropical coffee plant? *Procedia Environmental Sciences*. v. 29. p. 284-285. Dec. 2015.

RAMALHO. J. C.; PAIS. I. P.; LEITÃO. A. E.; GUERRA. M. R.; FERNANDO. H.; MÁGUAS. C. M.; CARVALHO. M. L.; SCOTTI-CAMPOS. P.; RIBEIRO-BARROS. A. I.; LIDON. F. J. C.; DAMATTA. F. M. Can elevated air [CO₂] conditions mitigate the predicted warming impact on the quality of coffee bean? *Frontiers in Plant Science*. v. 9. p. 1-14. Mar. 2018.

RAMALHO. J. C.; RODRIGUES. A. P.; LIDON. F. C.; MARQUES. L. M. C.; LEITÃO. A. E.; FORTUNATO. A. S.; PAIS. I. P.; SILVA. M. J.; SCOTTI-CAMPOS. P.; LOPES. A.; REBOREDO. F. H.; RIBEIRO-BARROS. A. I. Stress cross-response of the antioxidative system promoted by superimposed drought and cold conditions in *Coffea* spp. *PLoS ONE*. v. 13. p. 1-30. June 2018.

RAMALHO. J. C.; RODRIGUES. A. P.; SEMEDO. J. N.; PAIS. I. P.; MARTINS. L. D.; SIMÕES-COSTA. M. C.; LEITÃO. A. E.; FORTUNATO. A. S.; BATISTA-SANTOS. P.; PALOS. I. M.; TOMAZ. M. A.; SCOTTI-CAMPOS. P.; LIDON. F. C.; DAMATTA. F. M. Sustained photosynthetic performance of *Coffea* spp. under long-term enhanced [CO₂]. *PLoS ONE*. v. 8. n. 12. p. 1-19. Dec. 2013.

RODRIGUES. W. P.; MACHADO-FILHO. J. A.; SILVA. J. R.; FIGUEIREDO. F. A.; FERRAZ. T. M.; FERREIRA. L. S.; BEZERRA. L. B. S.; ABREU. D. P.; BERNARDO. W. P.; PASSOS. L. C.; SOUZA. E. F.; GLENN. D. M.; RAMALHO. J. C.; CAMPOSTRINI. E. Whole-canopy gas exchanges in *Coffea* sp. is affected by supra-optimal temperature and light distribution within the canopy: the insights from an improved multi-chamber system. *Scientia Horticulturae*. v. 211. p. 194-202. Nov. 2016.

RODRIGUES. W. P.; MARTINS. M. Q.; FORTUNATO. A. S.; RODRIGUES. A. P.; SEMEDO. J. N.; SIMÕES-COSTA. M. C.; PAIS. I. P.; LEITÃO. A. E.; COLWELL. F.; GOULAO. L.; MÁGUAS. C.; MAIA. R.; PARTELLI. F. L.; CAMPOSTRINI. E.; SCOTTI-CAMPOS. P.; RIBEIRO-BARROS. A. I.; LIDON. F. C.; DAMATTA. F. M.; RAMALHO. J. C. Long-term elevated air [CO₂] strengthens photosynthetic functioning and mitigates the impact of supra-optimal temperatures in tropical *Coffea arabica* and *C. canephora* species. *Global Change Biology*. v. 22. n. 1. p. 415-431. Jan. 2016.

RODRIGUES. W. P.; MARTINS. L. D.; PARTELLI. F. L.; LIDON. F. C.; LEITÃO. A. E.; RIBEIRO-BARROS. A. I.; DAMATTA. F. M.; RAMALHO. J. C. Interação de altas temperaturas e déficit hídrico no cultivo de café Conilon (*Coffea canephora* Pierre ex A. Froehner). In: PARTELLI. F. L.; BONOMO. R. (org.). *Café Conilon: o clima e o manejo da planta*. Alegre: CAUFES. p. 39-[?5].

RODRIGUES. W. P.; SILVA. J. R.; FERREIRA. L. S.; MACHADO FILHO. J. A.; FIGUEIREDO. F. A. M. M. A.; FERRAZ. T. M.; BERNARDO. W. P.; BEZERRA. L. B. S.; ABREU. D. P. de; CESPOM. L.; RAMALHO. J. C.; CAMPOSTRINI. E. Stomatal and photochemical limitations of photosynthesis in coffee (*Coffea* spp.) plants subjected to elevated temperatures. *Crop & Pasture Science*. v. 69. n. 3. p. 317-325. Jan. 2018.

RODRIGUES. W. P.; VIEIRA. H. D.; CAMPOSTRINI. E.; FIGUEIREDO. F. A. M. M. A.; FERRAZ. T. M.; PARTELLI. F. L.; RAMALHO. J. C. Physiological aspects. growth and yield of *Coffea* spp. in areas of high altitude. *Australian Journal of Crop Science*. v. 10. n. 5. p. 666-674. May 2016.

SANTOS. C. A. F.; LEITÃO. A. E.; PAIS. I. P.; LIDON. F. C.; RAMALHO. J. C. Perspectives on the potential impacts of climate changes on the coffee plant and bean quality. *Emirates Journal of Food and Agriculture*. v. 27. n. 2. p. 152-163. Mar. 2015.

SCOTTI-CAMPOS. P.; PAIS. I. P.; PARTELLI. F. L.; BATISTA-SANTOS. P.; RAMALHO. J. C. Phospholipids profile in chloroplasts of *Coffea* spp. genotypes differing in cold acclimation ability. *Journal of Plant Physiology*. v. 171. n. 3-4. p. 243-249. Feb. 2014.

SCOTTI-CAMPOS. P.; PAIS. I. P.; RIBEIRO-BARROS. A. I.; MARTINS. D.; TOMAZ. M. A.; RODRIGUES. W. P.; CAMPOSTRINI. E.; SEMEDO. J. N.; FORTUNATO. A. S.; MARTINS. M. Q.; PARTELLI. F. L.; LIDON. F. C.; DAMATTA. F. M.; RAMALHO. J. C. Lipid profile adjustments may contribute to warming acclimation and to heat impact mitigation by elevated [CO₂] in *Coffea* spp. *Environmental And Experimental Botany*. v. 167. p. 1-17. Aug. 2019.

SEMEDO. J. N.; RODRIGUES. W. P.; DUBBERSTEIN. D.; MARTINS. M. Q.; MARTINS. L. D.; PAIS. I. P.; RODRIGUES. A. P.; LEITÃO. A. E.; PARTELLI. F. L.; CAMPOSTRINI. E.; TOMAZ. M. A.; REBOREDO. F. H.; SCOTTI-CAMPOS. P.; RIBEIRO-BARROS. A. I.; LIDON. F. C.; DAMATTA. F. M.; RAMALHO. J. C. Coffee responses to drought, warming and high [CO₂] in a context of future climate change scenarios. In: ALVES. F.; LEAL. W.; AZEITEIRO. U. (ed.). *Theory and practice of climate adaptation*. Switzerland: Springer. 2018. chapter 26. p. 465-477.

TORMENA. C. D.; MARCHEFAVE. G. G.; RAKOCEVIC. M.; BRUNS. R. E.; SCARMINIO. I. S. Sequential mixture design optimization for divergent metabolite analysis: enriched carbon dioxide effects on *Coffea Arabica* L. leaves and buds. *Talanta*. v. 191. p. 382-389. Jan. 2019.

Technological advances to cope with water deficit stress in soy

Data Published in:

LIMA. L. F. S.; FERREIRA. L. C.; FUGANTI-PAGLIARINI. R.; MARIN. S. R. R.; OLIVEIRA. M. C. N.; MERTZ-HENNING. L. M.; FARIAS. J. R. B.; NEUMAIER. N.; NAKASHIMA. K.; NUNES. L. M.; NEPOMUCENO. A. L. Agronomic evaluation of genetically modified soybean genotypes in response to water deficit. *Global Science and Technology*. v. 11. p. 77-88. 2018.

MARINHO. J. P.; COUTINHO. I. D.; LAMEIRO. R. da F.; MARIN. S. R. R.; COLNAGO. L. A.; NAKASHIMA. K.; YAMAGUCHI-SHINOZAKI. K.; NEPOMUCENO. A. L.; MERTZ-HENNING. L. M. Metabolic alterations in conventional and genetically modified soybean plants with GmDREB2A;2 FL and GmDREB2A;2 CA transcription factors during water deficit. *Plant Physiology and Biochemistry*. v. 140. p. 122-135. 2019.

Developing A Potato Germplasm That Is More Adaptable To Climate Change

Data Published in:

PINHEIRO. N. L. Caracterização de cultivares de batata com marcadores microsatélites e prospecção de genes de referência para tolerância à seca. 2015. Dissertação (Mestrado em Fitomelhoramento) – Programa de Pós-Graduação em Agronomia. Faculdade de Agronomia Eliseu Maciel. Universidade Federal de Pelotas. Pelotas. 2015.

REISSER JUNIOR. C.; CASTRO. C. M.; MEDEIROS. C. A. B.; ROHR. A.; PEREIRA. A. da S. Fenotipagem de batata (*S. tuberosum* L.) para tolerância à seca, baseada na redução do potencial osmótico da água com polietileno glicol em solução hidropônica. Pelotas: Embrapa Clima Temperado. 2015. (Documento 387).

ROHR. A. Parâmetros genéticos, respostas associadas ao déficit hídrico e estrutura populacional em germoplasma de batata (*Solanum tuberosum* L.). 2016. Tese (Doutorado em Agronomia) – Programa de Pós-Graduação em Agronomia. Universidade Federal de Pelotas. Pelotas. 2016.

ROHR. A.; BRITO. G. G. de; REISSER JUNIOR. C.; PEREIRA. A. da S.; CASTRO. C. M. Characterization of potato genotypes in response to drought. In: ANNUAL MEETING OF THE POTATO ASSOCIATION OF AMERICA. 99.. 2015. Portland. Program & Abstracts [...]. Portland: PAA. 2015. p. 49.

Research center of Genomics Applied to Climate Change

References

GUTIERREZ. A. P. A.; ENGLE. N. L.; NYS. E. de; MOLEJON. C.; MARTINS. E. S. Drought preparedness in Brazil. *Weather and Climate Extremes*. v. 3. p. 95-106. June 2014.

McELROY. D. Valuing the product development cycle in agricultural biotechnology: what's in a name? *Nature Biotechnology*. v. 22. n. 7. p. 817-822. July 2004.

PRADO. J. R.; SEGERS. G.; VOELKER. T.; CARSON. D.; DOBERT. R.; PHILLIPS. J.; COOK. K.; CORNEJO. C.; MONKEN. J.; GRAPES. L.; REYNOLDS. T.; MARTINO-CATT. S. Genetically engineered crops: from idea to product. *Annual Review of Plant Biology*. v. 65. p. 769-790. Apr. 2014.

No-till for recovering degraded pastures in the Amazon Biome

Data Published in:

ANDRADE. C. M. S. de; FERREIRA. A. S. Técnicas de reforma de pastagens degradadas na Amazônia. In: DIAS-FILHO. M. B.; ANDRADE. C. M. S. de (ed.). *Recuperação de pastagens degradadas na Amazônia*. Brasília: Embrapa. 2019. p. 289-360.

Evaluation of conservation management on the adaptive capacity of agricultural production systems in the state of Rio de Janeiro

Data Published in:

COELHO. M.; FONTANA. A.; MONTEIRO. J. M. G.; GOULART. A. C.; FONSECA. K.; COSTA. M. M. Estoque de carbono orgânico do solo sob floresta e pastagem no Município de São José de Ubá. Estado do Rio de Janeiro. Rio de Janeiro: Embrapa Solos. 2011. 31 p. (Boletim de Pesquisa e Desenvolvimento 196).

GOULART. A. C.; MONTEIRO. J. M. G.; COELHO. M.; FONTANA. A.; GONÇALVES. A. O. Estoque de carbono e nutrientes na serapilheira e solos de fragmentos florestais da Mata Atlântica do estado Rio de Janeiro. Rio de Janeiro: Embrapa Solos. 2012. 7 p. (Comunicado Técnico 67).

MARTINS. A. L. S.; SCHULER. A. E.; MONTEIRO. J. M. G.; FIDALGO. E. C. C.; ALMEIDA. E. P. C. Desenvolvimento rural: uma abordagem participativa em sistemas produtivos na comunidade de Faraó. Cachoeiras de Macacu-RJ. In: CONGRESSO DA SOCIEDADE BRASILEIRA DE SISTEMA DE PRODUÇÃO. 2014. Foz do Iguaçu. Anais [...]. Florianópolis: Sociedade Brasileira de Sistemas de Produção. 2014. p. 657-661.

MONTEIRO. J. M. G.; ALVES. B.; ZUCHELLO. F.; SANTANNA. S. A. C. Emissão de gases do efeito-estufa em solos sob floresta e sob pastagem. In: BRADO. R. B.; FIDALGO. E. C. C. F.; BONNET. A. (org.). *Monitoramento da revegetação do COMPERJ: etapa inicial*. Brasília: Embrapa. 2014. v. 1. p. 207-220.

MONTEIRO. J. M. G.; FONTANA. A.; HISSA. H.; COELHO. M.; GOULART. A. C.; MONTEIRO. M. C. Soil organic carbon stocks under pasture atlantic forest in Rio de Janeiro state. Brazil. In: WORLD CONGRESS OF SOIL SCIENCE. 2014. Jeju. Abstracts [...]. Korea. 2014. Disponível em: <https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1000853/1/JoyceMonteiro011.pdf>. Acesso em: 30 jan. 2020.

MONTEIRO. J. M. G.; SCHULER. A. E.; PRADO. R. B.; FIDALGO. E. C. C.; TURETTA. A. P. D.; MARTINS. A. L. da S.; OLIVEIRA. A. P. de; DONAGEMMA. G. K. Soil and water management for ecosystem services provision in agricultural

landscapes: the challenge of monitoring. In: NEHREN. U.; SCHLÜTER. S.; RAEDIG. C.; SATTLER. D.; HISSA. H. (ed.). *Strategies and tools for a sustainable rural Rio de Janeiro*. Switzerland: Springer. 2019. cap. 5. p. 53-67.

PRADO. R. B.; FIDALGO. E. C. C.; BALIEIRO. F. C.; COUTINHO. H. L. C.; TURETTA. A. P.; GONÇALVES. A. O.; PEDREIRA. B. C. C. G.; SCHULER. A. E.; MONTEIRO. J. M. G.; COELHO. M.; DONAGEMMA. G. K.; MARTINS. A. L. S.; ALMEIDA. E. P. C.; OLIVEIRA. A. P. *Serviços ambientais no bioma Mata Atlântica do estado do Rio de Janeiro: abordagem metodológica e desafios*. In: PARRON. L. M.; GARCIA. J. R.; OLIVEIRA. E. B. de; BROWN. G. G.; PRADO. R. B. (org.). *Serviços ambientais em sistemas agrícolas e florestais do bioma Mata Atlântica*. Brasília: Embrapa. 2015. p. 202-213.

Social Technologies applied to agroecosystems to face climate change in the Baiha semiarid

Data Published in:

VENTURA. A. C.; ANDRADE. J. C. S. *Polyculture in the semi-arid regions of Brazil*. *Field Actions Science Reports*. v. 3. p. 1-20. 2011.

VENTURA. A. C.; FERNÁNDEZ. L.; ANDRADE. J. C. S. *Tecnologias sociais: as organizações não governamentais no enfrentamento das mudanças climáticas e na promoção de desenvolvimento humano*. *Cadernos EBAPE.BR (FGV)*. v. X. p. 605. 2012.

VENTURA. A. C.; FERNÁNDEZ. L.; TRUJILLO. R. *Potencial das tecnologias sociais para o enfrentamento das mudanças climáticas e para a promoção do desenvolvimento humano: um olhar sobre o semiárido baiano*. *Bahia Análise & Dados*. v. 21. p. 915-931. 2011.

Biochar as a soil conditioner in agricultural systems in the Cerrado

Data Published in:

MADARI. B. E.; SILVA. M. A. S.; CARVALHO. M. T. M.; MAIA. A. H. N.; PETTER. F. A.; SANTOS. J. L. S.; TSAI. S. M.; LEAL. W. G. O.; ZEVIANI. W. M. *Properties of a sandy clay loam Haplic Ferralsol and soybean grain yield in a five-year field trial as affected by biochar amendment*. *Geoderma*. v. 305. p. 100-112. 2017.

PETTER. F. A.; MADARI. B. E.; SILVA. M. A. S. da; CARNEIRO. M. A. C.; CARVALHO. M. T. M.; MARIMON JR.. B. H.; PACHECO. L. P. *Soil fertility and upland rice yield after biochar application in the Cerrado*. *Pesquisa Agropecuária Brasileira*. v. 47. n. 5. p. 699-706. May 2012.

Cover crops and green manures for adapting agriculture to climate change and reducing the emission of Greenhouse Gases in the Cerrado

References

FERREIRA. A. C. B.; BORIN. A. L. D. C.; BOGIANI. J. C.; LAMAS. F. M. *Suppressive effects on weeds and dry matter yields of cover crops*. *Pesquisa Agropecuária Brasileira*. v. 53. p. 566-574. 2018.

MUZILLI. O. *A adubação verde como alternativa para a melhoria da fertilidade do solo e racionalização do uso de fertilizantes*. Londrina: Instituto Agronômico do Paraná. 1986. 16p. (Informe da Pesquisa. 68).

OLIVEIRA JUNIOR. R.; RIOS. R. S.; CONSTANTIN. J.; ISHII-IWAMOTO. E. L.; GEMELLI. A.; MARTINI. P. E. *Grass straw mulching to suppress emergence and early growth of weeds*. *Planta Daninha*. Viçosa-MG. v. 32. n. 1. p. 11-17. Mar. 2014.

PACHECO. L. P.; BARBOSA. J. M.; LEANDRO. W. M.; MACHADO. P. L. O. de A.; ASSIS. R. L. de; MADARI. B. E.; PETTER. F. A. Produção e ciclagem de nutrientes por plantas de cobertura nas culturas de arroz de terras altas e de soja. *Revista Brasileira de Ciência do Solo*. Viçosa-MG. v. 35. n. 5. p. 1787-1799. set./out. 2011.

PORTELA. J. C.; COGO. N. P.; BAGATINI. T.; CHAGAS. J. P.; PORTZ. G. Restauração da estrutura do solo por sequências culturais implantadas em semeadura direta, e sua relação com a erosão hídrica em distintas condições físicas de superfície. *Revista Brasileira de Ciência do Solo*. Viçosa-MG. v. 34. n. 4. p. 1353-1364. ago. 2010.

ROTH. C. H.; MEYER. B.; FREDE. H. G.; DERPSCH. R. The effect of different soybean tillage systems on infiltrability and erosion susceptibility of an Oxisol in Parana, Brazil. *Journal of Agronomy and Crop Science*. v. 157. n. 4. p. 217-226. Dec. 1986.

SIDIRAS. N.; PAVAN. M. A. Influência do Sistema de manejo do solo na temperatura do solo. *Revista Brasileira de Ciência do Solo*. v. 10. p. 181-184. 1986.

Underground dams: contributing to climate change resilience of family-based agroecosystems in the semiarid region of northeastern Brazil

Data Published in:

NASCIMENTO. A. F. do; SILVA. M. S. L. da; Marques. F. A.; OLIVEIRA NETO. M. B. de; PARAHYBA. R. da B. V.; AMARAL. A. J. do. Caracterização geoambiental em áreas de barragens subterrâneas no Semiárido brasileiro. Recife: Embrapa Solos. 2015. 54 p. (Documento 180).

SILVA. M. S.; MARQUES. F. A.; NASCIMENTO. A. F.; LIMA. A. O.; OLIVEIRA NETO. M. B.; FERREIRA. G. B.; MELO. R. F.; ANJOS. J. B.; PARAHYBA. R. B. Barragem subterrânea: promovendo acesso e usos múltiplos da água no Semiárido brasileiro. Recife: Embrapa Solos. 2019. 42 p. (Cartilha).

Sustainability indicators in Agroecosystems

Data Published in:

BRASIL. Governo do Estado de Minas Gerais. Decreto nº 46.113. de 19 de dezembro de 2012. Aprova a Metodologia Mineira para Aferição do Desempenho Socioeconômico e Ambiental de Propriedades Rurais. Belo Horizonte: Diário do Executivo. 2012. p. 2. col. 1.

FERREIRA. J. M. L.; VIANA. J. H. M.; COSTA. A. M.; SOUZA. D. V.; FONTES. A. A. Indicadores de Sustentabilidade em Agroecossistemas. Informe Agropecuário. Belo Horizonte. v. 33. n. 271. p. 12-25. nov./dez. 2012.

MARQUES. P. A. S.; FERREIRA. J. M. L. Aplicativo ISApp. Informe Agropecuário. Belo Horizonte. v. 38. n. 300. p. 73-80. 2017.

Future agricultural scenarios for pastures in Brazil

Data Published in:

BOSI. C. Parameterization and evaluation of mechanistic crop models for estimating *Urochloa brizantha* cv. BRS Piatã productivity under full sun and in silvopastoral system. 2018. Tese (Doutorado em Engenharia de Sistemas Agrícolas) – Escola Superior de Agricultura “Luiz de Queiroz”. Universidade de São Paulo. Piracicaba. 2018.

CRUZ. P. G.; SANTOS. P. M.; PEZZOPANE. J. R. M.; OLIVEIRA. P. P. A.; ARAUJO. L. C. Modelos empíricos para estimar o acúmulo de matéria seca de capim-marandu com variáveis agrometeorológicas. *Pesquisa Agropecuária Brasileira*. Brasília. v. 46. n. 7. p. 675-681. jul. 2011.

PEZZOPANE. J. R. M.; CRUZ. P. G.; SANTOS. P. M.; BOSI. C.; ARAUJO. L. C. Simple agrometeorological models for estimating Guineagrass yield in Southeast Brazil. *International Journal of Biometeorology*. v. 58. n. 7. p. 1479-1487. Jan. 2014.

PEZZOPANE. J. R. M.; SANTOS. P. M.; BETTIOL. G. M.; BOSI. C.; PETINARI. I. B. Zoneamento de aptidão climática para os caprins marandu e tanzânia na região sudeste do Brasil. São Carlos: Embrapa Pecuária Sudeste. 2012. 27 p. (Documento 108).

PEZZOPANE. J. R. M.; SANTOS. P. M.; EVANGELISTA. S. R. M.; BOSI. C.; CAVALCANTE. A. C. R.; BETTIOL. G. M.; GOMIDE. C. A. de M.; PELLEGRINO. G. Q. Panicum maximum cv. Tanzânia: climate trends and regional pasture production in Brazil. *Grass and Forage Science*. v. 72. n. 1. p. 104-117. Jan. 2016.

PEZZOPANE J. R. M.; SANTOS P. M.; MENDONÇA F. C.; ARAUJO. L. C.; CRUZ. P. G. Dry matter production of Tanzania grass as a function of agrometeorological variables. *Pesquisa Agropecuária Brasileira*. Brasília. v. 47. n. 4. p. 471-477. Apr. 2012.

SANTOS. P. M.; EVANGELISTA. S. R. M.; PEZZOPANE. J. R. M. (ed.). Cenários agrícolas futuros para pastagens no Brasil. São Carlos: Embrapa Pecuária Sudeste. 2014. 39 p. (Documento 114).

SANTOS. P. M.; VINHOLIS. M. de M. B.; DIAS FILHO. M. B.; VOLTOLINI. T. V.; MITTELMANN. A.; PEZZOPANE. J. R. M.; EVANGELISTA. S. R. M.; MOURA. M. S. B. de; GOMIDE. C. A. de M.; CAVALCANTE. A. C. R.; CORRÊA. C. G.; BETTIOL. G. M.; SANTOS. R. M.; ANGELOTTI. F.; OLIVEIRA. P. P. A.; SOUZA. F. H. D. de; ALMEIDA. I. R. de; BOSI. C.; CRUZ. P. G. da; ANDRADE. A. S.; ARAUJO. L. C. de; PELLEGRINO. G. Q. Produção animal no Brasil: caracterização. simulação de cenários para pastagens e alternativas de adaptação às mudanças climáticas. São Carlos: Embrapa Pecuária Sudeste. 2015. 99 p. (Documento 119).

Infrared thermography to diagnose bioclimatic conditions in livestock systems in the Amazon biome

Data Published in:

BARROS. D. V.; SILVA. L. K. X.; LOURENÇO JUNIOR. J. B.; SILVA. A. O. A.; SILVA. A. G. M.; FRANCO. I. M.; OLIVEIRA. C. M. C.; THOLON. P.; MARTORANO. L. G.; GARCIA. A. R. Evaluation of thermal comfort. physiological. hematological. and seminal features of buffalo bulls in an artificial insemination station in a tropical environment. *Tropical Animal Health and Production*. v. 47. n. 5. p. 805-813. 2015.

BRCKO. C. C.; SILVA. J. A. R.; MARTORANO. L. G.; VILELA. R. A.; NAHÚM. B. S.; SILVA. A. G. M.; BARBOSA. A. V. C.; BEZERRA. A. S.; LOURENÇO JUNIOR. J. B. Infrared thermography to assess thermoregulatory reactions of female buffaloes in a humid tropical environment. *Environment. Front. Vet. Sci.*. v. 7. art. 180. p. 1-7. 2020.

MARTORANO. L. G. Termografia infravermelho para diagnosticar respostas calóricas em animais de grande e médio porte na Amazônia. In: CONGRESSO DOS MÉDICOS VETERINÁRIOS DA AMAZÔNIA LEGAL – AMAZONVET. 2.. 2019. [S. n.]; CONGRESSO NACIONAL DE ANIMAIS SELVAGENS. 2019. [S. n.].

MONTEIRO. S. N.; AMARAL JUNIOR. J. M.; SOUSA. M. A. P.; CASTRO. V. C. G.; CARMO. E. S. N.; MORAIS. E.; NAHUM. B. S.; MARTORANO. L. G. Infrared thermography in the assessment of thermal comfort of confined water buffaloes in the Amazon biome. In: SIMPÓSIO INTERNACIONAL SOBRE GASES DE EFEITO ESTUFA NA AGROPECUÁRIA. 2.. 2016.

PANTOJA. M. H. A.; SILVA. J. A. R.; BARBOSA. A. V. C.; MARTORANO. L. G.; GARCIA. A. R.; LOURENÇO JUNIOR. J. B. Assessment of indices of thermal stress indicators among male buffaloes reared in the Eastern Brazilian Amazon. *Acta Scientiarum. Animal Sciences*. v. 40. e37831. 2018.

PILATO. G. C.; MARTORANO. L. G.; SILVA. L. K. X.; BELDINI. T. P.; NEVES. K. A. L. Padrões de aluos em sistema pecuário extensivo diagnosticados por termografia infravermelho no Oeste do Pará. *Agroecossistemas*. v. 10. n. 1. p. 55-72. 2018a.

PIRES. A. P.; MARTORANO. L. G.; MENDONÇA NETO. J. S. N.; ROCHA. S. L. C. S.; PACHECO. A. Avaliação de conforto térmico em meliponário urbano de Belterra-Pará. In: Congresso de Tecnologias e Desenvolvimento na Amazônia. 3.. 2019. [S. n.]. Anais [...]. [S. l.: s. n.]. 2019.

PIRES. A. P.; PACHECO. A.; MARTORANO. L. G.; SILVA. A. S. L.; VIANA. P. S.; DINIZ. M. C.; GALVÃO. A. T.; MORAES. J. R. S. C. Índices produtivos de abelhas nativas associados às condições ambientais em Arapiuns. Pará. *Agroecossistemas*. v. 9. n. 2. p. 204-222. 2017.

ROCHA. S. L. C.; MARTORANO. L. G.; SOUSA. A.; MELLO. K. K. S. Condições térmicas em viveiro com criação de pirarucu (*Arapaima gigas*) na comunidade Pixuna do Tapará. município de Santarém. Pará. In: SEMINÁRIO PIBIC EMBRAPA AMAZÔNIA ORIENTAL. 22.. 2018.

SILVA. J. A. R.; ARAÚJO. A. A.; LOURENÇO JUNIOR. J. B.; SANTOS N. F. A.; GARCIA. A. R.; NAHÚM. B. S. Conforto térmico de búfalas em sistema silvipastoril na Amazônia Oriental. *Pesquisa Agropecuária Brasileira*. v. 46. n. 10. p. 1364-1371. 2011.

SILVA. L. K. X.; MARTORANO. L. G.; SILVA. W. C.; GARCIA. A. R.; FERNANDES. G. B.; REIS. A. S. B.; GOMES. W. N.; CORREA. F. R. A.; SILVA. F. P.; BELDINI. T. P.; SERRUYA. F. J. D.; OLIVEIRA. C. M. C. Associated use of infrared thermography and ozone therapy for diagnosis and treatment of an inflammatory process in an equine: case report. *PUBVET – Medicina Veterinária e Zootecnia*. v. 14. 2020.

SILVA. L. K. X.; GARCIA. A. R.; MARTORANO. L. G.; FRANCO. I. M.; SILVA. A. O.; SOUSA. J. S.; BARROS. D. V.; FATURI. C. Scrotum surface infrared thermography associated with semen quality of buffaloes (*Bubalus bubalis*). In: EcoSummit 2016: Ecological Sustainability; Engineering Change. França. 2016.

SILVA. L. K. X.; MARTORANO. L. G.; SILVA. W. C.; REIS. A. B.; SILVA. F. P.; FERNANDES. G. B.; NEVES. K. A. L. Respostas fisiológicas associadas a variações térmicas diagnosticadas por termograma infravermelho em equinos submetidos a esforço físico intenso. *Agroecossistemas*. v. 10. n. 1. p. 265-279. 2018a.

SILVA. L. K. X.; SOUSA. J. S.; SILVA. A. O. A.; LOURENÇO JUNIOR. J. B.; FATURI. C.; MARTORANO. L. G.; FRANCO. I. M.; PANTOJA. M. H. A.; BARROS. D. V.; GARCIA. A. R. Testicular thermoregulation. scrotal surface temperature patterns and semen quality of water buffalo bulls reared in a tropical climate. *Andrologia*. v. 50. n. 2. e12836. 2018b.

SILVA. W. C.; MARTORANO. L. G.; SILVA. L. K.; ROCHA. S. L. C. Nuances na temperatura corporal de bezerros a partir de scanner com termografia infravermelho. In: SEMINÁRIO PIBIC EMBRAPA AMAZÔNIA ORIENTAL. 22.. 2018.

SOUSA. M. A. P.; AMARAL JUNIOR. J. M.; LIMA. A. C. S.; NUNES. M. P. M.; ARAUJO. J. C.; MONTEIRO. S. N.; MARTORANO. L. G.; SILVA. A. G. M. Infrared thermography to estimate thermal comfort in meat sheep. In: SIMPÓSIO INTERNACIONAL SOBRE GASES DE EFEITO ESTUFA NA AGROPECUÁRIA. 2.. 2016.

References

KOTRBA. R.; KNÍŽKOVÁ. I.; KUNC. P.; BARTOS. L. Comparison between the coat temperature of the eland and dairy cattle by infrared thermography. *Journal of Thermal Biology*. v. 32. p. 355-359. 2007.

MALAMA. E.; BOLLWEIN. H.; TAITZOGLU. I. A.; THEODOSIOU. T.; BOSCO. C. M.; KIOSSIS. E. Chromatin integrity of ram spermatozoa. Relationships to annual fluctuations of scrotal surface temperature and temperature-humidity index. *Theriogenology*. v. 80. n. 5. p. 533-541. 2013.

MARAI. I. F. M.; HAEEB. A. A. M. Buffalo's biological functions as affected by heat stress: a review. *Livest Science*. v. 127. p. 89-109. 2010.

McMANUS. C. A.; CANDICE. B.; TANURE. A.; PERIPOLLI. V. A.; SEIXAS. L. A.; FISCHER. V. B.; GABBI. A. M. C.; SILVIO. R. O.; MENEGASSI. B.; STUMPF. M. T. D.; KOLLING. G. J. B.; DIAS. E. B.; COSTA JUNIOR. J. B. G. Infrared thermography in animal production: an overview. *Computers and Electronics in Agriculture*. v. 123. p. 10-16. 2016.

MEDEIROS. L. F. D.; VIEIRA. D. H.; OLIVEIRA. C. A.; SCHERER. P. O. Frequências respiratória e cardíaca em caprinos de diferentes raças e idades. *Revista Brasileira de Medicina Veterinária*. v. 23. n. 5. p. 199-202. 2001.

MENEGASSI. S. R. O.; BARCELLOS. J. O. J.; DIAS. E. A.; KOETZ. J. R. C.; PEREIRA. G. R.; PERIPOLLI. V.; McMANUS. C.; CANOZZI. M. E. A.; LOPES. F. G. Scrotal infrared digital thermography as a predictor of seasonal effects on sperm traits in Braford bulls. *International Journal of Biometeorology*. v. 59. p. 357-364. 2015.

PERISSINOTTO. M.; MOURA. D. J.; MATARAZZO. S. V.; SILVA. I. J. O.; LIMA. K. A. O. Efeito da utilização de sistemas de climatização nos parâmetros fisiológicos do gado leiteiro. *Engenharia Agrícola*. v. 26. n. 3. p. 663-671. 2006.

PILATO. G. C.; MARTORANO. L. G.; SILVA. L. K. X.; BELDINI. T. P.; NEVES. K. A. L. Padrões de alvos em sistema pecuário extensivo diagnosticados por termografia infravermelho no oeste do Pará. *Revista Agroecossistemas*. v. 10. n. 1. p. 55-72. 2018b.

PLESU. R.; TEODORIU. G.; TARANU. G. Infrared thermography applications for building investigation. *Constructii Architectura*. v. LVIII (LXII). n. 1. 2012.

ROBERTO. J. V.; SOUZA. B. B. Utilização da termografia de infravermelho na medicina veterinária e na produção animal. *Journal Animal Behavior Biometeorology*. v. 2. n. 3. p. 73-84. 2014.

SANTOS. L. S.; MARTORANO. L. G.; BATALHA. S. S.; PONTES. A. N.; SILVA. O. M.; WATRIN. O. S.; GUTIERREZ. C. B. B. Imagens orbitais e termografia infravermelho na avaliação da temperatura de superfície em diferentes usos e cobertura do solo na floresta nacional do Tapajós e seu entorno- PA. *Revista Brasileira de Geografia Física*. v. 9. n. 4. p. 1234-1253. 2016a.

SANTOS. L. S.; MARTORANO. L. G.; BATALHA. S. S. A. Thermal index extracted from orbital sensor and thermographic camera in Tapajós national forest and its surrounding area. In: *EcoSummit 2016: Ecological Sustainability; Engineering Change*. França. 2016b.

SILVA. E. M. N.; SOUZA. B. B.; SOUSA. O. B.; SILVA. G. A.; FREITAS. M. M. S. Avaliação da adaptabilidade de caprinos ao semiárido através de parâmetros fisiológicos e estruturas do tegumento. *Revista Caatinga*. v. 23. n. 2. p. 142-148. 2010.

SOUZA. B. B.; SOUZA. E. D.; CEZAR. M. F. Temperatura superficial e índice de tolerância ao calor de caprinos de diferentes grupos raciais no semiárido nordestino. *Ciência e Agrotecnologia*. v. 32. n. 1. p. 275-280. 2008.

Estratégia de uso e conservação da biodiversidade para adaptação da agropecuária brasileira às mudanças do clima

References

DIAS. B. F. S. Biodiversidade. por que importa! *Cause Magazine*. Rio de Janeiro. v. 5. 2017. p. 94-100. Disponível em: https://edisciplinas.usp.br/pluginfile.php/3994886/mod_resource/content/1/Dias_2017_Biodiversidade%20porque%20importa.pdf. Acesso em: 5 fev. 2020.

DIAS. B. F. S. Biodiversidade: uma propriedade única do Planeta Terra. In: KLABIN. I. 25+25 Sustentabilidade: o estado da arte. daRio de Janeiro: Fundação Brasileira para o Desenvolvimento Sustentável (FBDS); Andrea Jakobsson Estúdio Editorial. 2019. p. 164-177.

FAUSTO. C.; NEVES. E. G. Was there ever a Neolithic in the Neotropics? Plant familiarization and biodiversity in the Amazon. *Antiquity*. v. 92. n. 366. p. 1604-1618. Dec. 2018.

IPBES. Global Biodiversity Assessment on Biodiversity and Ecosystem Services. Germany: IPBES. 2019. Disponível em: <https://ipbes.net/global-assessment-report-biodiversity-ecosystem-services>. Acesso em: 5 fev. 2020.

LIEBMAN. M.; SCHULTE. L. A. Enhancing agroecosystem performance and resilience through increased diversification of landscapes and cropping systems. *Elementa: Science of the Anthropocene*. v. 3. p. 1-8. Feb. 2015.

MILLENNIUM ECOSYSTEM ASSESSMENT. Millennium Assessment Reports. Washington. D.C.. 2005. Disponível em: <http://millenniumassessment.org/en/index.html>. Acesso em: 5 fev. 2020.

WILLIAMS. G. C. Sex and evolution: monographs in population biology. Princeton: Princeton University Press. 1975. v. 8.

Technological completion of native and exotic fruits for production systems in the Cerrado

Data Published in:

JUNQUEIRA. N. T. V.; CHAVES. R. C.; NASCIMENTO. A. C.; RAMOS. V. H. V.; PEIXOTO. J. R.; JUNQUEIRA. L. P. Efeito do óleo de soja no controle da antracnose e na conservação da manga cv. palmer em pós-colheita. *Revista Brasileira de Fruticultura*. Jaboticabal. v. 26. n. 2. p. 222-225. 2004.

ZACARONI. A. B.; JUNQUEIRA. N. T. V.; SUSSEL. A. A. B.; FREITAS. S. I.; JUNQUEIRA. K. P.; JUNQUEIRA. N. T. V. Desempenho agrônomo de gravioleira (*Annona muricata* L.) sobre diferentes espécies de porta-enxertos. *Cadernos de Agroecologia*. v. 9. 2014.

Biodiversity for Nutrition and Food

Data Published in:

BFN BRASIL. Curso Online "Biodiversidade para Alimentação e Nutrição: Benefícios para a agricultura, saúde e modos de vida". Disponível em: <http://www.b4fn.org/pt/curso-online/>.

MINISTÉRIO DO MEIO AMBIENTE. Cadernos de boas práticas de extrativismo sustentável orgânico. Cadernos técnicos. 2020. Disponível em: <https://www.mma.gov.br/publicacoes/desenvolvimento-rural/category/200-extrativismo-sustent%C3%A1vel>. Acesso em: 6 fev. 2020.

Ecofisiologia de plantas nativas da Caatinga na Embrapa – Semiárido Referências

References:

MORGANTE. C. V.; CHAVES. A. R. de M.; MOTA. A. P. Z.; AIDAR. S. de T. Transcriptome analysis of the vegetative desiccation tolerance plant *Tripogonella spicata* (Nees) P. M. Peterson & Romasch. In: BRAZILIAN BIOTECHNOLOGY CONGRESS. 7.; BIOTECHNOLOGY IBERO-AMERICAN CONGRESS. 2.. 2018. Brasília. DF. Proceedings [...]. Brasília: SBBiotec. 2018.

REZENDE. L. F. C.; ARENQUE. B. C.; AIDAR. S. de T.; MOURA. M. S. B. de; RANDOW. C. V.; TOURIGNY. E.; MENEZES. R. S. C.; OMETTO. J. P. H. B. Is the maximum velocity of carboxylation (V_{cmax}) well adjusted for deciduous shrubs in DGVMs: a case study for the Caatinga Biome in Brazil. *Modeling Earth Systems and Environment*. v. 2. p. 42-47. Mar. 2016.

SANTOS. C. A. F.; NASCIMENTO. C. E. S.; CAMPOS. C. O. Preservação da variabilidade genética e melhoramento do umbuzeiro. *Revista Brasileira de Fruticultura*. Cruz das Almas. v. 21. n. 2. p. 104-109. ago. 1999.

ARAUCAMATE – Estudo da distribuição potencial da araucária e da erva-mate para programa de uso e conservação genética

Data Published in:

MARCONDES. V. M. S.; BOGNOLA. I. A.; SOARES. M. T. S. Definição de variáveis climáticas e edáficas relacionadas à ocorrência de araucária no Estado do Paraná. In: EVENTO DE INICIAÇÃO CIENTÍFICA DA EMBRAPA FLORESTAS. 15.. 2016. Colombo. Anais [...]. Colombo: Embrapa Florestas. 2016. p. 65-66.

WREGÉ. M. S.; FRITZSONS. E.; SOARES. M. T. S.; BOGNOLA. I. A.; SOUSA. V. A.; SOUSA. L. P. de; GOMES. J. B. V.; AGUIAR. A. V.; GOMES. G. C.; MATOS. M. de F. da S.; SCARANTE. A. G.; FERRER. R. Distribuição natural e habitat da araucária frente às mudanças climáticas globais. *Pesquisa Florestal Brasileira*. Colombo. v. 37. n. 91. p. 331-346. jun./set. 2017.

WREGÉ. M. S.; SOUSA. V. A.; FRITZSONS. E.; SOARES. M. T. S.; AGUIAR. A. V. Predicting current and future geographical distribution of araucaria in Brazil for fundamental niche modeling. *Environment and Ecology Research*. v. 4. n. 5. p. 269-279. Oct. 2016.

Rede de pesquisa em polinização de frutíferas do Norte e Nordeste

Data Published in:

CAVALCANTE. M. C.; FREITAS. B. M.; MAUÉS. M. M. Polinização de algumas culturas agrícolas: polinização da castanha-do-brasil (*Bertholletia excelsa*). Petrolina: Embrapa Semiárido. 2012. v. 249. p. 58-68. (Documentos/Embrapa Semiárido. Online).

CAVALCANTE. M. C.; GALETTO. L.; MAUÉS. M. M.; PACHECO FILHO. A. J. S.; BOMFIM. I. G. A.; FREITAS. B. M. Nectar production dynamics and daily pattern of pollinator visits in Brazil nut (*Bertholletia excelsa* Bonpl.) plantations in Central Amazon: implications for fruit production. *Apidologie*. v. 49. n. 4. p. 505-516. Aug. 2018.

MAUÉS. M. M. Economia e polinização: custos, ameaças e alternativas. In: RECH. A. R.; AGOSTINI. K.; OLIVEIRA. P. E.; MACHADO. I. C. (org.). *Biologia da polinização*. Rio de Janeiro: Projeto Cultural. 2014. v. 1. p. 607-636.

MAUÉS. M. M.; CAVALCANTE. M. C.; SANTOS. A. C. S.; KRUG. C. Brazil nut in the Amazon. In: ROUBIK. D. W. (org.). *The pollination of cultivated plants: a compendium for practitioners*. Rome: FAO. 2018. v. 1. p. 220-225.

MAUÉS. M. M.; KRUG. C.; WADT. L. H. O.; DRUMOND. P. M.; SANTOS. N. A. S. A castanha-do-brasil: avanços no conhecimento das práticas amigáveis à polinização. Rio de Janeiro: Funbio. 2015.

Impact of climate change on pollinators of Brazilian agricultural crops

Data Published in:

GIANNINI. T. C.; CHAPMAN. D.; BIESMEIJER. J.; SARAIVA. A. M.; ALVES dos SANTOS. I. Improving species distribution

models using biotic interactions: a case study of parasites, pollinators and plants. *Ecography*. v. 36. p. 649-656. Nov. 2013a.

GIANNINI, T. C.; ACOSTA, A. L.; SILVA, C. I.; OLIVEIRA, P. E. A. M.; IMPERATRIZ-FONSECA, V. L.; SARAIVA, A. M. Identifying the areas to preserve passion fruit pollination service in Brazilian tropical savannas under climate change. *Agriculture Ecosystems & Environment*. v. 171. p. 39-46. May 2013b.

GIANNINI, T. C.; BOFF, S.; CORDEIRO, G. D.; CARTOLANO, E. A.; VEIGA, A. K.; IMPERATRIZ-FONSECA, V. L.; SARAIVA, A. M. Crop pollinators in Brazil: a review of reported interactions. *Apidologie*. v. 46. n. 2. p. 209-223. Sep. 2015a.

GIANNINI, T. C.; CORDEIRO, G. D.; FREITAS, B. M.; SARAIVA, A. M.; IMPERATRIZ-FONSECA, V. L. The dependence of crops for pollinators and the economic value of pollination in Brazil. *Journal of Economic Entomology*. v. 108. n. 3. p. 849-857. June 2015b.

GIANNINI, T. C.; TAMBOSI, L. R.; ACOSTA, A. L.; JAFFÉ, R.; SARAIVA, A. M.; IMPERATRIZ-FONSECA, V. L.; METZGER, J. P. Safeguarding ecosystem services: a methodological framework to buffer the joint effect of habitat configuration and climate change. *PLoS ONE*. v. 10. n. 6. p. 1-48. June 2015c.

GIANNINI, T. C.; COSTA, W. F.; CORDEIRO, G. D.; IMPERATRIZ-FONSECA, V. L.; SARAIVA, A. M.; BIESMEIJER, J.; GARIBALDI, L. A. Projected climate change threatens pollinators and crop production in Brazil. *PLoS ONE*. v. 12. n. 8. p. 1-13. Aug. 2017a.

GIANNINI, T. C.; MAIA-SILVA, C.; ACOSTA, A. L.; JAFFÉ, R.; CARVALHO, A. T.; MARTINS, C. F.; ZANELLA, F. C. V.; CARVALHO, C. A. L.; HRNCIR, M.; SARAIVA, A. M.; SIQUEIRA, J. O.; IMPERATRIZ-FONSECA, V. L. Protecting a managed bee pollinator against climate change: strategies for an area with extreme climatic conditions and socioeconomic vulnerability. *Apidologie*. v. 48. n. 6. p. 784-794. June 2017b.

Artigos submetidos (em revisão)

GIANNINI, T. C.; ALVES, D. A.; ALVES, R.; CORDEIRO, G. D.; CAMPBELL, A. J.; AWADE, M.; BENTO, J. M. S.; SARAIVA, A. M.; IMPERATRIZ-FONSECA, V. L. Unveiling the contribution of bee pollinators to Brazilian crops with implications for bee management. Submetido para *Apidologie*.

GIANNINI, T. C.; COSTA, W. F.; BORGES, R. C.; MIRANDA, L.; COSTA, C. P. W.; SARAIVA, A. M.; IMPERATRIZ-FONSECA, V. L. Climate change in the Eastern Amazon: crop-pollinator and occurrence-restricted bees are potentially more affected. Submetido para *Regional Environmental Change*.

PAZ, F. S.; PINTO, C. E.; BRITO, R. M.; IMPERATRIZ-FONSECA, V. L.; GIANNINI, T. C. Which are the main pollinators of edible plant species in the Brazilian Amazon Forest? Submetido para *Neotropical Entomology*.

Divulgação científica

AGÊNCIA FAPESP. Estudo da Poli-USP mostra queda acentuada de polinização com impacto na agricultura. Agência Fapesp. São Paulo. 11 ago. 2017. Disponível em: <http://agencia.fapesp.br/estudo-da-poli-usp-mostra-queda-acentuada-de-polinizacao-com-impacto-na-agricultura/25866/>. Acesso em: 10 fev. 2020.

BARROS, B. Mudanças no clima no país afetarão abelhas e polinização de culturas. *Revista Valor Econômico*. São Paulo. 09 ago. 2017. Disponível em: <http://www.valor.com.br/agro/5073044/mudancas-no-clima-no-pais-afetarao-abelhas-e-polinizacao-de-culturas>. Acesso em: 10 fev. 2020.

BEER, R. Por que salvar as abelhas. *Revista Veja*. São Paulo. 19 fev. 2016. Disponível em: <https://veja.abril.com.br/ciencia/por-que-salvar-as-abelhas/>. Acesso em: 10 fev. 2020.

GIANNINI. T. C.; CORDEIRO. G. D. Abelhas polinizadoras importantes para a agricultura brasileira. Mensagem Doce. São Paulo. v. 136. p. 21-24. maio 2016.

GIANNINI. T. C.; COSTA. W. F.; CORDEIRO. G. D.; IMPERATRIZ-FONSECA. V. L.; SARAIVA. A. M. Efeito das mudanças climáticas sobre os polinizadores de algumas culturas agrícolas no Brasil. Mensagem Doce. São Paulo. n. 143. p. 1-4. set. 2017.

GIANNINI. T. C.; SILVA. C. M.; ACOSTA. A. L.; RIBBI. R. J.; MARTINS. C. F.; ZANELLA. F. C. V.; CARVALHO. C. A. L.; HRNCIR. M.; SARAIVA. A. M.; IMPERATRIZ-FONSECA. V. L. Proteção da abelha jandaíra no Nordeste Brasileiro considerando-se as mudanças climáticas. Mensagem Doce. São Paulo. n. 143. p. 1-4. set. 2017.

GIANNINI. T. C. Cenários de impacto das mudanças climáticas sobre algumas abelhas polinizadoras no Brasil. Mensagem Doce. São Paulo. p. 16-18. set. 2016.

GIANNINI. T. C. O valor econômico do serviço de polinização em alguns cultivos brasileiros. In: ASSOCIAÇÃO BRASILEIRA DE ESTUDOS DAS ABELHAS – A.B.E.L.H.A. (org.). Agricultura e polinizadores. São Paulo: A.B.E.L.H.A.. 2015. p. 44-53. Disponível em: <https://www.abelha.org.br/publicacoes/ebooks/Agricultura-e-Polinizacao.pdf>. Acesso em: 10 fev. 2020.

REVISTA HORIZONTE GEOGRÁFICO. A importância dos polinizadores na agricultura – mais abelhas, mais alimentos. Edição especial. São Paulo: Audio Chromo. 2016. Disponível em: <http://www.edhorizonte.com.br/wp-content/uploads/2017/05/A-import%C3%A2ncia-dos-polinizadores-na-agricultura.pdf>. Acesso em: 10 fev. 2020.

WATANABE. F. Em 90% do Brasil, mudanças no clima reduzirão abelhas e afetarão alimentos. Folha de São Paulo. São Paulo. 9 ago. 2017. Disponível em: <https://www1.folha.uol.com.br/ambiente/2017/08/1908471-em-90-do-brasil-mudancas-no-clima-reduzirao-abelhas-e-afetarao-alimentos.shtml>. Acesso em: 10 fev. 2020.

Selection of bacteria promoting plant growth for traditional food crops in the semi-arid environment

Data Published in:

NASCIMENTO. R. D. E C. Eficiência de bactérias diazotróficas para a cultura o milho em diferentes condições edafo-climáticas. 2018. (Dissertação de Mestrado) – Universidade Federal do Recôncavo da Bahia. Cruz das Almas. 2018.

References:

MARINHO. R. C. N.; FERREIRA. L. V. M.; SILVA. A. F. da; MARTINS. L. M. V.; NÓBREGA. R. S. A.; FERNANDES-JÚNIOR. P. I. Symbiotic and agronomic efficiency of new cowpea rhizobia from Brazilian semi-arid. *Bragantia*. v. 76. 2017.

SANTOS. J. W. M.; SILVA. J. F.; FERREIRA. T. D. S.; DIAS. M. A. M.; FRAIZ. A. C. R.; ESCOBAR. I. E. C.; SANTOS. R. C.; LIMA. L. M.; MORGANTE. C. V.; FERNANDES-JÚNIOR. P. I. Molecular and symbiotic characterization of peanut bradyrhizobia from the semi-arid region of Brazil. *Applied Soil Ecology*. v. 121. p. 177-184. 2017.

SIZENANDO. C. I. T.; RAMOS. J. P. C.; FERNANDES-JUNIOR. P. I.; LIMA. L. M. de; FREIRE. R. M. M.; SANTOS. R. C. dos. Agronomic efficiency of Bradyrhizobium in peanut under different environments in Brazilian Northeast. *African Journal of Agricultural Research*. v. 11. p. 3482-3487. 2016.

The Plants for the Future Initiative: native species of the Brazilian flora of current or potential economic value

References

CORADIN. L.; CAMILLO. J.; PAREYN. F. G. C. (ed.). Espécies nativas da flora brasileira de valor econômico atual ou potencial: Região Nordeste. Brasília: MMA. 2018.

FAO – Food and Agriculture Organization of the United Nations. Building on gender, agrobiodiversity and local knowledge: a training manual. Rome. Italy: FAO. 2005. Disponível em: <http://www.fao.org/docrep/007/y5609e/y5609e01.htm>. Acesso em: 18 set. 2019.

FAO – Food and Agriculture Organization of the United Nations. The international treaty on plant genetic resources for food and agriculture: equity and food for all. Rome. Italy: FAO. 2008. Disponível em: <http://www.fao.org/plant-treaty/en/>. Acesso em: 10 fev. 2020.

KUNKEL. G. Plants for human consumption: an annotated checklist of the edible phanerogams and ferns. Germany: Koenigstein Koeltz Scientific Books. 1984.

MITTERMEIER. R. A.; ROBLES-GIL. P.; MITTERMEIER. C. G. Megadiversity. Earth's biologically wealthiest nations. Mexico City: CEMEX. Agrupación Sierra Madre. 1997.

MYERS. N. The primary source: tropical forests and our future. New York: W. W. Norton and Company. 1984.

PRESCOTT-ALLEN. R.; PRESCOTT-ALLEN. C. How many plants feed the world? *Conservation Biology*. v. 4. n. 4. p. 365-374. Dec. 1990.

RAPOPORT. E. H.; DRAUSAL. B. S. Edible plants. In: S. LEVIN (ed.). *Encyclopedia of biodiversity*. New York: Academic Press. 2001. p. 375-382.

SOLBRIG. O. T. Biodiversity: an introduction. In: SOLBRIG. O. T.; EMDEN. H. M. van; OORDT. P. G. W. J. van (eds.). *Biodiversity and global change. Monograph nº 8*. Paris: International Union of Biological Sciences. 1992. p. 13-20.

WILSON. E. O. The current state of biological diversity. In: WILSON. E. O. (ed.). *Biodiversity*. Washington. D.C.: National Academy Press.. 1988. p. 3-18.

Sustainable and intensive multifunctional agroecosystem designs

Data Published in:

FREITAS. M. do S. C. de; SOUTO. J. S.; GONÇALVES. M.; ALMEIDA. L. E. da S.; SALVIANO. A. M.; GIONGO. V. Decomposition and nutrient release of cover crops in mango cultivation in Brazilian Semi-Arid region. *Revista Brasileira de Ciência do Solo*. v. 43. p. 1-21. 2019.

GIONGO. V.; CUNHA. T. J. F.; MENDES. A. M. S.; GAVA. C. A. T. Carbono no sistema solo-planta no Semiárido brasileiro. *Revista Brasileira de Geografia Física*. Recife. v. 4. n. 6. p. 1233-1253. 2011.

GIONGO. V.; GONDIM. R. S.; SALVIANO. A. M.; PEREIRA FILHO. A.; VEZZANI. F. M. Estratégias para uma agricultura de baixa emissão de carbono no cultivo de meloeiro. In: FIGUEIREDO. M. C. B. de; GONDIM. R. S.; ARAGÃO. F. A. S. de (ed.). *Produção de melão e mudanças climáticas: sistemas conservacionistas de cultivo para redução das pegadas de carbono e hídrica*. Brasília. DF: Embrapa. 2017. cap. 1. p. 213-230.

GIONGO. V.; MENDES. A. M. S.; SANTANA. M. da S.; COSTA. N. D.; YURI. J. E. Soil management systems for sustainable melon cropping in the Submedian of the São Francisco Valley. *Revista Caatinga*. Mossoró. v. 29. n. 3. p. 537-547. July/Sept. 2016.

GIONGO. V.; SALVIANO. A. M.; ANGELOTTI. F.; TAURA. T. A.; LEITE. L. F. C.; CUNHA. T. J. F. Low carbon technologies for agriculture in dryland: brazilian experience. In: RAO. C. S.; SHANKER. A. K.; SHANKER. C. (ed.). *Climate resilient agriculture: strategies and perspectives*. Rijeka. Croatia: InTech. 2018. cap. 6. p. 105-127.

PEREIRA FILHO. A.; TEIXEIRA FILHO. J.; SALVIANO. A. M.; YURI. J. E.; GIONGO. V. Nutrient cycling in multifunctional agroecosystems with the use of plant cocktail as cover crop and green manure in the semi-arid. *African Journal of Agricultural Research*. v. 14. n. 5. p. 241-251. 2019.

SANTOS. T. de L.; NUNES. A. B. A.; GIONGO. V.; BARROS. V. da S.; FIGUEIREDO. M. C. B. de. Cleaner fruit production with green manure: the case of Brazilian melons. *Journal of Cleaner Production*. v. 181. p. 260-270. 2018.

Butiazais Route: connecting people for the conservation and sustainable use of biodiversity

Data Published in:

MARCHI. M. M.; BARBIERI. R. L.; MUJICA. J. S.; COSTA. F. A. da. Flora herbácea e subarbustiva associada a um ecossistema de butiazal no bioma Pampa. *Rodriguésia*. Rio de Janeiro. v. 69. n. 2. p. 553-560. out. 2018.

RIVAS. M.; BARBIERI. R. L. Boas práticas de manejo para o extrativismo sustentável de butiá. *Pelotas: Embrapa Clima Temperado*. 2014.

RIVAS. M.; FILIPPINI. J. M.; CUNHA. H.; HERNÁNDEZ. J.; RESNICHENKO. Y.; BARBIERI. R. L. Palm forest landscape in Castillos (Rocha. Uruguay): contributions to the design of a conservation area. *Open Journal of Forestry*. v. 7. p. 97-120. Mar. 2017.

SOSINSKI JÚNIOR. E. E.; HAGEMANN. A.; DUTRA. F.; MISTURA. C.; COSTA. F. A.; BARBIERI. R. L. Manejo conservativo: bases para a sustentabilidade dos butiazais. *Pelotas: Embrapa Clima Temperado*. 2015. (Boletim de Pesquisa e Desenvolvimento 230).

SOSINSKI JÚNIOR. E. E.; URRUTH. L. M.; BARBIERI. R. L.; MARCHI. M. M.; MARTENS. S. G. On the ecological recognition of Butia palm groves as integral ecosystems: why do we need to widen the legal protection and the in situ/on-farm conservation approaches? *Land Use Policy*. v. 81. p. 124-130. Feb. 2019.

