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WORKING PAPER

ROLE OF ABC PLAN AND PLANAVEG IN THE ADAPTATION OF BRAZILIAN AGRICULTURE TO CLIMATE CHANGE

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EXECUTIVE SUMMARY

Highlights

- **This working paper presents a set of sustainable practices for the Brazilian agriculture in the short and long-terms,** that contribute to the provision and maintenance of ecosystem services, conservation and restoration of biomes, and more resilient low-carbon productive systems that are more adapted to current and future impacts from climate change.
- **It proposes a matrix that highlights opportunities to increase resilience and adaptation to climate change** of the main technical approach recommended by the ABC Plan and Planaveg, which can be used by investors and financial institutions to assess risks.
- **Climate change adaptation strategies in the agriculture sector can provide environmental and financial benefits** for farmers, and economic, social and environmental benefits for society at large, in addition to reducing risk to investors, financial institutions and insurance companies.
- **Increased investment and adoption of the systems recommended by the ABC Plan and the restoration strategies proposed by Planaveg are needed**, in order for their importance to land use and legal compliance, and vulnerability reduction of farmers to climate variability and extreme climate events to be realized.

CONTENTS

Working Papers contain preliminary research, analysis, conclusions and recommendations. They are distributed to stimulate discussions and critical commentary and to influence the debate underway about emerging issues. Most Working Papers are eventually published in another form and their contents may be revised.

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Context

Brazil is a global leader in agricultural production and may become the largest exporter of food in the coming years. To make this happen, the country needs to be prepared to face the impacts of climate change. The market share of a given country in the future will depend, on one hand, on its ability to plan and adapt its agricultural systems to new climate regimes and, on the other hand, on its ability to comply with international commitments to mitigate emissions and protect biodiversity. Without a solid set of policies and practices that encourage the development and application of more resilient techniques, agricultural productivity could fall and access to emerging markets as well as participation in consolidated markets could be lost.

A decrease of 17% in global agricultural productivity, caused by climate change, is predicted by 2050. It is estimated that climate variability and extreme climate events experienced in Brazil between 1979-2008 explain the annual fluctuations of around 0.8 tons of corn per hectare and is responsible for 25% to 38% and 26% to 34% of the variability in the production of rice and soybeans, respectively. Agriculture is essentially an outdoor activity and is therefore particularly sensitive and susceptible to climate change. The main impacts of these changes are alterations in the pace of gains in plant and animal biomass; modification of phenological seasonal patterns; reduction in plant and animal fertility; and an increase in susceptibility to diseases. These impacts, in isolation or combined, lead to a decrease in production and productivity, restrict the supply of food and primary products, increase the price of agricultural goods and negatively impact populations, especially the poorest and most vulnerable ones. In addition, these alterations may also increase the risk and cost of capital for investors and agencies, which invest in or promote farm credit and insurance premiums.

The adaptation of agriculture to climate change can be viewed as a process to promote the use of management practices based on ecosystems (solutions based on nature) that can provide positive results. In agricultural farming systems, adaptation means adopting management practices that use biodiversity, ecosystem services and the ecological processes of natural or modified biomes to foster the ability of crops and livestock to adapt to changes and variations in climate.

Technologies available in Brazil, such as the genetic improvement of cultivars of plants and breeds of animals, no-till systems, biological fixation of nitrogen, digital sensors to evaluate the soil and plant, agricultural zoning of climate risk, agroecological zoning, and other technologies, are key to maintaining the country as a top agricultural producer. The country has robust technical knowledge and successful experience with commercial scale production systems of greater resilience and productivity. The more diversified an agricultural system is, the greater its ecosystem function and its resilience. Integrated systems optimize resources, conserve land and are less susceptible to variations in climate; therefore they also produce greater aggregate value. Adoption is growing, but conventional systems, whose production costs contribute to a trend of stagnation in agricultural GDP, still dominate the landscape, despite a significant increase in production due to an increase in productivity and expansion of the farmed area.

The ABC Plan was structured along six lines: Restoration of degraded pastures, integrated crop-livestock-forest systems and agroforestry systems, biological fixation of nitrogen, no-till systems, planted forests and treatment of animal waste, and specific actions to adapt to changes in climate. **These actions are synergistic with those provided in Planaveg**, which are designed to restore native vegetation on at least 12 million hectares by 2030, in areas of Permanent Preservation (PP) and Legal Reserve (LR) and in degraded areas with low agricultural potential.

The ABC Plan and Planaveg are fundamental to promoting adaptation of agriculture to climate change, primarily because they ensure the conservation of biodiversity and protect pollinators; maintain the supply and quality of water; attenuate climate extremes, such as droughts and heat waves, the main culprits for falling production; reduce the occurrence of natural disasters, especially risks of flooding and soil erosion; maintain the balance of biogeochemical cycles; sequester carbon in the soil; provide production diversity and generate income for farmers; and contribute to greater resilience of the production systems to climate change.

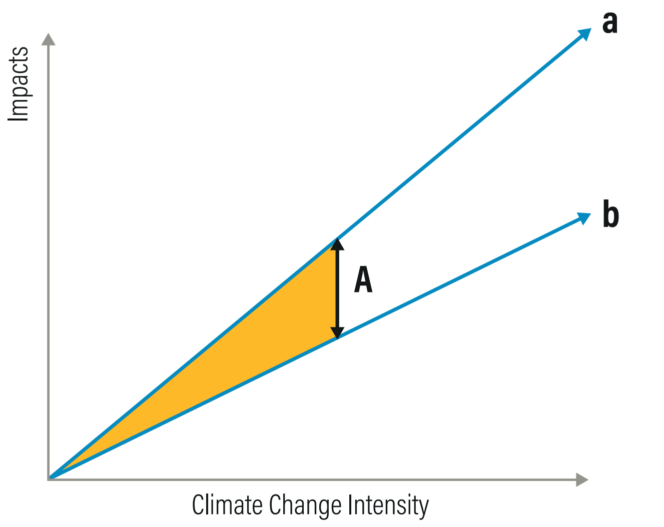
This potential is still poorly understood by the domestic agricultural sector. Currently, the implementation of the ABC Plan falls far short of its funding capacity. Less than 1.4% of the rural credit made available through the Safra Plan for agriculture and livestock has been used in the

ABC Plan. More than half of it is invested in activities such as no-till and restoration of pastures. Regarding the specific activities of the program, performance is marginal. As a basis for comparison, between 2013 and 2018, the ABC Plan provided financing of R$350 million for integrated systems, something around R$39/ha/year, compared with R$613.00/ha/year invested in soybean crops by other programs. For environmental compliance, a key step in the implementation of Planaveg, the ABC Plan financed only R$45 million in contracts, while during the same period other programs disbursed over R$430 million in projects that contributed to the conversion of native vegetation. Almost ten times as much finance was invested in the conversion of native vegetation compared with what was invested in compliance.

Urgency exists to finance agriculture that is resilient and adapted to present and future climate change, as recommended in the ABC Plan and Planaveg, without which Brazil will lose its capacity to be productive and competitive. The impacts of climate change on maintaining agricultural production will depend, on one hand, on the intensity of the alterations in the climate and, on the other, on the capacity of production systems to adapt. Therefore, mitigation is not enough. It is necessary to adapt production to the changes that are already underway. The greater the success in adapting, the smaller the expected deleterious effects of variability and climate extremes on the performance of crop and livestock farming.

The agricultural sector, financial institutions, investors, insurance companies, and society need to understand the importance of the sustainable intensification of agricultural production and forest restoration to increasing the resilience of Brazilian agriculture. The advantages of resilient systems are well known among academics and specialists. But the dissemination of this knowledge needs to be strongly encouraged. The intensive use of natural resources, without intelligent methods designed to maximize returns, contributes to the degradation of ecosystem services, compromises the production of food and the profitability of agriculture and can affect the national economy. The adoption of climate change adaptation strategies in the agricultural sector, currently responsible for around 20% of domestic GDP, brings environmental and financial benefits to farmers and economic, social and environmental benefits to society and to our ability to face climate crises (Figure 1).

Figure 1 | **Conceptual model of the potential of actions contained in the ABC Plan and Planaveg to reduce the impacts of climate change on agriculture.**



Line **a** indicates business as usual. Line **b** indicates a reduction in the impacts as a result of the adoption of climate change adaptation practices. Shaded area **A** indicates the potential of the actions contained in the ABC Plan and Planaveg to reduce the impacts of climate change on agriculture. Adapted from Stern, 2007.

Investors, financial institutions and insurance companies must invest in production systems that are more resilient to climate change. Investing in adapted production systems, through economically viable arrangements with low environmental risk, reduces losses caused by climate change, increases return on investment and repayment of loans, strengthens loan guarantees, expands access to national and international markets and reduces the risk for investors, financial institutions and insurers.

The objective of this work is to contribute to establishing a sustainable and integrated approach to the management of landscapes that enables the development of the agriculture sector, based on reduced degradation of ecosystems, restoration of biomes and the adoption of low-carbon production systems that are more resilient and adapted to the impacts of present and future climate change. The benefits to the environment provided by the actions contained in the ABC Plan and Planaveg to increase the capacity of Brazilian agriculture to adapt to climate change are highlighted here.

INTRODUCTION

32% of Brazilian territory is occupied by agriculture and livestock, being one of the five largest agricultural areas in the world (COALITION, 2019). As a global leader in agricultural production, Brazil's food production is enough to feed a billion people (EMBRAPA, 2018). Estimates indicate that the country's planted area will expand faster than any other country until 2050, making Brazil the largest agricultural producer by mid-2030 (NELSON et al., 2014).

GDP from agribusiness, which encompasses the segments of agriculture inputs, primary agriculture production, agricultural processing and services, was worth R$1.4 trillion in 2018, or around 20% of domestic GDP. The GDP of primary production was R$350 billion, approximately 5% of domestic GDP (CEPEA, 2019).

Being an agricultural superpower, however, has social and environmental consequences. Over 70% of the country's greenhouse gas emissions (GHG), in 2016, came from a combination of agricultural inputs and land use change, the driving force behind deforestation and degradation of native vegetation in Brazil (SEEG, 2018). This places Brazil second (HANSEN et al., 2013, updated in 2018) on the list of countries experiencing the highest losses of tree cover[1] between 2001 and 2017.

Agriculture is highly dependent upon climate, and thus climate changes impact productivity and financial gains, putting growth expectations at risk (RAY et al., 2015). In order to maintain growth in production and productivity in the agriculture sector, while ensuring efficiency and sustainability, Brazil needs to face the impacts of climate change, safeguard the provision of ecosystem services and reduce GHG emissions. In addition, given that agricultural activity also depends on social, economic and political factors, the use of adaptation strategies depends on decision-making by the farmer, and not just the availability and knowledge that already exists about the effectiveness of the strategy (MARGULIS; DUBEUX, 2011).

In September 2015, Brazil presented its Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC), indicating targets, in relation to 2005 levels, for the reduction of Brazilian emissions by 37% by 2025 and by 43% by 2030.

Two Brazilian public policies concerning the agricultural sector and land use are relevant to compliance with NDCs: The Sectoral Plan for Mitigation and Adaptation to Climate Change for a Low-Carbon Emission Agriculture (ABC Plan) and the National Plan for Native Vegetation Recovery (Planaveg).

Originally, the ABC Plan (BRASIL, 2012a) was aimed at actions for mitigation (reduction of GHG emissions) and adaptation. But the targets established were based on the potential for mitigation, considered a direct benefit of the different actions proposed, while the actions for adaptation were mentioned only as additional benefits. In the literature, these additional benefits are considered co-benefits. They are aimed at sustainable development and involve environmental gains such as improved air and water quality, protection against floods, increased animal weight gain and crop productivity, generation of electric energy for rural or remote areas, and increased income and job opportunities (OECC, 2009; PAIVA et al., 2015). Since mitigation will not be discussed in this Working Paper, the gains from adaptation actions, without considering the reduction in GHG emissions, will be designated by the term "benefit."

This Working Paper is guided by a vision that the systemic nature of agricultural production, constrained by the climate and availability of natural resources, compels a sustainable approach on the management of landscapes, in which the development of the agricultural sector cannot occur without the conservation of natural resources, maintenance of ecosystems services, restoration of biomes and the adoption of low-carbon production systems. The objective of this approach is to (1) contribute to advancing research on the links between the practices of the ABC Plan and Planaveg (BRASIL, 2017) and, (2) encourage the adoption of strategies for domestic agriculture and livestock to adapt to climate change, through incentives and greater distribution of resources of the Safra Plan for low-carbon production systems and for the restoration of biomes.

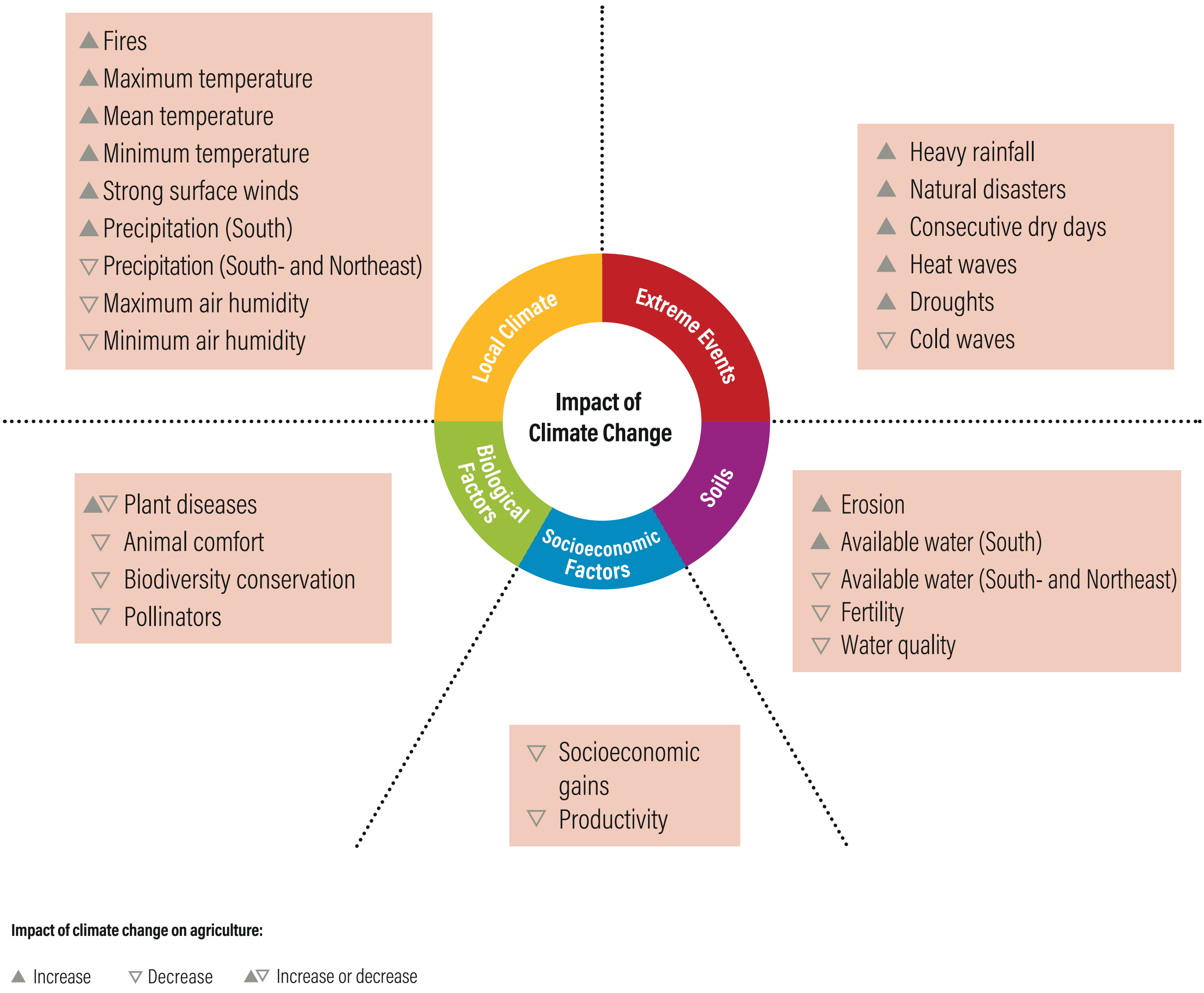
A summarized matrix of the benefits assessed by type of agricultural system, as recommended in the ABC Plan, and by type of vegetation recovered, as recommended in Planaveg, is proposed here, highlighting their advantages and disadvantages when compared to conventional production systems, in terms of adaptation of agriculture to climate change that poses risks to production and productivity.

The synergy between the forest and landscape restoration and more resilient agriculture production that is adapted to climate change is promising, but still lacks in-depth studies. With this Working paper, WRI Brasil and German Corporation for International Cooperation (GIZ), in collaboration with a group of specialists, systematized a summary of knowledge and experiences to date, based on the identification and compilation of scientific articles, studies, projects and experiences in Brazil.

IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

Developing countries are, in general, the most vulnerable to the impacts of climate change (IPCC, 2001; NOBRE, 2005). And Brazil is especially vulnerable when considering the impacts f a changing climate on its ecosystems and agriculture (NOBRE, 2005). There are many impacts of climate change for agriculture, including: (1) changes in crop development cycles, (2) reduction in water availability, (3) increases in soil erosion vulnerability, (4) changes in evapotranspiration rates, (5) alteration in plant and feedstocks disease, (6) increases in the frequency and intensity of extreme events (temperature and rainfall), and (7) increases of the occurrence of droughts, second summers, floods, and other events (Figure 2).

Figure 2 | **Diagram of the negative impacts of climate change on agriculture.**



For Brazilian farmers and the country's economy, these effects are associated with a high risk of falling agricultural productivity, and in some cases a complete collapse in regional yield. Unfortunately, climate change is already underway (IPCC, 2014) and, regardless of the success of the actions to reduce GHG emissions, there is urgency to implement transformative adaptation actions to deal with its negative impacts.

Studies show the impact of temperature in the development and productivity of crops (BERGAMASCHI; MATZENAUER, 2014; CRUZ et al., 2011; HEINEMANN et al., 2009). Changes in temperature primarily influence the duration of the crop cycle, since each crop species and variety has optimal temperature ranges for its development. Temperatures outside these ranges compromise their development and can impact productivity. High temperatures, for example, lead to a shortened crop cycle, reducing the period for maturing of grains, which can compromise productivity. In addition, this leads to higher evapotranspiration and an increase in the respiration rate, primarily maintenance respiration.

Elevated temperatures affect the photosynthesis of C4 plants, as corn and sugarcane, less than C3 plants, such as soybeans, because C3 plants have more photorespiration. In the cultivation of beans, for example, air temperature is the climate element that has the highest influence on the percentage of viable pods, and temperatures above 35°C impair flowering and grains filling (FERREIRA et al., 2003; HEINEMANN et al., 2009). When high temperatures are accompanied by low relative humidity of the air and strong winds, it can also affect the attachment and the retention of pods (FERREIRA et al., 2003).

Low temperatures, in turn, reduce the rate of crop development, and can, in some cases, even paralyze the entire development process (BERGAMASCHI; MATZENAUER, 2014; CRUZ et al., 2011). It can reduce yield, due to the abortion of grains and, when below 12°C, in the vegetative phase, by slowing the growth of the plants (FERREIRA et al., 2003; HEINEMANN et al., 2009).

In some perennial crops, like coffee, elevated temperatures lead to the abortion of flowers, thus compromising productivity (ASSAD et al., 2004). At 34°C, the net photosynthesis of the coffee stops (MEIRELES et al., 2009). In the cultivation of oranges, temperatures above 35°C for around 10 consecutive days induce a hormonal imbalance that causes the fruit drop (MAJUSKI, 2016). In the cultivation of sugarcane, an increase in temperature during maturation phase, which in the southeastern region of Brazil extends from May to October, causes flowering, reduces the concentration of sucrose in the stalk causing a pith process and loss of productivity (MARIN et al., 2009).

In the cultivation of cacao, temperature and rainfall are the climate elements that most influence the growth and production of the cacao plant, and the monthly average range for its cultivation must remain between a minimum of 15°C and a maximum of 30°C (SOUZA et al., 2009). Severe droughts drastically affect the production of cacao plants. In Barro Preto (Bahia), a severe El Niño that occurred in 2015-2016 caused the most serious drought of the last 15 years and led to cacao plant mortality of 15% in an agroforestry system (cabruca[2]), severe reduction (89%) in productivity and increased incidence of witches' broom, a chronic disease in the cacao plant (GATEAU-REY et al., 2018).

It is important to note that shaded cacao trees are better protected against severe droughts than cacao trees planted as mono-crop (TSCHARTNTKE et al., 2011), which means that the losses in the region for that period would have been much greater with the intensive cultivation of cacao as monoculture. High rates of solar radiation cause stress which damages the crop (TAIZ; ZEIGER, 1991). Higher solar radiation can also increase evapotranspiration of crops and lead to a loss in yield (BERGAMASCHI; MATZENAUER, 2014). Lower radiation can also reduce crop yield, even when the other climate elements and soil water are adequate (ALVES et al., 2011).

The availability of soil water, which depends primarily on precipitation and evapotranspiration, is another important factor in the productivity of crops. In this way, alterations in the frequency and intensity of rainfall in each region, as predicted by climate change models, will experience grave consequences, primarily for rainfed crops, which are completely dependent on precipitation.

In the event of long dry spells, water stress can lead to reduction in productivity (BERGAMASCHI et al., 2006). For soybeans, significant water deficits, accentuated by elevated temperatures during the flowering and grains filling, cause physiological changes in the plant, such as stomatal closure, rolling of leaves and, consequently, an increase in premature dropping of flowers and pods, with a reduced number of healthy pods and an increase in empty pods (FARIAS et al., 2009).

The effect of water deficit can be heightened if combined with an increase in temperature (ASSAD et al., 2013). On the other hand, large volumes of rainfall can reduce the productivity of crops due to saturation of the soil and thus a delay in harvest. Average temperature and spatial distribution of precipitation during the planting season explain more than 30% of the variation in productivity in crops (LOBELL; FIELD, 2007).

One of the greatest risks to the production of food is the increase in the frequency of extreme temperature events, such as droughts and flooding. In Brazil, 95% of the losses in agriculture occurred as a result of floods or droughts (PINTO et al., 2008a), and IPCC projections indicate an increase in the frequency of extreme temperature and precipitation phenomena.

IPCC projections of variations in temperature of around 1°C to 5.8°C and an increase in rainfall of 15% would result in a reduction of 95% of the area suitable for the coffee in Goiás, Minas Gerais and São Paulo, and of 75% in Paraná (ASSAD et al., 2004). An example of the effect of climate on agricultural productivity in Brazil was observed in 2013, when a drought during the period of development of orange and coffee and excessive rainfall during the harvest caused a steep decline in production and contributed to a reduction of 1.89% in GDP (CEPEA, 2019).

The effects of climate change on nine crops (cotton, rice, coffee, sugarcane, beans, sunflowers, cassava, corn and soybeans), pastures and beef cattle would result in a negative impact of US$4 billion in 2050, with soybeans responsible for 50% of these losses (PINTO et al., 2008a). Using the same methodology and considering the IPCC's most pessimistic scenario, Brazil could lose around 2.5% of its GDP in 2050 due to the impacts of climate change on agriculture (MARGULIS; DUBEUX, 2011).

The productivity of soybeans is affected directly by temperature, precipitation and the concentration of CO_2. Studies show that soybeans respond positively to an increase in the concentration of CO_2, meaning that an increase of around 3°C in temperature could reduce this gain (HEINEMANN et al., 2006; ONAT et al., 2017). Climate change could lead to a migration of corn growing sites to the south of Brazil, leading to competition against other crops like beans, and an increase in the incidence of pests and diseases (PINTO et al., 2008b).

Soybean and pasture combined represent 88% of the agricultural area in Brazil, including pasture, permanent crops, temporary crops and silviculture (IBGE, 2018). CMIP5-IPCC models indicate that the most productive regions in the country's central-north, the effects of climate change are dependent on planting date, with a strong reduction in the productivity of soybeans planted in September, in the systems using double-crop, primarily due to water deficit and the effects of dry spells during the growing season, accentuated by high temperatures (PIRES, 2015).

In the cultivation of corn, the main climate factors that negatively impact productivity are precipitation, air temperature and solar radiation (SANS; SANTANA, 2002). Maximum growth of this crop occurs between 26°C and 34°C, with upper and lower limits of 8°C and 44°C (KINIRY, 1991). Temperatures during the germination phase until the maturation phase must remain around 25°C and, during the maturation phase for the grains, a temperature below 15°C will slow the process (SANS; SANTANA, 2002). When nighttime temperatures are above 24°C, the respiration rate increases and, therefore, reduces the rate of photo assimilates, resulting in a production drop (SANS; SANTANA, 2002).

In the coming years, an upward trend is expected in the frequency of days with temperatures above 34°C, with a strong impact on the productivity of coffee and bean crops (ASSAD; PINTO, 2008). Without new management and adaptation solutions, corn and soybean production could fall by 90% and 80%, respectively (TEIXEIRA et al., 2016).

Thermal discomfort influences animal weight gain and milk production. In the main milk producing mesoregions of Pernambuco (Garanhuns and the valleys of Ipojuca and Ipanema), the intensification of thermal stress has resulted in a reduction in milk production and food consumption of animals, especially in cattle with higher production levels (SILVA et al., 2009). In areas in which the thermal stress is already pronounced, such as those situated in the interior and along the coastline of Pernambuco, the impacts have been even greater, both during the hottest months (December to February) and during the coldest months (June to August) (SILVA et al., 2009).

In Brazil, the largest increases in temperature projected for the coming decades are expected for the Central-West region. However, by the end of the century, the North and Northeast regions will also be affected. Models also indicate a trend toward reduced precipitation in every region of the country, except in the South and the southern portion of the Southeast, as well as a higher incidence of extreme events (ASSAD et al., 2017). One of the probable impacts of a higher frequency of intense precipitation events is an increase in soil erosion (ALMAGRO et al., 2017) which could have disastrous implications for agricultural production.

Climate change can affect the incidence of crop diseases, through direct and indirect effects on the host plant, on the pathogen and on the interaction between them, and alter the action of biological control agents and vectors (GHINI; HAMADA, 2008). A rise in temperature and humidity in the air and soil could increase the incidence of diseases in rice (PRABHU et al., 2008), corn (PINTO et al., 2008b) and coffee (POZZA; ALVES, 2008). Likewise, a severe impact of climate change is projected on pollinators and, consequently, on productivity (GIANNINI et al., 2017).

Studies indicate that, for the period between 2009-2018, the world's economic costs resulting from natural catastrophes exceeded, in seven years, the 30-year average of US$140 billion a year (NFGS, 2019). On the other hand, biophysical models indicate that, by 2050, world agricultural production could fall by 17%, when compared with a scenario of an unchanged climate (NELSON et al., 2014). Economic models also indicate that, over this period, crop productivity will fall, the area cultivated with primary crops (corn, soybeans, millet, rice, sunflower, cotton, cassava and other crops) will rise and consumption will decline (NELSON et al., 2014; NGFS, 2019).

ECOSYSTEM SERVICES AND ECOSYSTEM-BASED ADAPTATION

Ecosystem services are the ecological characteristics, functions or processes that directly or indirectly contribute to well-being (ALCAMO et al., 2003; COSTANZA et al., 2017) and may be classified into supporting, provisioning, regulating and cultural services groups. Agricultural activities are often dependent on these services. When farming uses intensive practices, it can have an impact on biodiversity, climate, soils, water resources and consequently, on the provision of ecosystem services.

At the end of the 20th century, we began to understand that intact, functioning ecosystems produce various valuable services, oftentimes more significant than the results of their extraction or exploration (COSTANZA et al., 2017). In 2011, the overall economic value of ecosystem services was estimated to be between US$125 and US$145 trillion, an amount far higher than the world's gross product for that year, and the loss of ecosystem services for the period 1997 to 2011 due to change in land use totaled somewhere between US$4.3 and US$20.2 trillion per year (COSTANZA et al., 2014). Even if overestimated, these results reinforce that ecosystem services are fundamental to the world's economy.

Given the difficulty in valuation assessment, ecosystem services are oftentimes neglected and not included in the accounting of production cashflows, nor included in the indices currently used to measure global economies and human development, resulting in serious market and pricing system distortions. However, since resources used in a rural enterprise are evaluated based on their economic value, it is important that the ecosystem services are also assessed so that natural capital can be incorporated into the processes of business decision-making (GVCES, 2016).

The economic value of rural enterprises, in other words, the value of cash flows generated over time, can be associated with natural capital and its risk can be integrated into the accounting of companies, investments, financial and insurance institutions and countries. In their analysis of environmental and water resource risk, financial agents routinely consider questionnaires about socio-environmental aspects (socio-environmental safeguards), with the aim of checking the management of the company or enterprise receiving financing. These questionnaires, however, provide only a subjective analysis and rely on the knowledge of the particular analyst. This subjectivity can be minimized or resolved with the adoption of standardized tools for valuing ecosystem services.

In Brazil, since 2013, the Getúlio Vargas School of Business Administration (GVces/EAESP-FGV) has conducted the initiative Trends in Ecosystem Services (TeSE) based on the Business Guidelines for the Economic Valuation of Ecosystem Services (Devese) and their respective tools for quantifying and valuing the economic impacts suffered by companies and externalities caused by them regarding the ecosystem services. Data from TeSE indicate that, from 2014 to 2017, 40 studies were conducted for 24 companies to calculate this value. In 2018, a technical brief (GVCES, 2018) presented guidelines to aid users in the use of Devese to quantify and economically value the ecosystem services for the regulation of global climate, especially the application of the avoided deforestation method.

Currently, there are various tools available to evaluate and value ecosystem services (BAGSTAD et al., 2013; WBCSD, 2013; WEI et al., 2017), many supported in geographic information systems, but these are still rarely used in Brazil. They can aid in the evaluation, valuing and management of impacts on natural capital, contributing to decision-making.

Mitigation strategies are insufficient when the effects of climate change already present some degree of irreversibility—such as global warming, atypical seasonal changes, increase in climate extremes (intense rains, droughts, dry spell, etc.) and rising sea levels. The need therefore arises to develop solutions that support society's adjustment to the new conditions imposed by climate.

Adaptation is a process of maintaining or adopting management practices based on ecology that can provide positive results (VIGNOLA et al., 2015). Ecosystem-based adaptation (EbA) uses biodiversity and ecosystem services as part of an adaptation strategy that is aimed at reducing the effects of climate change (SCBD, 2009; RIZVI et al., 2015). EbA prescribes that, in the adaptation process, environmental conservation, management and restoration are essential to minimizing the risks to material production, human health and well-being (SCBD, 2009; RIZVI et al., 2015). EbA in agricultural systems consists of management practices that use or take advantage of biodiversity, ecosystem services and ecological processes (on a plot of land, farm or landscape) with a view to increasing the capacity of crops and livestock to adapt to changes and variations in climate (VIGNOLA et al., 2015).

As a multifunctional strategy, EbA revives the systemic nature inherent to agriculture in primary production and it is more effective precisely because of this. In this sense, the conservation and restoration of ecosystems mean much more than complying with legislation or a style of production. EbA increase the resilience of agriculture to provide essential services with natural inputs for which there are no substitutes and whose availability has become increasingly uncertain with climate change.

However, there are barriers to be overcome for the adaptation strategies based on ecosystems to be adopted, notably the following types: i) structural or operational (structures of institutional financing and incentive programs); ii) governance (laws, regulations, institutional arrangements and existing adaptive capacity); iii) social and cultural (social norms, values, education and awareness); iv) biological (intensity and frequency of natural dangers, such as extremes in temperature and precipitation); and v) capacity (in other words, lack of financial resources, lack of awareness or access to information or technology and limited human, individual, organizational and social capacities) (RIZVI; van RIEL, 2015).

FACING CLIMATE IMPACTS ON AGRICULTURE

For the agricultural sector, the ABC Plan proposes an expansion of actions for restoration of degraded pastures (RDP), crop-livestock-forest integration (CLFI), agroforestry systems (AFS), no-till systems (DSS), biological fixation of nitrogen (BFN), planted forests and treatment of animal waste. Planaveg focuses on the recovery of native vegetation, primarily in permanent preservation areas (PPA), legal reserves (RL) and degraded areas with low suitability for agriculture. There is, therefore, synergy between these two public policies (Box 1).

Box 1 | Synergy between ABC Plan and Planaveg

One of the eight Sectoral Plans already completed based on the National Policy on Climate Change (PNMC), the ABC Plan was created in 2010 with the objective to reduce man-made (anthropogenic) greenhouse gas emissions in agriculture sector and boost competitiveness. The actions proposed in the ABC Plan are grounded on good agriculture practices. As a result of the work of over 30 government agencies, NGOs and private enterprise, the plan was approved in May 2011. The six lines of financing provided for in the ABC Plan are incentivized through the ABC Program, a line of credit launched in the 2010/2011 Agriculture and Livestock Plan. Later in January 2017, the federal government established the National Policy for the Recovery of Native Vegetation (Proveg), faced with the challenge of implementing Law No. 12.651, of May 25, 2012, also known as the New Forest Code, which addresses the protection of native vegetation. The aim of Proveg is to coordinate, integrate and promote policies, programs and actions to aid in the restoration of forests and other types of native vegetation and to boost environmental regularization of rural properties in Brazil, in accordance with the New Forest Code, on a total area of, at least, 12 million hectares by December 31, 2030. These targets comply with the line of financing for reforestation and restoration of degraded areas of the ABC Program.

In November 2017, the National Plan for the Recovery of Native Vegetation (Planaveg) was launched as the main instrument for the implementation of Proveg. The objective of Planaveg is to expand and strengthen public policies, financial incentives, markets, good agriculture practices and other measures necessary for the recovery of native vegetation on at least 12 million hectares by 2030, primarily in permanent preservation areas (PPA) and Legal Reserve (LR) areas, as well as degraded and low suitability areas for agriculture.

Three important programs and policies complement the initiatives and strategies of Planaveg and create the conditions necessary to motivate, facilitate and implement the recovery of native vegetation. Implementation of these existing efforts requires continuous support from the government in order to strengthen them in the coming years. They work in synergy with the ABC Plan:

- Sustainable intensification of agriculture - increase productivity of pastures and cropland in regions outside the areas to be recovered, through programs designed to promote the sustainable intensification of agriculture, which is part of the ABC Plan;
- Native vegetation protection law - implement the determinations and the instruments of the New Forest Code, including the Rural Environmental Registry (CAR) and Environmental Regularization Programs (PRA);
- Land regularization - expand the number of rural properties with titles and eligibility for resources for forest recovery.

The main items financed by the ABC Plan that are part of the rural credit policy and that have more in common with Planaveg are:

- Implementation and improvement of integrated systems (crop-livestock, crop-forest, livestock-forest or crop-livestock-forest) and agroforestry systems (ABC Integration);
- Implementation, maintenance and improvement of commercial forest management, including those designed for industrial use or the production of charcoal (ABC Forests); and
- Compliance or regularization of rural properties in accordance with environmental legislation, including restoration of legal reserve and permanent preservation areas, recovery of degraded areas and implementation and improvement of plans for sustainable forest management (ABC Environmental).

The items financed with synergies between the ABC Plan and Planaveg are:

- Acquisition of seeds and seedlings for the formation of pastures and forests; and
- Implementation of nurseries for seedlings production.

The ABC Plan (BRASIL, 2012a) and Planaveg (BRASIL, 2017) are strategically important to the country and the world. The effective implementation of these plans delineates possible paths to ensuring increased agricultural productivity and, potentially, profitability for the farmer, considering, directly or indirectly, environmental aspects. In this Working Paper, we highlight potential of the ABC Plan and Planaveg as strategies for the adaptation of agriculture to the impacts of climate change, since their mitigation aspects have already been widely discussed. It is important to note, however, that there is a strong synergy between adaptation and mitigation (MBOW et al., 2014a).

Numerous strategies and actions that reduce the effects of climate change on agriculture also reduce losses in productivity and economic losses (KOOHAFKAN et al., 2011). The ABC Plan and Planaveg followed this reasoning, detailing actions to be implemented based on local circumstances and the needs of each farmer, including the restoration of native vegetation on a large scale.

The strategy to adapt to climate change in the agricultural sector is to invest more efficiently, promoting diversified systems and the sustainable use of biodiversity and water resources, with support for the transition process, organization of production, income generation guarantees, research (primarily in genetic resources and improvement of plants and animals, water resources, adaptation of production systems, identification of vulnerabilities and modeling), among other initiatives. In cattle farming, an area in which Brazil leads the world in commercial herd size (GOMES et al., 2017), the ABC Plan promotes the intensification of production through improvement of pasture quality, greater supply of food for animals, higher occupancy rate for pastures and, consequently, greater productivity.

The debate surrounding strategies for the development of sustainable production systems has revealed that production stability and sustainability, and not just productivity, must be taken into consideration. In agricultural systems, sustainability can be considered maintenance of production over time, without degradation of the natural base upon which that production is dependent (CARVALHO et al., 2009).

The primary aim of the ABC Plan is the adoption of low man-made GHG emission strategies and specific action for adaptation to climate change. However, technologies cited in the ABC Plan, such as RDP, CLFI, BFN, DSS and planted forests, have great potential to make agriculture more resilient to climate change, providing numerous benefits for the production system (Box 2), contributing to increased productivity and net income for the farmer, and creating jobs in rural areas. Various actions are already being implemented within the scope of the ABC Plan. In Planaveg, on the other hand, most forest restoration programs are still in the planning phase, except for some pilot activities that are aimed at large-scale planting of native species, with the potential to multiply business opportunities and create jobs in rural areas.

Box 2 | **Main benefits of the different actions of the ABC Plan, as a strategy for adaptation to climate change.**

- Reduces
  - variation in temperature;
  - evaporation;
  - transpiration;
  - impact of extreme climate events;
  - damage from flooding;
  - erosion caused by high winds;
  - damage from high temperatures;
  - need for fertilizers.
- Favors the infiltration and storage of soil water.
- Improves the quality of water and the soil.
- Increases biodiversity.
- Aids
  - in the control of pests and diseases;
  - in the maintenance of pollinators;
  - in the maintenance of land for future generations.

BENEFITS OF ADAPTATION – PART 1: SYSTEMS WITH TREES

The benefits of the actions of the ABC Plan and Planaveg (Figure 3), whose objective is the adaptation of Brazilian agriculture to climate change, will be discussed in two parts, with a view to differentiating the actions that involve tree strata from the others. It is important to note that: i) despite the term "forest" adopted in the integrated systems that include trees, these systems also apply to natural biomes that do not include forests; ii) in the restoration of pastures, silvipastoral or agro-silvipastoral practices can be adopted, as will be discussed in the actions that do not involve trees; and iii) actions concerning biological fixation of nitrogen and treatment of animal waste will not be discussed because they are not actions directly related to adaptation.

In Part 1, we will discuss crop-livestock-forest integration (CLFI), agroforestry systems (AFS), crop-forest integration (CFI), livestock-forest integration (LFI), planted forests, which are actions of the ABC Plan, and recovery of native vegetation and degraded areas, actions of Planaveg. In Part 2, we will discuss crop-livestock integration (CLI), the no-till (NT) systems and restoration of degraded pastures (RDP), all actions of the ABC Plan. These actions provide benefits to Brazilian cattle farming and society.

Benefits of Crop-Livestock-Forest Integration (CLFI)

The CLFI system is considered the most complex, but it is, nevertheless, recommended for any level of production, using intercropping, succession or rotation cultivation. It is a system that provides various benefits and the area occupied by CLFI increases every year. In fact, VIEIRA FILHO (2018), based on a survey conducted by CLFI Network ("Rede ILPF"), indicates that in Brazil over 1 million hectares employed CLFI for the 2015-2016 harvest.

This system combines, on the same area, different production systems, such as those for grains, fibers, meat, milk and agro-energy from biomass. In this manner, it allows for a diversification of economic activities on the farm and minimizes risks of losses caused by climate events or by a fall in market prices. In CLFI systems, there is a complementarity and synergy between the biotic and abiotic components (BALBINO et al., 2011).

Figure 4 shows the expected effects on local climate, extreme events, soils, biological factors and on socioeconomic factors, because of the adoption of CLFI. It is estimated that CLFI provides positive effects on all the factors considered. Table 1 summarizes, based on the results obtained by the study, the effects of CLFI systems on local climate, environment and farm, for crop and livestock farming.

Figure 3 | **Agriculture production systems supported by actions contained in the ABC Plan and Planaveg and discussed in this work.**

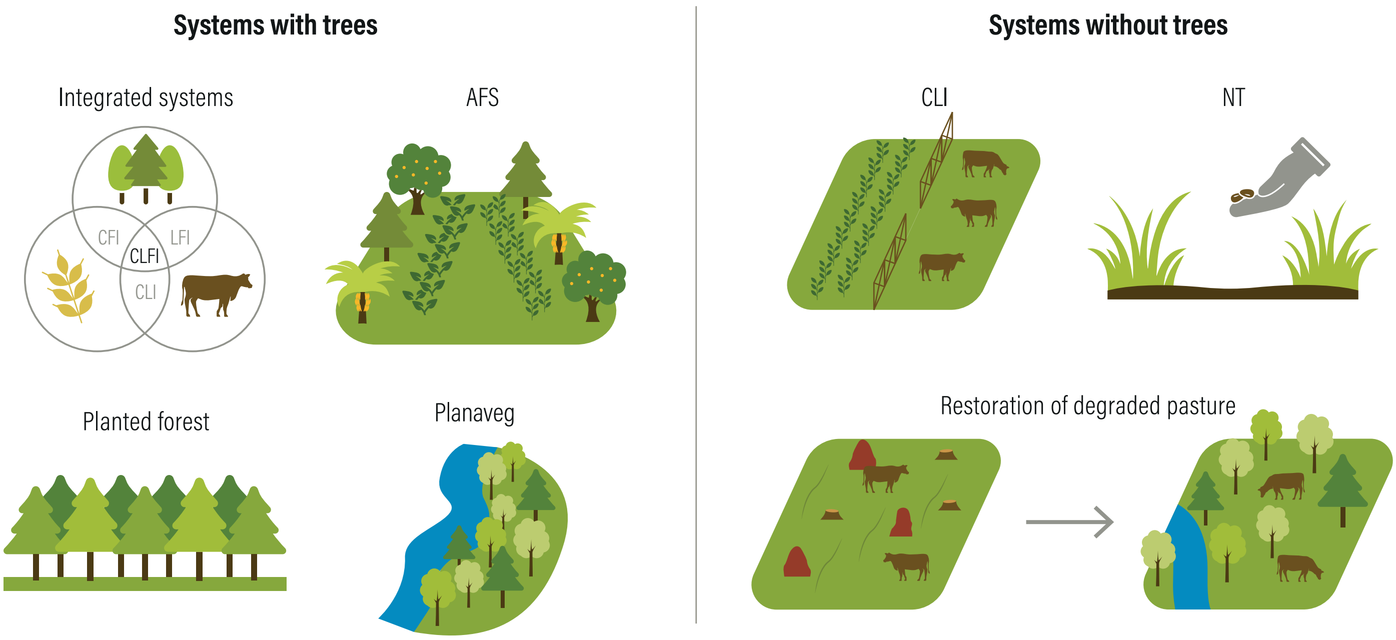


Figure 4 | **Impacts of actions of the ABC PLAN by integrated systems with trees (CLFI or crop-livestock-forest integration, CFI or crop-forest integration and LFI or livestock-forest integration) and effects on the capacity for adaptation to climate change.**

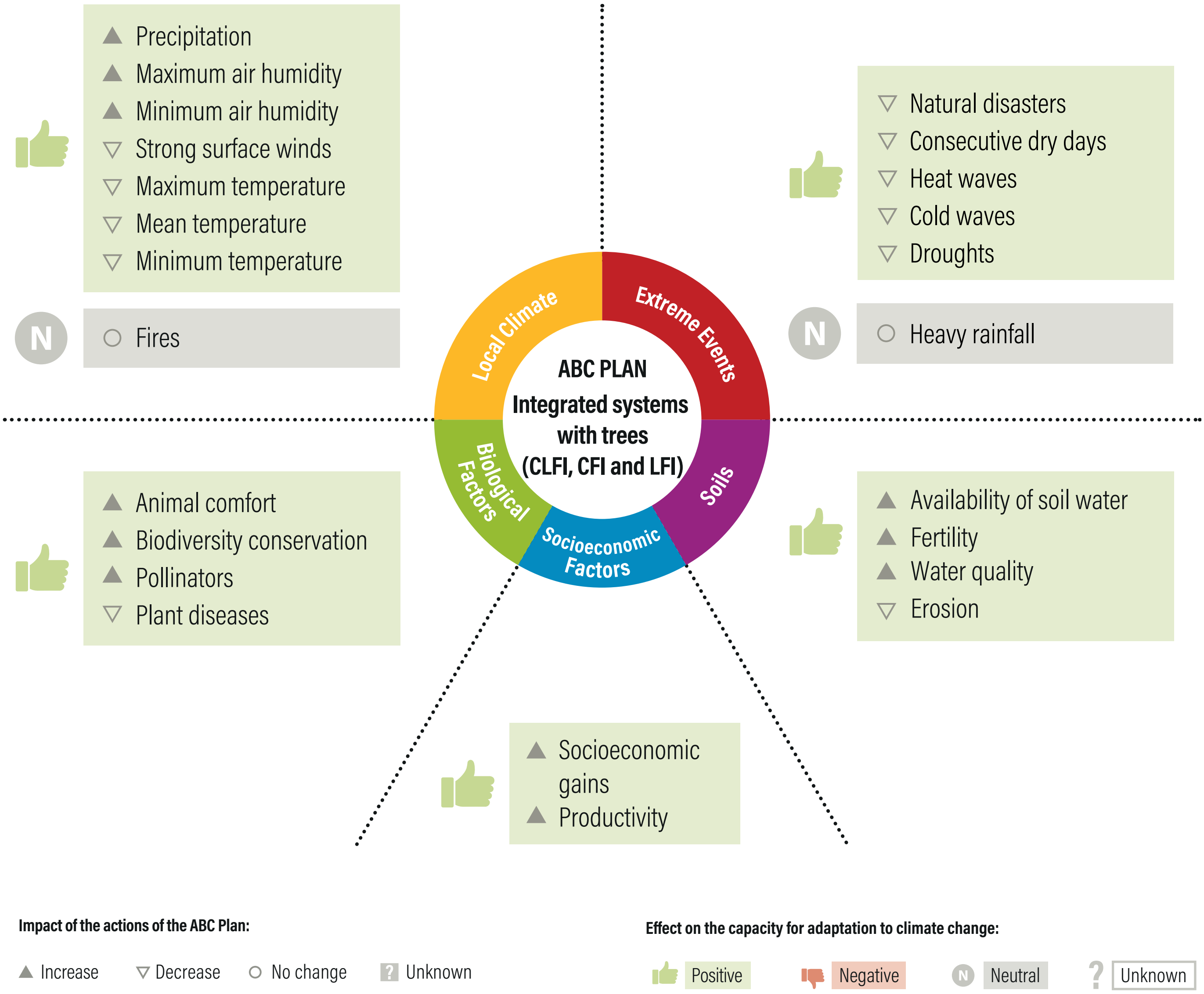


Table 1 | **Benefits of the crop-livestock-forest integrated (CLFI) system, as a strategy for adaptation and resilience to climate change, for the local climate, for the agriculture enterprise and the environment, for agriculture and livestock farming.**

LOCAL CLIMATE	ENTERPRISE/ENVIRONMENT
Provides greater adaptation and resilience to climate change Provides more amenable temperatures Provides less exposure to direct sunlight and/or high temperatures Increases humidity in air and soil Presence of trees protect against frost, winds, hail, storms and high temperatures Expands the positive balance of energy	Generates products such as firewood, fruit and forage Increases and stabilizes revenue for farmer Avoids deforestation of new areas and increases the land sparing effect Reduces seasonality of manual labor on property Reduces the silting of watercourses Improves the recharge and quality of water Promotes biodiversity Favors new niches and habitats for pollinators and natural enemies of insects-pests and disease pathogens.
AGRICULTURE	**LIVESTOCK**
Reduces productivity losses due to dry spells Increases recycling and reduces loss of nutrients, reducing the need for fertilizers Increases organic matter in the soil (carbon sequestration) due to the accumulation of forage and forest biomass Increases the activity of microbes Increases the infiltration and retention of soil water Forest component reduces incidence of winds (windbreaks) and reduces toppling of plants, spread of diseases and drift during the application of pesticides Optimizes the use of machinery and equipment Maintains the soil covered for longer, reducing risks of surface erosion	Improves animal comfort due to the shade created by trees Shading of trees creates thermal comfort zones Improves the quality and productivity of pastures Increases the occupation rate of pastures Increases weight gain Reduces the slaughter age for beef cattle In dairy farming, increases milk production, since it reduces heat stress

Source: BALBINO *et al.*, 2011; MAGALHÃES *et al.*, 2018a, 2018b; MALERBO-SOUZA *et al.*, 2003; MOSIMANN *et al.*, 2017; OLIVEIRA *et al.*, 2010; RODRIGUES *et al.*, 2017; SILVA *et al.*, 2009; VIEIRA FILHO, 2018.

However, CLFI has some disadvantages, particularly an increase in competition between plant species and the mechanical damage incurred during harvest or crop treatment on some components (OLIVEIRA et al., 2010). A disorganized distribution of the tree component can hinder the use of machinery and harm could be caused by animals because of trampling, which can compact the soil.

It is important to note also that the implementation of the CLFI system requires specialist monitoring and training and represents a significant change in the practice of the traditional farmer. One of the assumptions of CLFI is promoting synergy between activities and, therefore, it is likely that few producers have the capacity to make long-term plans without the necessary technical assistance (ALVARENGA; GONTIJO NETO, 2012).

Benefits of the Agroforestry Systems (AFS)

The term AFS is, at times, used to group any and all integrated production systems that optimize land use and promote environmental and socioeconomic sustainability. In this approach, agroforestry systems encompass anything from traditional rotation agriculture, such as forest rest, to commercial arrangements, such as CLFI (SCHEMBERGUE et al., 2017).

In this Working Paper, the term AFS will be used in the strict sense, according to Becker (2010) and Castro et al. (2009), which is "a system that uses a large diversity of plants, managed to serve the vital needs of the community (food, health, clothing and construction of houses and shelters) and that involves itinerant cultivation, traditional systems open to the market and intercropping of perennial trees, bushes and palms". In various regions, poor farmers are adopting AFS as a way of adapting to the impacts of climate change (RIZVI et al., 2015).

AFS were revived from ancient cultures and have expanded to practically every region, serving evolving needs in land use in developing countries, especially in tropical regions, with the integration of agricultural crops and forests (DANIEL et al., 1999). These are management systems of natural or exotic resources that maintain the ecological system and forest structure (BECKER, 2010) with annual or perennial crops.

In landscapes in which native vegetation is very fragmented, AFS play an important role and their environmental benefits are: provide habitats to species that tolerate a certain level of disturbance; contribute to reducing rates of natural habitat conversion due to lower pressure for use as farmland; support the integrity of forest remnants, serving as ecological corridors or buffer zones; and provide ecosystem services, such as carbon sequestration, better air, water and soil quality, and conservation of biodiversity (MARTINS, 2013).

AFS are used by farmers to adapt to climate change, considering, temperature and precipitation primarily (SCHEMBERGUE et al., 2017; TSCHARTNTKE et al., 2011). In Brazil, the adoption of AFS in municipalities with lower average rainfall shows that farmers consider it a strategy to adapt to the changes in climate that harm agricultural productivity (SCHEMBERGUE et al., 2017).

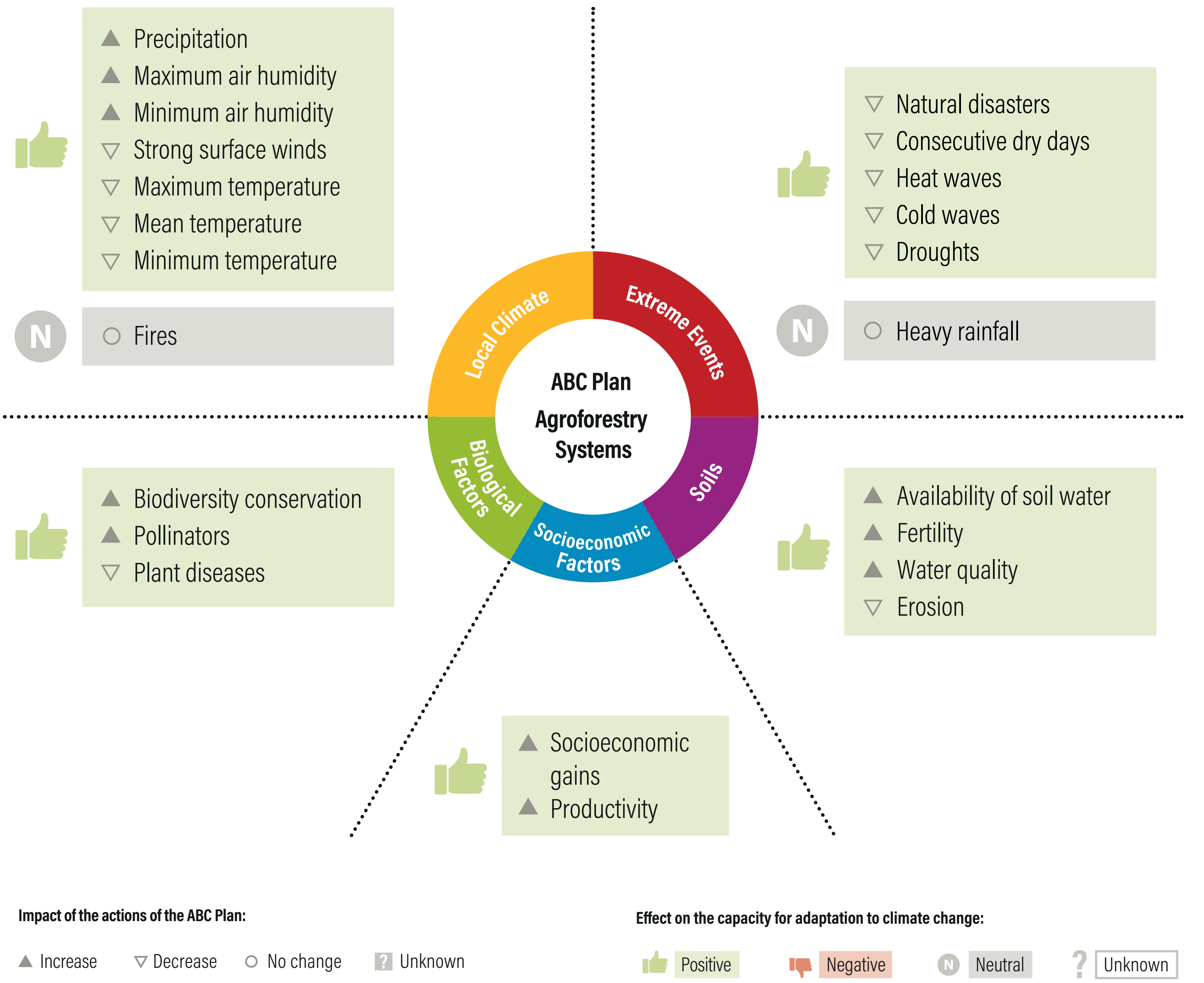
The shade of trees that compose AFS provides a favorable microclimate for crop development, by reducing the incidence of solar energy, air temperature, wind and evapotranspiration, because of its structure resembling that of a forest (TSCHARTNTKE et al., 2011). AFS also contribute social and economic value, since they reduce the vulnerability of families to climate stress, pest outbreaks, falling prices and food insecurity (TSCHARTNTKE et al., 2011).

Figure 5 shows the expected effects on local climate, extreme events, soils, biological factors and on socioeconomic factors, because of the adoption of AFS. It is estimated that AFS provide positive effects on all the factors considered, proving to be an important strategy to adapt to climate change.

In Africa, studies on the use of AFS highlight their potential to moderate high temperatures, as well as to counter annual climate fluctuations, thus creating a more suitable microclimate for the development and productivity of crops (MBOW et al., 2014a; 2014b). These characteristics show the high potential for AFS to contribute to food security and adaptation to the effects of climate change. AFS may be a win-win solution for Africa, with the potential to control erosion, increase soil fertility, biodiversity and the efficient use of water, and reduce the impacts of extreme climate events, although the success of AFS as an adaptation strategy depends on integrated, efficient management (MBOW et al., 2014b).

In Brazil, AFS are particularly numerous in Pará, Acre, Minas Gerais, Mato Grosso, in the South and the Northeast, possibly due to the effectiveness of the system in maintaining water and regenerating soil fertility (SCHEMBERGUE et al., 2017).

Figure 5 | **Impacts of actions of the ABC Plan by agroforestry systems (AFS) and effects on the capacity for adaptation to climate change.**



Benefits of Crop-Forest Integration (CFI)

The CFI system involves an intercropping of tree species, native or exotic, with annual or perennial crops (BALBINO et al., 2011).

A prominent example of CFI is the coffee crop, in which the planting of trees is of great importance. Studies show the influence of increasing temperatures on the productivity of coffee, causing effects such as flower abortion and reduced productivity (ASSAD et al., 2004; ZULLO JÚNIOR et al., 2006).

Compared to coffee planted in the full sun, coffee planted with 30% of the area occupied by macadamia received 29.4% less solar radiation and reduced air temperature of 0.6°C in the crop's microclimate, reducing the risk of flower abortion (COLTRI, 2012). In Paraná, the introduction of silky oak on coffee plantations increased profitability by up to 32% (SANTOS et al., 2000). In both cases, the main environmental benefits are the action of pollinators, the conservation of water and thermoregulation, which prevents heat waves and extreme cold.

Benefits of Livestock-Forest Integration (LFI)

The LFI system (either silvipastoral system or arborization of pastures) is a type of integrated system in which the production of forage plants and the raising of animals is integrated with trees, simultaneously or sequentially, in the same unit of area. It is vital to use forest and forage species that are suitable for the production environment (PORFÍRIO-DA-SILVA et al., 2009). In Brazil, LFI systems predominantly use exotic trees, primarily eucalyptus. But the type of tree and the spacing between them are important factors that can influence the expected benefits, such as strategy of adaptation and resilience to climate change (Table 2). LFI with less dense eucalyptus and dispersed native trees provides the best thermal comfort compared to the system with dense eucalyptus; the greater the spacing between the rows of trees and the lower density allows for better wind circulation, reduced air temperature and increased relative humidity in the shade, favoring animal well-being (KARVATTE JÚNIOR et al., 2016).

In livestock farming, the weight gain of livestock and productivity observed in CLFI and LFI systems, due to the provision of shade, have contributed to the dissemination of information about the relevance of integrated systems (IS) to climate change adaptation. However, it is necessary to overcome the speculation that still exists in the field against technology based on integrated systems. Some studies point to livestock farming profiting significantly from the adoption of these technologies, but the potential rates of return must be clearly shown. It is necessary to expand and disseminate results to show that these systems protect production from the climate change that is already occurring and that will inevitably continue to occur, providing sustainability as a result of increased hardiness. It is also important to adjust technologies to the different producer and management profiles.

Benefits of Planted Forests

The production of planted forests (native and exotic) is supported by the ABC Plan and allows their economic exploitation on rural properties. Planted forests produce numerous environmental benefits and are a source of long-term income for agriculture-dependent families, since they increase the supply of wood for industrial (cellulose and paper, furniture and wood panels) and energy purposes (charcoal and firewood), provide materials for construction, reduce pressure on native forests, and capture CO_2 from the atmosphere, thus mitigating climate change.

Currently, Brazil has 9.86 million hectares of planted forests, and the most important species are eucalyptus, which occupies 75% of the area, and pine, 21%. Rubber trees, acacia, teak, parica and pine are among the other species planted (IBGE, 2018). Of the total area planted, 29% are small independent farm owners and medium-sized producers, who invest in forest planting for the sale of *in natura* wood through out grower schemes. These forest plantations reduce pressure on native forests and show clear potential for adapting crops to climate change.

It is important to note that a large part of industrial forestry was created before the ABC Plan, which was established in 2011. In fact, in 2011 the area planted with eucalyptus was a little under 5 million hectares (IBÁ, 2018), as compared to 7.4 million in 2017 (IBGE, 2018). In the ABC Plan, the line of credit for planted forests turned over less than 6% of the resources in the 2015/2016 harvest and 6.4% in the 2017/2018 harvest (FREITAS, 2018). It is necessary to encourage the implementation of forest and perennial crops, increase their scale and promote reforestation with native species and agroforestry systems, as economically viable short-term solutions for mitigation and adaptation to climate change (BATISTA et al., 2017).

Forest plantations contribute to reducing surface water runoff and, consequently, water erosion and increase the amount of organic material and porosity of the soil. When managed appropriately, commercial forest plantations present soil loss through water erosion within acceptable limits (EMBRAPA FLORESTAS, 2015).

Table 2 | **Benefits of the livestock-forest integration (LFI) system, as a strategy for adaptation and resilience to climate change, for the local climate, for the agriculture enterprise and the environment, for agriculture and livestock farming.**

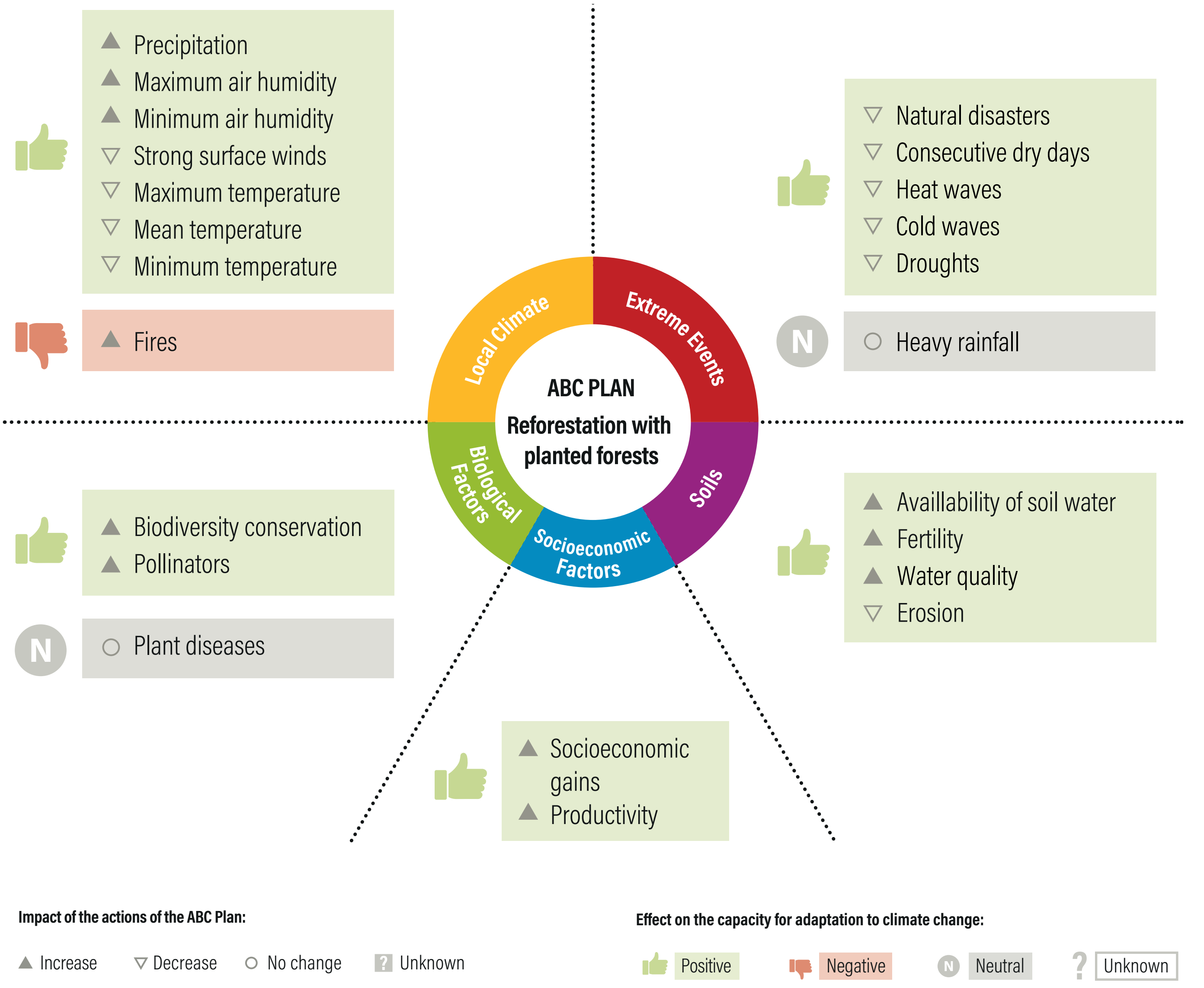
LOCAL CLIMATE	ENTERPRISE AND ENVIRONMENT	LIVESTOCK
Trees modify the microclimate of the pasture	Increases the income of the enterprise with forest products, such as firewood, posts, chips and logs	Improves the fertility of the pasture
They reduce the incidence of solar radiation	Increases the conservation of the soil and water and reduces the intensity of erosion, particularly when planted at countour	Increases biomass and the nutritional value of forage
They provide more amenable temperatures, higher humidity and lower rates of plant evapotranspiration.	Increases the provision of ecosystem services and the biological activity of the soil	Increases the rate of occupation of pastures and reduces the frequency of pasture rehabilitation
They protect against frost, winds, hail, storms and high temperatures		Increases the comfort and protection of animals and pastures and improves animal performance

Source: KARVATTE JÚNIOR *et al.*, 2016; LAVELLE *et al.*, 2006; PACIULLO *et al.*, 2011; PORFÍRIO-DA-SILVA *et al.*, 2009; SILVA *et al.*, 2015.

Commercial forest plantations lead to an accentuated reduction in biodiversity but can also function as refuge for some native species and as facilitators in the ecological restoration of native forests (VIANI et al., 2010).

Figure 6 shows the expected effects on local climate, extreme events, soils, biological factors and on socio-economic factors, because of the adoption of planted forests. It is estimated that planted forests provide positive effects on practically all factors considered, except for fire risk, which can be increased in some scenarios. In fact, forest stands, primarily pine and eucalyptus, are implemented in a dense manner, with low diversity in the shrub and tree strata, in which the propagation of fire occurs very quickly. Water capture installations and observation towers need to be installed, as well as a road system with signs and strategically placed fire equipment distributed throughout the forest enterprise. In addition, fire risk zoning should be established as a fire mitigation strategy.

Figure 6 | **Impacts of actions of the ABC Plan by planted forests and effects on the capacity for adaptation to climate change.**



Benefits of Restoration of Native Vegetation and Degraded Areas

The main benefits of revegetation with native species and mixed planting of trees are the generation of a favorable microclimate, protection of springs and riverbanks, protection and increase of pollinators, reduction in incidence of pests, increase in the availability of soil water and a reduction in soil erosion (Figure 7). Stingless bees, one of the many benefits of this action (Table 3), are crucial to the ecosystem, due to their effectiveness as pollinators.

The Forest Code in force offers three ways legal reserve deforested before July 2008 can comply with legal requirements: recompositing, natural regeneration, and/or compensation (BRASIL, 2012b). However, if deforestation occurred after July 2008, compensation is not an option.

Figure 7 | **Impacts of actions of Planaveg by the recovery of native vegetation and degradades lands and effects on the capacity for adaptation to climate change.**

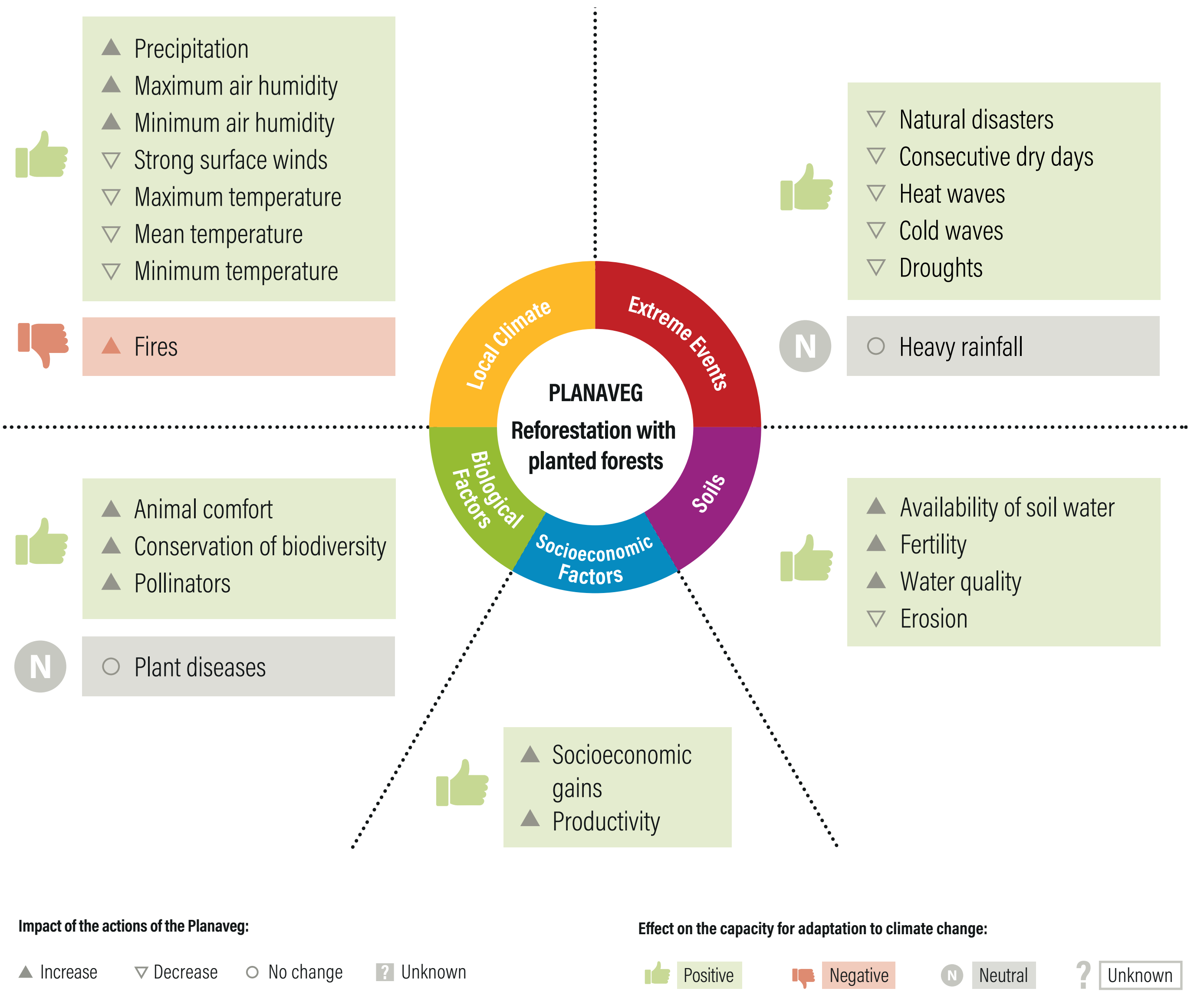


Table 3 | **Benefits from the recovery of native vegetation in permanent preservation areas, legal reserve and degraded areas.**

LOCAL CLIMATE/ENVIRONMENT	AGRICULTURE AND LIVESTOCK
Revegetation and preservation of LR and PP areas	
Contributes to the stability of local climate	Increases the availability of soil water
Ensures air quality	Increases the fertility of the soil
Serves as a physical barrier to wind	Increases the agricultural productivity of adjacent areas due to the presence of pollinators and natural enemies of pests and organisms that spread diseases
Contributes to the conservation of soil, water resources and biodiversity	Ensures thermal comfort for animals in adjacent pastures
Maintains natural enemies for the control of pests and diseases, due to its high diversity of plants, animals and microorganisms	Ensures animal watering, because it is a source of water for drinking holes
Provides shelter and food for animals that pollinate and spread seeds of native species of economic and/or ecological importance	Increases income in the production system
Recovery of degraded areas	
Regulates local climate	Reestablishes nutrient cycle processes
Conserves water resources	Benefits pollinators and natural enemies of pests and diseases
Conserves biodiversity	

Source: CHIARI *et al.*, 2005, 2008; CUNHA *et al.*, 2003; GIANNINI *et al.*, 2015, 2017; KLEIN *et al.*, 2007; MALERBO-SOUZA *et al.*, 2003; MANGABEIRA, 2010; MILFONT *et al.*, 2013; RODRIGUES *et al.*, 2017; SCARAMUZZA *et al.*, 2016.

The size of the degraded area occupied by annual and permanent crops in Brazil is unknown. These areas present low productivity, whether due to low agricultural potential, incorrect soil management or using inappropriate species or cultivars for the particular environment. Usually, the recovery of these areas is done through the adoption of mechanical practices, application of inputs and correctives and with the introduction of appropriate species or cultivars. It is estimated that the liability of permanent preservation and legal reserve areas that need restoration or compensation is 21 million hectares (SOARES FILHO et al., 2014), concentrated on the southern border of the Amazon and almost the entirety of the Atlantic Forest and Cerrado.

Predominant actions aimed at the restoration of native vegetation and degraded areas include the use of exotic species, primarily eucalyptus and pine. On the other hand, there is growth in the use of silviculture of native species, such as brazilwood, cedar, acacia, peroba rosa, jequitiba, and Brazilian mahogany among others, which are promising strategies for the production of hardwood and an alternative to illegal deforestation for the extraction of wood. In this case, the Verena Project[3] stands out. Since 2015, the project has been systematizing knowledge on reforestation with native species for economic use and disseminating technical and economic information to expand forest cover in degraded areas, with a view to promote a low-carbon economy for adaptation to climate change.

In the silviculture of native species, different management systems can be adopted, anything from no-till to integrated systems. Some projects, such as Amata, Fazenda da Toca, TNC Cacau Floresta and others, are already in development in Brazil, and working toward large-scale planting of native species, which can multiply business opportunities and create jobs in rural areas (BATISTA et al., 2017).

Embrapa and the Secretariat of Extractivism and Sustainable Rural Development of the Ministry of the Environment, in cooperation with various specialists from different institutions, developed WebAmbiente[4], a database of 782 native plant species with solutions for environmental recovery in every Brazilian biome, which aids decision-making in the process of environmental compliance of the rural landscape.

A technology designed to promote rural landscape compliance along with financial gains is the introduction of AFS for environmental restoration, through production systems based on ecological succession that is analogous to natural ecosystems. In these systems, exotic or native trees are combined with crops, vines, forage plants and shrubs, according to a pre-established spatial and temporal arrangements, with high diversity of species and interactions between them (EMBRAPA, n.d.).

In livestock production systems, whether integrated or not, the legal reserve provides important benefits. It conserves soil, water resources and biodiversity; maintains populations of species that control pests and diseases, due to its high diversity of plants, animals and microorganisms; provides shelter and food for animals that pollinate and spread seeds of economically and/or ecologically important native species; and plays an important role in the mitigation of GHGs (BRANCALION et al., 2012).

Permanent preservation areas are fundamental in any agricultural system mainly in crop and livestock farming. In addition to the benefits of the conservation of soil, water and biodiversity, the permanent preservation areas provide water (extracted from watering holes) for livestock. It is fundamental that watercourses are isolated and cannot be accessed by animals to prevent trampling of river borders and contamination by animal waste (PEREIRA et al., 2017).

The presence of pollinators provides an increase in crop productivity. They play an important functional role in most terrestrial ecosystems and represent a vital ecosystem service for agricultural productivity (POTTS et al., 2010). In a tropical environment, 94% of flowering plants depend on pollinators (OLLERTON et al., 2011).

There are vertebrate (birds, bats, small mammals and reptiles) and invertebrates (various species of insects such as bees, beetles, butterflies, moths, flies, wasps, etc.) pollinators; bees visit 90% of agricultural crops, flies 30% and vertebrates around 6% (IMPERATRIZ-FONSECA; JOLY, 2017). Pollinators are important for different crops, such as beetles in the production of dendê fruit; different types of bees (stingless, honey, wild, etc.) in the production of açaí, alfalfa, cotton, coffee, coconuts, guaraná, apples, passionfruit, papaya, pears and soybeans, etc.; in addition to bees in greenhouses for the cultivation of eggplants, melons, watermelons, strawberries, cucumbers, peppers and tomatoes (FREITAS; BONFIM, 2017).

The maintenance of an area with native vegetation on agricultural properties ensures production (IMPERATRIZ-FONSECA; SILVA, 2010). In Brazil, the total value of the production of 44 crops in 2013 (for which there was knowledge both of the dependence and the production value for that year) was approximately US$45 billion and the economic value of the pollination obtained for these 44 crops during the same period was approximately US$12 billion, or almost 30% of the total value (GIANNINI et al., 2015). Of the 141 species of plants cultivated in Brazil—for human consumption, animal production, biodiesel and fibers—approximately 60% (85 species) depend on a certain degree of pollination (GIANNINI et al., 2015).

Native vegetation remnants are also important repositories of native species that control agricultural pests because they offer shelter, food and places for reproduction and nesting for these organisms. The management of the structure of the agricultural landscape, with the maintenance of natural vegetation areas adjacent to crops is an important factor to be considered in the development of ecological management programs for pests (MURTA et al., 2008), and also as an economically viable alternative since there is no need to spend on the importation, raising and release of natural enemies.

BENEFITS OF ADAPTATION – PART 2: SYSTEMS WITHOUT TREES

Benefits of Crop-Livestock Integration

The Crop Livestock Integration systems (CLI) are structured according to the profiles and objectives of the farm, and based on peculiarities of the region, such as climate and soil conditions, infrastructure, experience of the farmer and availability of technology (VILELA et al., 2011). In the 2015-2016 harvest, Brazil had 9.5 million hectares with CLI (VIEIRA FILHO, 2018). These systems have higher performance on both yield and revenues compared with one-crop or stand-alone systems, in agriculture and livestock farming (continuous or rotational grazing). Environmental benefits are also higher, improving pollinators biodiversity and soil protection (VIEIRA FILHO, 2018).

In the Central-West and Southeast regions of Brazil, three types of integration are generally observed: i) in livestock farms, grain crops (rice, soy beans, corn and sorghum) are introduced in pasturelands to restore the productivity of the grass; ii) in farms specializing in grain crops, forage grasses are introduced to improve soil coverage in no-till systems and, during the fallow, use of forage in the diet of cattle (double-crop system);

and iii) in farms that, systematically, adopt CLI to intensify the use of land and benefit from the synergy between the two activities (VILELA et al., 2011).

In southern Brazil, the areas that, in summer, are generally planted with corn, beans, soybeans or rice, are used for animal production in the winter, on annual pastures, with primarily oats, ryegrass, wheat or rye (MORAES et al., 2011).

Figure 8 shows the expected effects on soils, biological and on socioeconomic factors, as consequence of the adoption of CLI. Note that these systems are not expected to provide significant adaptation effects in minimum air humidity, the occurrence of strong winds, precipitation, minimum temperature and on the incidence of cold waves, events expected in the climate change currently underway. On the other the absence of trees in the CLI system means that the conservation of biodiversity and the action of pollinators depend on the size of the area and the distance from areas with native vegetation. Table 4 summarizes, based on the results obtained by the study, the effects of CLI systems on the environment of the farm for crop and livestock farming.

Figure 8 | **Impacts of actions of the ABC Plan by crop-livestock integration (CLI) systems and effects on the capacity for adaptation to climate change.**

Table 4 | **Benefits of the crop-livestock integration (CLI) system, as a strategy for adaptation and resilience to climate change, for the local climate and the agriculture enterprise, for agriculture and livestock farming, compared to monoculture systems.**

LOCAL CLIMATE / ENTERPRISE	AGRICULTURE	LIVESTOCK
Provides greater agricultural production and fewer greenhouse gas emissions per unit of human-digestible protein Increases resilience to climate change (both in terms of productivity and financial return) Contributes to the rehabilitation of soil quality (chemical, physical and biological) Provides agricultural products from the summer harvest and autumn grazing—winter for annual pastures Provides greater sustainability to agriculture production Generates more frequent cash flow for the farmer	Breaks the cycle of pests and diseases Increases organic matter content of the soil Increases and improves the development of soil microbiota Increases the cycling of nutrients Has potential to sequester and accumulate CO_2 in the soil, due to the high production of dry material on the surface and in the soil Increases the diversity of macro and microbiota in the soil Improves the control of invasive species In soils in the Pampa biome, it increases porosity and reduces the density of the soil	Increases the stability of production of forage to feed the herd throughout the year Increases the productivity of pastures by improving the fertility of the soil through use of crops Higher weight gain in rearing calves with a combination of Tanzania grass and corn Higher weight gain in the transition from dry season to wet season in the Cerrado

Source: CARVALHO *et al.*, 2016; DOMICIANO, 2016; GIL *et al.*, 2018; MARCHÃO *et al.*, 2009; MIRANDA *et al.*, 2005; MORAES *et al.*, 2011; TRACY; ZHANG, 2008; VILELA *et al.*, 2011.

Benefits of the No-till System

No-till (NT) incentives are part of the ABC Plan that has been strongly adopted by farmers. Out Of the R$1.361 billion contracted by the ABC Plan for the 2017/2018 harvest, 38% was for the no-till systems, through a little over 1,000 contracts with an average value of R$518,019.38 (FREITAS, 2018). Organic material is transformed into rich natural fertilizer, and the decomposed straw from the previous harvests is converted into fertilizer for the soil. Its advantages are a reduction in the use of chemical inputs and the control of erosion, since the permanent coverage of the soil slows runoff. In the NT system, straw protects the surface, favoring the infiltration of water through a change in the porosity geometry of the soil, reduces variations in temperature, due to an increase in the solar radiation reflection ratio (albedo), and reduces the evaporation of water from the soil (SALTON et al., 1998).

A consolidated and well-balanced NT system is terms of soil fertility and the use of cultivars and varieties that have high root growth potential can mitigate the effects of a moderate reduction in precipitation and drought spells. Even though the increase in air temperature reduces productivity, the deepening of the root system and the use of straw on the surface of the soil can partially attenuate this effect (REDIN et al, 2016).

Because it presents a greater number of significant interactions, deeper root systems have shown to be more effective than straw at mitigating the effects of temperature. An increase in the concentration of CO_2 favored the productivity of corn, but the increase did not exceed 13.51%; however, this was expected, since corn is a C4 plant, which presents greater photosynthetic efficiency (COSTA et al., 2009).

A study conducted in the states of Rio de Janeiro, Minas Gerais, Paraná and Distrito Federal concluded that the use of NT systems had a positive environmental impact, particularly in improving the quality of the soil and the water and reducing the use of agrochemicals (LIMA et al., 2014).

MAGALHÃES (2017) evaluated the effects of climate change on locations (rural properties and experimental stations) in 10 municipalities in Minas Gerais by modeling of historical series of climate data, concluding there was an increase in the average yield of grains due to the increase in the concentration of CO_2 in the atmosphere. An increase in solar radiation also tended to favor an increase in productivity. The depth of the root system and the amount of straw on the surface of the soil, which presented significant interaction with variations in solar radiation (MAGALHÃES, 2017), indicate that NT systems could be employed as a strategy for adaptation to climate change.

Figure 9 shows the expected effects on local climate, extreme events, soils, biological factors and on socioeconomic factors, as consequence of the adoption of no-till systems. It is estimated that NT systems provide positive effects, primarily, in the adaptation to increases predicted in maximum and mean temperatures, and in maximum humidity.

Regarding extreme effects, the consequences may be positive on droughts and dry days without rain, since straw, if well managed, conserves humidity in the soil for longer periods of time. For soils, a positive effect is expected in the control of erosion, and the availability of water and on fertility. For the other factors, no changes are expected, or the effects are unknown.

Figure 9 | **Impacts of actions of the ABC Plan by no-till (NT) systems and effects on the capacity for adaptation to climate change.**

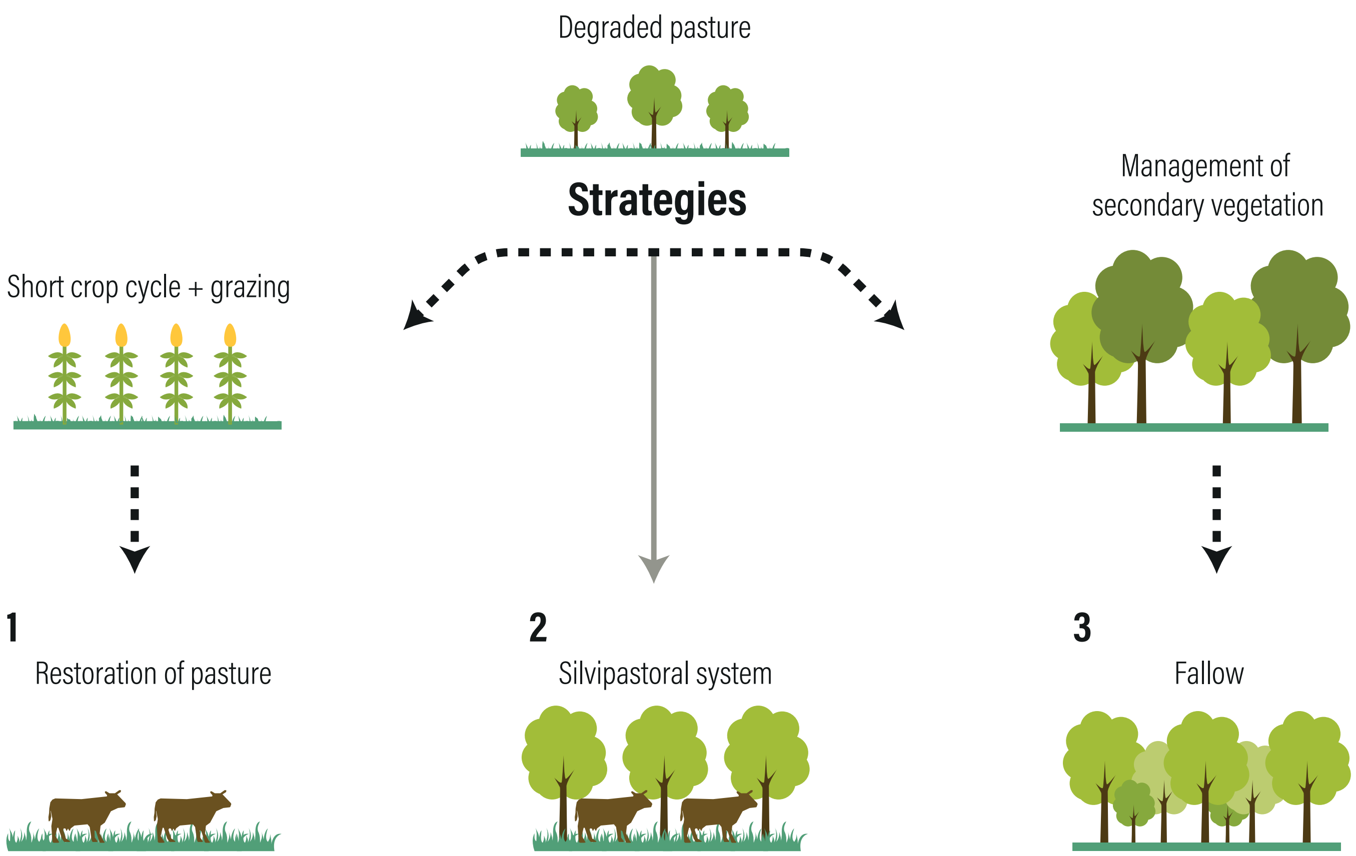
Benefits of the Restoration of Degraded Pastures (RDP)

The technology that receives the highest demand for financing from the ABC Plan is the restoration of pastures. Of the 3,812 contracts for the 2017/2018 harvest, 2,367 were for RDP, with an average value of R$280,000, representing over 48% of the available resources (FREITAS, 2018). Restoring pastures in a traditional way, in other words, by using fertilizers, lime and urea, is not enough to ensure the sustainability of the system since further applications will be necessary by each 4 or 5 years (MACEDO et al., 2000; VILELA et al., 1998).

In Brazil, a large part of the degraded areas is occupied by degraded pastures. The degradation of pastures is characterized by loss of vigor, productivity and capacity for natural recovery of the forage plants that sustain levels of production and quality required by the animals. Of the 169.7 million hectares of pasture (data from 2018), approximately 63.7 million hectares present signs of some stage of degradation (LAPIG, 2019). In the ABC Plan, the aim is to restore 15 million hectares of degraded pastures. These areas are present throughout Brazil, especially in regions on the agricultural frontier (DIAS-FILHO, 2015).

There are several strategies to restore and recover pastures, some involving intermediary stages (Figure 10). In the ABC Plan, common demands include restoration (reestablishment of production, through fertilization and soil correction, without mechanized preparation of the area and without change in forage) and renovation or reform (MACEDO et al., 2000). Renovation and reform can be direct—with replanting of forage plants or the introduction of a new species or cultivars, replacing what is degraded—or indirect, with the formation of pasture integrated with crops (CLI), forest (LFI) or crops and forest (CLFI) (DIAS-FILHO, 2017).

Figure 10 | **Strategies for recovery degraded pastures.**



Source: Adapted from Dias-Filho et al., 2005.

These practices were improved as climate conditions began to reduce the resilience of the pasture and as restoration became increasingly expensive. With increasing demands for adaptation to climate change, primarily due to water deficiency, various species of genetically improved forage plants have been placed on the market, providing important gains to Brazilian livestock grazing and increasing the resilience of tropical pastures. Among the grass cultivars that, directly or indirectly, are best adapted to climate effects, for the various regions of Brazil, we highlight Tobiatã, Centenario, Centauro, Aruana, Vencedor, Tanzania, Mombasa, Massai, Milenio (all of the genus *Panicum*) and Marandu, Iapar 65, Xaraés and Piatã (of the genus *Urochloa*).

Embrapa has made available a search tool to support decision-making[5], based on the construction of scenarios that simulate climate conditions and actual production in the medium (2025) and long (2055) term, for the cultivation of five forage plants (palisade, Tanzania and buffel grasses, prickly pear and annual ryegrass). The grasses Paiaguás and Mombasa are the main forage grasses adapted to current conditions, since they enable weight gain for livestock and increase the resilience of pastures.

The restoration of almost 63.7 million hectares of pastures that are in some stage of degradation (LAPIG, 2019) will provide numerous benefits, but require an important change in Brazilian cattle farming. Production must be intensified, in search of faster weight gains and increases in pasture biomass. In other words, the modern livestock farmer needs to be a producer of pasture. Unfortunately, this is still not the case for most of the livestock farmers in Brazil, primarily in the Amazon region, where oftentimes the producer is more interested in ensuring ownership of the land than achieving gains in productivity. In this way, he uses an extensive management system that is cheaper and less efficient. In fact, data from TerraClass Amazônia (INPE et al., 2014) indicates that, of the 47 million hectares of pastures in the region, at least 10 million are degraded or abandoned and 17 million hectares are considered secondary vegetation or undergoing regeneration, with little or no production technology.

Figure 11 shows the expected effects on local climate, extreme events, soils, biological factors and on socioeconomic factors, as consequence of the restoration of degraded pastures (RDP). It is estimated that RDP provides positive effects on maximum and mean temperatures, maximum air humidity, resistance to heat waves, to drought and consecutive dry days and on the occurrence of natural disasters. Its effects on soils are also positive, both in the control of erosion, and in the availability of water and fertility. Table 5 summarizes, based on results obtained by the study, the effects of the restoration of degraded pastures on climate and for the rural enterprise.

Figure 11 | **Impacts of actions of the ABC Plan by the recovery of degraded pastures and effects on the capacity for adaptation to climate change.**

Table 5 | **Benefits of the restoration of pastures as a strategy for adaptation and resilience to climate change, for local climate and the agriculture enterprise.**

LOCAL CLIMATE	ENTERPRISE
Reduces mean temperature	Increases production, especially during the dry season
Increases the albedo	Increases weight gain per animal
Increases evapotranspiration	Good control of invasive species under intensive grazing
	Increases carbon sequestration and availability of nutrients

Source: ANDRADE *et al.*, 2014; FÁVERO *et al.*, 2008; KLUTHCOUSKI *et al.*, 2000; MARTINEZ *et al.*, 2014; Mello *et al.*, 2004.

ECONOMIC AND FINANCIAL BENEFITS OF THE ADAPTATION OF AGRICULTURE

Crop and livestock farming use natural resources intensively, and farmers that do not comply with environmental laws impose a great risk in the portfolio of agribusiness and the financial sector (MONZONI; VENDRAMINI, 2017). Pressure on natural resources and ecosystem services can cause negative impacts on production, profitability, solvency, depreciation of financial guarantees, potential environmental fines for non-compliance and loss of access to domestic and international markets. All of this can impact a country's economy.

Brazil occupies almost half of South America, spanning several climate zones and responsible for 53% of the agriculture output from this region. The country has high levels of biodiversity and can deploy various production arrangements to adapt to climate change that reconcile productivity with environmental conservation. However, the adoption of these systems remains timid and efforts are needed to disseminate their economic and financial benefits for them to be implemented on a large scale.

The benefits of the ABC Plan and Planaveg in guiding activities that promote the adaptation and resilience of agriculture to climate change were discussed in the previous section. Economic and environmental benefits are still relatively unknown and need to be disseminated among farmers and better internalized by the financial and insurance sectors.

There is a synergy between the conservation of native vegetation and agriculture output. Actions and financing should be complementary, through the strategies and actions of Planaveg and through the items financed by the ABC Plan. The ecosystem services that directly affect agriculture and forest production are precisely the least well known and, for this reason, the least recognized by financial institutions (CREDIT SUISSE, 2016).

Important initiatives are being proposed for the financial sector, especially the need to consider the economic risks of the climate change underway. The report presented in April 2019 by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS)[6], joined by 34 directors and five observers of central banks from five continents, indicates that it is necessary to act to mitigate and adapt to climate change. The main recommendations include integrating the financial risk of climate change into the monitoring of the financial system and encouraging central banks to lead, by example in their own operations, by integrating sustainability factors into the management of their own funds, pension funds and reserves, for example (NGFS, 2019).

Indirectly, for traditional credit operations, banks have been incorporating water provision in their analysis, an extremely important ecosystem service, and other agents have their own tools to analyze risk for this specific service. But it is necessary to expand and include the other ecosystem and environmental services.

Many financial agents still do not have methodologies to consider the risk associated with the future climate in the processes of analysis for the projects they finance. Tools, such as Agricultural Zonning of Climate Risk (ZARC, from the Portuguese acronym), for example, which guides much of the agriculture credit and, consequently, different sectoral policies, need to consider the future climate (medium and long term) in their analysis of risk for financing. The same should be done regarding the ABC Plan and Planaveg.

Economic and Financial Benefits of the ABC Plan

With the expansion of regulatory mechanisms for conservation/environmental preservation and for the negative effects resulting from the indiscriminate use of natural resources, there is a growing understanding that the productive benefits associated with ecosystem services also provide financial benefits for the farmer and economic benefits for companies and investors. Considering that profitability is a key element in the viability of bank financing, the increase in productivity of the primary activity, or the adoption of measures that provide positive economic results for the whole farm, is fundamental for reducing risk and making financing feasible.

There are currently various studies that analyze investment in systems aimed at integrating and restoring pastures, in different productive arrangements and in different locations, which point to an increase in cash flow generated over time on rural properties, and some of them previous to the ABC Plan and Planaveg.

There are also studies on AFS, which are currently supported by the National Program for Strengthening Family Agriculture (Pronaf) and Planaveg.

A comparison of these results, which can also help to maintain the potential for mitigation of different land use systems (BUSTAMANTE et al., 2014), must be made with reservations, since there are specificities regarding the production systems, as well as environmental, social and technological differences. There are also differences in calculation methodologies and interest rates used. Moreover, the analyses do not consider the scale of the enterprise or the opportunity costs of the land, which vary from one region to another.

Nevertheless, it is possible to state that:

- All the works consulted (Table 7) point to economic advantages, whether they are integrated systems, pasture restoration systems or AFS;
- For beef cattle (VALE, 2004) and dairy cattle (SANTOS; GRZEBIELUCKAS, 2014), LFI is economically viable, allowing for faster return on capital (SANTOS; GRZEBIELUCKAS, 2014) and representing an alternative for sustainable regional development, since 1 ha of IPF is the equivalent of 1.93 ha split between pasture monocultures and eucalyptus, representing a gain of almost 100% in area (VALE, 2004);
- AFS, thanks to its multifunction composition, generates revenue every year, with higher costs in the first three years of implementation due to the higher demand for crop practices, labor and inputs (ARCO-VERDE, 2008). AFS is financially viable, but the benefits generated by annual crops may not be enough to offset the costs of implementation;
- CLI is more profitable for farmers than stand-alone systems (GOMES, 2015; LAZAROTTO et al., 2010; MENDONÇA, 2018; SILVA et al., 2012), since, while cattle farming, whether dairy or beef cattle, specializes in livestock and systems of grain production can only focus on agricultural activities, CLI is more diversified. Because it is more complex, it involves all the activities present in two systems and requires more technical and market knowledge from the farmer (LAZAROTTO et al., 2010);
- Restoration of pastures and CLFI (BEDOYA et al., 2012) provide satisfactory economic results and contribute to mitigating GHGs and to increasing livestock productivity.

Table 7 | **Economic indicators in different agriculture production systems: beef cattle (BC), dairy cattle (DC), plant production (PP), crop-livestock integration (CLI), livestock-forest integration (LFI), crop-livestock-forest integration (CLFI), recovery of degraded pastures (RDP) and agroforestry system (AFS).**

SOURCE AND LOCATION	SYSTEMS STUDIED	ECONOMIC INDICATORS			
		NPV (R$)	IRR (%)	PAYBACK (YEARS)	B/C
	PP (reforestation of eucalyptus)	7,223.94	24.8	-	3.24
Vale (2004)[1], LFI for Zona da Mata (MG) with empirical data, basis of study: 1 hectare	DC (conventional dairy cattle)	6,015.27	52	-	1.28
	LFI (eucalyptus associated with *Brachiaria brizantha* (70%) and *Calopogonium muconoides* (30%) + dairy cattle)	16,302.54	27.5	-	
	AFS 1 – (rice, cassava, banana, inga, cupuassu, pejibaye, goupie, chestnut and gliricidia as hedge)	3,134.00	14.83	-	1.46
Arco-Verde (2008)[2] – AFS implemented in 1995 in Cantá (RR), basis of study: 2.3 hectares	AFS 2 – (corn, soybeans, cassava, banana, inga, cupuassu, pejibaye, goupie, chestnut and gliricidia as hedge)	7,006.00	23	-	1.89
	PP (soybeans and corn in the summer and wheat in the winter)	96,635.00	13.99	1.017	1.0

Lazzarotto *et al.* (2010)[3] - research data in Guarapuava (PR) from 1995 to 2007, basis of study: 300 hectares					
	BC (beef cattle, with purchase of calves, rearing and fattening, in a period of less than one year)	159,583.00	14.95	1.016	1.01
	CLI (soybeans and corn in the summer and wheat in the winter, and beef cattle in the summer and winter)	190,787.00	14.91	1.024	1.01
	PP conventional (soybeans, corn and wheat)	374,732.21	1.8	-	-
	CLI1 (pastures of black oats, annual ryegrass, white clover and red clover with grazing of light animals (192 ± 40.9 kg))	199,318.03	4.1	-	-
Silva *et al.* (2012)[4] - CLI in dairy cattle in Castro (PR), basis of study: 100 hectares	CLI2 (pastures of black oats, annual ryegrass, white clover and red clover with grazing of heavy animals (278 ± 41.2 kg))	159,270.15	4.5	-	-
	CLI3 (pastures of annual ryegrass with grazing of light animals (192 ± 40.9 kg)	244,940.88	3.6	-	-
	CLI4 (pastures of annual ryegrass with grazing of heavy animals (278 ± 41.2 kg)	131,597.11	4.8	-	-
	Reference system (60 ha of extensive grazing with palisade grass, 6 ha of intensive grazing with *Panicum maximum* cv. Mombasa + 15 ha of corn silage)	- 328,066.77	1.2	-	-
Bedoya *et al.* (2012)[5]– simulations for dairy cattle on typical farms, Uberlândia (MG)	RDP (48 ha of intensive grazing with Mombasa grass and 33 ha corn silage)	566,702.96	8.3	-	-
	CLFI (40 ha of intensive grazing with Mombasa grass, 19 ha of corn silage and 22 ha of eucalyptus)	322,125.50	7.5	-	-
	BC (entry of steers at 9 months, sold at 27 months and 20@)	920.59	13.15	7.23	1.2
Santos; Grzebieluckas (2014)[6], farm in Tangará da Serra (MT), basis of study: 1 hectare	PP (reforestation of eucalyptus)	15,.843.80	10.69	6.78	3.67
	LFI (eucalyptus and entry of steers at 9 months, sold at 20 months and 18@)	13,791.03	19.55	5.82	2.26
Gomes (2015)[7], CLI and PP, Tangará da Serra (MT), basis of study: 170 hectares	PP (succession of soybeans, corn, fallow)	196,702.00	-	10	-
	CLI (succession of soybeans, corn silage with palisade grass after grazing)	2,251,430.00	-	5	-
	PP1 (corn)	763,332.28	40	3	-
Mendoça[8] , CLI and PP two systems (corn and pasture), Sertãozinho (SP), basis of study: 75 hectares	PP2 (*Brachiaria brizantha* cv. Marandu)	-25,554.65	5	8	-
	CLI (corn and *B. brizantha* cv. Marandu, planted together, with grass planted in a row in between the corn and with the application of herbicide)	797,326.26	32	-	-

Notes: NPV = net present value, in R$; IRR = internal rate of return, in %; payback = IRR, in years; B/C = benefit-cost ratio; 1- interest of 8% p.a. and annual land cost of R$120.00/p.a.; 2- Work with economic-financial assessment of each crop; interest of 8% p.a.; 3- MARR (minimum acceptable rate of return) = 12.1% p.a., mean cost of own and third party capital; 4- rate of 6% p.a.; 5- Payback and return on investment on a horizon of 21 years, interest of 5% p.a.; @ (arroba) = ~12 kg; 6- MARR of 8% p.a. and period of 12 years; 7- MARR = 6.2%; calculation of relative rate of profitability (PI) = 1.75 for PP and 3.31 for CLI; 8- interest of 0.15% per month.

Therefore, investing in production systems to adapt to climate change (forest restoration, pasture restoration, CLI, CLFI, LFI, AFS), using economically viable production arrangements that have low environmental risk, provides an avoided cost, due to the increase in resilience and reduction in risk imposed by climate change at the scale of the farm, and due to the maintenance of ecosystem and environmental services at the scale of the landscape. These important services could be used to improve the cash flow of future agriculture and forest enterprises and, consequently, increase the attractiveness of investment in low-carbon agriculture and forest restoration due to the reduction of risk of non-payment of the principal.

It is important to emphasize that the implementation of agriculture techniques adapted to climate change should evolve in parallel with the introduction of management practices that enable the maintenance of production systems in the long term (management of pastures, animal feed alternatives, training of labor in the field, etc.) so that, in addition to environmental gains, there is also a financial return, as demonstrated in the investment analysis (BEDOYA et al., 2012).

It is important to consider territorial planning and curb speculative land expansion, by channeling investments into productivity gains in the field by optimizing the allocation of financial resources. It is estimated that, in the Cerrado alone, the area with degraded pastures is enough to accommodate the increased production of soybeans and meat necessary to meet domestic and international demand up to 2040 (STRASSBURG et al., 2017). With the legal opening up of an additional 25 million hectares and simultaneous gain of 56% in livestock productivity, Brazil would ensure its rate of growth in the share of global food and fibers production until 2050 (SOTERRONI et al., 2018). The convergence of investment in productivity and environmental protection is the most effective way of ensuring the provision of the environmental services on which agriculture itself depends.

Economic and Financial Benefits of Planaveg

Natural capital and ecosystem services are commonly considered in the agriculture economy as externalities and are not included in cash flow accounting, creating gaps in the market and pricing systems. They are also normally not inserted in the calculations used to evaluate global economies and human development (BENINI et al., 2017). Even when their functions are identified and recognized, ecosystem services are rarely measured in the accounting of rural establishments because they do not generate cash.

Planaveg plays a role in ensuring forests as a source of essential services, primarily microclimate and water flow. The economic value of the environmental benefits of restoration and management practices in adapting to climate change and their effect on the resilience of agriculture can be quantified in different ways.

Deforestation in Brazi continues to be high. Since 1990 Brazil has lost 116 million hectares of native vegetation, of which 51 million in Amazon, 42 million in Cerrado, 12 million in Caatinga and 6 million in Atlantic Forest (Mapbiomas, 2019). Despite general deforestation rates has decreased in the last decade, deforestation in Amazon and Cerrado are increasing again since 2017, and important measures as Soybean Moratorium is losing supporters (BPBES, 2018). It also important to emphasize that preliminary data point to deforestation in the Cerrado, for the period August 2017 to July 2018, of 6,657 km2, 11% less than the previous period and 33% lower than in 2010.

On the other hand, the same report indicates that 7,900 km^2 was deforested in the Amazon, which represents an increase of 13.7% over figures for 2017 (MMA, 2018), while in the deforestation in the period 2018-2019 reached 9,762 km^2 an increase of 30% (Inpe, 2019). In the Atlantic Forest, the area of around 29,000 hectares deforested in 2015 to 2016 substantially exceeds the area restored during the same period (BPBES, 2018). The Atlantic Forest Atlas indicates that in 2018 there were 16.3 million hectares of native forest remaining, the equivalent of 12.4% of the original area of the biome (SOS MATA ATLÂNTICA, 2019).

Investing in the restoration of degraded areas and native vegetation, through economically viable production arrangements with low environmental risk, provides an avoided cost due to the increase in resilience of agriculture at the scale of the farm and reduces risks created by climate change. At the scale of the landscape, the recovery generates benefits that could be used to improve the cash flow of future agriculture and forest enterprises and, consequently, increase the attractiveness of investment in low-carbon agriculture and restoration, since it reduces the risk of non-payment of the principal. The role of forest stands in the regulation of climate (LOVEJOY; NOBRE, 2018), rainfall cycles and in the local regulation of water flow (FILOSO et al., 2017) is vital to agriculture. In Brazil, it is estimated that the value that forests provide to agriculture, through environmental services, such as climate regulation and seasonal rainfall, is somewhere between US$56 and US$737/ha/year (STRAND et al., 2018).

In its NDCs, Brazil has committed to restoring or reforesting at least 12 million hectares of degraded lands and forests by 2030. Studies on the costs of restoring vegetation and degraded areas are not very common, but some studies indicate the important opportunity that Brazil has to invest in a low-carbon forest economy (GVCES, 2016; GVCES; FEBRABAN, 2018; INSTITUTO ESCOLHAS, 2016).

Considering that profitability is key to securing bank loans, an increase in productivity of the primary activity and/or the adoption of measures that provide positive economic results for the whole farm are fundamental. Therefore, the adoption of adaptation strategies that reduce vulnerability to risks and reduce losses due to the climate change underway needs to be encouraged.

There are still many challenges to be considered to make the recovery and restoration of degraded areas and native vegetation the most cost-effective and feasible at scale. But the sustainable intensification of agriculture can be an ally of forest restoration, supplying food for society, while, at the same time, freeing up areas that are less suitable for production for restoration of vegetation. However, technological improvements, by increasing the efficiency with which resources are used and an economic good is produced, can stimulate the demand for this resource or product, causing a so-called boomerang effect or Jevons Paradox[7].

The challenge is to convince the agriculture and financial sector that, by investing in the restoration of degraded areas and forests, a cost is avoided as a result of increased environmental resilience and decreased risk exposure to climate change, fundamental for agriculture production at the scale of the farm and for society at the scale of the landscape.

Economic Instruments and Support Programs for Low-Carbon Agriculture

Low-carbon agriculture and restoration of degraded areas and native vegetation contribute to reducing GHG emissions, provide benefits for agriculture systems and aid in the provision of ecosystem services essential for production. As a result, integrated systems that combine the restoration of native vegetation with practices established in the ABC Plan and Planaveg possess greater resilience than stand-alone systems.

Economic instruments are important to guiding the valuation of natural capital as a way of influencing the decision-making process of farmers and consumers through the internalization of environmental costs.

A combination of economic instruments used worldwide is presented in Table 7, highlighting tax incentives (exemptions, reduced tax rates, tax credits, etc.), credit incentives, direct compensation (payment for environmental services) and disincentives. These mechanisms can be used alone or in combination with specific programs, as highlighted in examples in Table 8.

Table 7 | **Economic instruments supporting the development of low-impact agriculture.**

AVAILABLE INSTRUMENTS	DESCRIPTION	EXAMPLES
Fiscal Mechanisms	Tax exemptions for activities of lower environmental impact, or, conversely, higher taxes on products or processes with high polluting potential (polluter-payer). Another type could be special access to additional financial resources from tax revenues, when environmental criteria established in state law are met.	Brazil: ICMS Florestal, ICMS Ecológico and Novilho Precoce do MS Great Britain: Carbon Reduction Commitment (CRC) and Climate Change Levy (CCL)
Cap-and-trade system	The trade of allowances based on the adoption of caps that represent the maximum limit for the emissions of market participants. These allowances come from participants that perform favorably and that emit less greenhouse gas than the allowance they were granted.	Europe: EU ETS California Cap-and-Trade Program New Zealand: NZ ETS Carbon Pricing Mechanism
Trading System with permissions beseline-and-credit	Establishes a baseline that represents an emissions/impact trend in the absence of financial incentives to reduce them. Encourages the generation of compensation credits.	Clean Development Mechanism (CDM) Voluntary programs (VCS, Gold Standard etc.)
Public and private financing	Lines of financing with the aim of encouraging behaviors that result in lower environmental impact of economic agents that are directly or indirectly benefited ▪ Reforestation and conservation of forests ▪ Recovery and sustainable management of pastures and cultivated areas	National Climate Change Fund (Fundo Clima), Low-Carbon Agriculture Program (Programa ABC), Constitutional Fund for Financing of North Region (FNO), PRONAF Floresta, Pronaf Eco, Green Climate Fund
Removal of distorting subsidies in polluting activities	Reduction or elimination of subsidies that make polluting products and processes artificially competitive, minimizing market distortions.	Removal of fossil fuel subsidies
Preferential tariffs	Provision of best tariffs and other advantageous contractual conditions for products or services with lower environmental impact	Incentive Program for Alternative Sources of Electric Energy (Proinfa)
Debt securities	Debt securities for raising funds through loans from shareholders. These debt securities can be used to enable projects with positive environmental impact.	Green bonds Agribusiness Receivables Certificates (CRA) Agribusiness Letters of Credit (LCA)
Payment for Environmental Services	Instrument for monetary transfer or financial compensation for those who maintain or rehabilitate ecosystem services, in keeping with the protector-receiver principle.	Producer of Water (Bacias PCJ) - Agência Nacional das Águas/TNC Conservator of Water – Extrema/MG

Table 8 | **Examples of programs available in Brazil that offer incentives to the valorization of natural capital.**

PROGRAM/PROJECT	EXPECTED BENEFITS	ECONOMIC INSTRUMENT USED
Program to Support the Raising of Cattle for Early Slaughter - Mato Grosso do Sul (http://www.precoce.semagro.ms.gov.br/)	Reduced methane emissions; increased resilience of beef cattle farming and its adaptation to climate change; improved quality of Brazilian meat; increase competitiveness in the international market.	Tax Incentives Reduction of ICMS tax rate in accordance with compliance with environmental criteria adopted in the management of production and herd.
Family Agriculture Program (Pronaf), ABC Environmental Program, Program to Support Medium-sized Producers (Proam), BNDES Finem Agropecuária (for AFS), BNDES Finame, Banco do Brasil, Banco da Amazônia, Banco do Nordeste, and others	Promotes production systems capable of reducing greenhouse gas emissions together with an increase in production and productivity. Increases the resilience of agriculture and its adaptation to climate change.	Credit Incentives Lines of credit with more attractive interest rates and/or extended grace periods for environmental compliance of production systems or production itself.
Reforestation Program of the State of Espírito Santo, Forest Fund of the Government of the State of Amazonas, Green Fund of Minas Gerais, Forest Replacement in Pernambuco	Conserves and restores native vegetation for protection of the soil, water resources and biodiversity.	Payment for Environmental Services (PES) Transfer of money or inputs (fencing, fertilizer) in exchange for conservation and restoration actions.
GTPS Sustainable Livestock Program - Sustainable Livestock Work Group (http://gtps.org.br/)	Promotes good practices with a view to intensifying production and reducing deforestation and its greenhouse gas emissions	Voluntary Commercial Agreements Although these are not actually economic instruments, commercial commitments have the effect of normalizing supply and demand in production chains, inducing investment in the agreed to good practices.
Soybean Moratorium, run by Soy Working Group (GTS), formed by ABIOVE, ANEC, civil society organizations, Ministry of the Environment and Banco do Brasil (http://www.abiove.org.br)	Promotes a decoupling of soybean production chain from new deforestation in the Amazon biome, ensuring that the expansion of soybean occurs exclusively on areas deforested before 2008.	

MATRIX OF THE IMPACTS OF CLIMATE CHANGE ON ADAPTATION AND RESILIENCE OF AGRICULTURE

The Impact Matrix of the ABC Plan and Planaveg presented here is an output built to support decision makers to identify and recognize benefits provided by each of the technologies under adaptation strategy view.

In these tables we consider qualitative attributes (increase, decrease, no change, unknown) of variables that will be affected by climate change. The main objective is to enable the direct identification of the effect and strategies of the ABC Plan and Planaveg in increasing resilience and adaptation of agriculture production systems to climate change. The matrix formed by this set of tables reflects the scientific and technical knowledge and experience of specialists who drafted this Working Paper.

When the ABC Plan was launched, the adaptation actions were not listed and identified, primarily because, at the time, the necessary quantitative knowledge was not available to show and scientifically prove what the impact on adaptation would be. At the same time, as soon as Planaveg was launched, it focused on mitigation and compliance with the Forest Code and NDC target. After greater reflection on the effect of revegetation on increasing the resilience of biomes, it was possible to identify how the Planaveg actions could aid in the adaptation of different agriculture production systems.

In assembling the charts that form the Impact Matrix, for each action provided for in the ABC Plan–discussed in this Working Paper considering actions with trees and actions without trees–and in Planaveg, the excepted impacts of climate change (Table 9), the expected effects of actions of the ABC Plan and Planaveg (Table 10) and the effects on the resilience of the production system (Table 11) are shown. All three tables considered aspects of local climate, the occurrence of extreme events, soil characteristics, biological factors and socioeconomic factors. For local climate we considered temperature (minimum, maximum and mean), air humidity (maximum and minimum), rainfall and occurrence of strong surface winds. For extreme climate events, the possible effects of the occurrence of heat and cold waves, of droughts, consecutive dry days, intense rains, natural disasters and fires are shown. For soils, effects on the availability of water for plants, on erosion, fertility and on the quality of water are considered.

Biological factors are also affected by climate change, and the tables show the effects already known on pollinators, on the animal environment (when the system involves animals), on the occurrence of diseases in plants and on the conservation of biodiversity, while for socioeconomic factors the effects on productivity and social and economic gains are considered.

Table 9 | **Expected impacts of climate change.**

<table>
<tr><th>COMPARTMENT</th><th colspan="2">VARIABLES</th><th>EXPECTED IMPACT</th></tr>
<tr><td rowspan="7">Local climate</td><td rowspan="3">Temperature</td><td>Maximum</td><td>▲</td></tr>
<tr><td>Mean</td><td>▲</td></tr>
<tr><td>Minimum</td><td>▲</td></tr>
<tr><td rowspan="2">Air humidity</td><td>Maximum</td><td>▽</td></tr>
<tr><td>Minimum</td><td>▽</td></tr>
<tr><td colspan="2">Rainfall</td><td>Southeast and to the North - ▽; to the South - ▲</td></tr>
<tr><td colspan="2">Strong surface winds</td><td>▲</td></tr>
<tr><td rowspan="7">Extreme events</td><td colspan="2">Heat waves</td><td>▲</td></tr>
<tr><td colspan="2">Cold waves</td><td>▽</td></tr>
<tr><td colspan="2">Droughts</td><td>▲</td></tr>
<tr><td colspan="2">Consecutive dry days</td><td>▲</td></tr>
<tr><td colspan="2">Heavy rainfall</td><td>▲</td></tr>
<tr><td colspan="2">Occurrence of natural disasters</td><td>▲</td></tr>
<tr><td colspan="2">Fires</td><td>▲</td></tr>
<tr><td rowspan="4">Soils</td><td colspan="2">Availability of soil water</td><td>Southeast and to the North - ▽; to the South - ▲</td></tr>
<tr><td colspan="2">Erosion</td><td>▲</td></tr>
<tr><td colspan="2">Fertility</td><td>▽</td></tr>
<tr><td colspan="2">Water quality</td><td>▽</td></tr>
<tr><td rowspan="4">Biological factors</td><td colspan="2">Pollinators</td><td>▽</td></tr>
<tr><td colspan="2">Plant diseases</td><td>▲ or ▽</td></tr>
<tr><td colspan="2">Animal comfort</td><td>▽</td></tr>
<tr><td colspan="2">Biodiversity conservation</td><td>▽</td></tr>
<tr><td rowspan="2">Socioeconomic factors</td><td colspan="2">Productivity</td><td>In general, ▽</td></tr>
<tr><td colspan="2">Socioeconomic gains</td><td>In general, ▽</td></tr>
</table>

Acronyms: NA= Not applicable, ▲ = Increase, ▽ = Decrease, ○ = No change, ? = Unknown.

Table 10 | **Effects of actions of the ABC Plan and PLANAVEG.**

COMPARTMENT	VARIABLES		EXPECTED EFFECTS – ABC PLAN – ACTIONS WITH TREES					ACTIONS WITHOUT TREES			PLANAVEG
			CLFI	AFS	CFI	LFI	PF	CLI	NT	RPD	RESTOR.
Local climate	Temperature	Maximum	▽	▽	▽	▽	▽	▽	▽	▽	▽
		Mean	▽	▽	▽	▽	▽	▽	▽	▽	▽
		Minimum	▽	▽	▽	▽	▽	○	○	○	▽
	Air humidity	Maximum	▲	▲	▲	▲	▲	▲	▲	▲	▲
		Minimum	▲	▲	▲	▲	▲	○	○	○	▲
	Precipitation		▲	▲	▲	▲	▲	○	○	○	▲
	Strong surface winds		▽	▽	▽	▽	▽	○	○	○	▽
	Fires		○	○	○	○	▲	○	○	○	▲
Extreme events	Heat waves		▽	▽	▽	▽	▽	▽	○	▽	▽
	Cold waves		▽	▽	▽	▽	▽	○	▽	○	▽
	Droughts		▽	▽	▽	▽	▽	▽	▽	▽	▽
	Consecutive dry days		▽	▽	▽	▽	▽	▽	▽	▽	▽
	Heavy rainfall		○	○	○	○	○	○	○	○	○
	Natural disasters		▽	▽	▽	▽	▽	○	○	▽	▽
Soils	Availability of soil water		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Erosion		▽	▽	▽	▽	▽	▽	▽	▽	▽
	Fertility		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Water quality		▲	▲	▲	▲	▲	▲	▲	▲	▲
Biological factors	Pollinators		▲	▲	▲	▲	▲	○	○	○	▲
	Plant diseases		▽	▽	▽	▽	○	○	▽	▽	○
	Animal comfort		▲	▲	NA	▲	NA	○	NA	▲	▲
	Biodiversity conservation		▲	▲	▲	▲	▲	○	○	○	▲
Socioeconomic factors	Socioeconomic gains		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Productivity		▲	▲	▲	▲	▲	▲	▲	▲	▲

Acronyms: CLFI = crop-livestock-forest integration, AFS = agroforestry system, CFI = crop-forest integration, LFI = livestock–forest integration, PF = planted forest, CLI = crop-livestock integration, NT = no-till system, RDP = recovery of degraded pastures, Restore = restoration of native vegetation and degraded areas, NA= Not applicable, ▲ = Increase, ▽= Decrease, ○ = No change, ? = Unknown.

Table 11 | **Effect on resilience of production system.**

COMPARTMENT	VARIABLES		EXPECTED EFFECTS								
			ABC PLAN								PLANAVEG
			ACTIONS WITH TREES					ACTIONS WITHOUT TREES			
			CLFI	AFS	CFI	LFI	PF	CLI	NT	RPD	RESTOR.
Local climate	Temperature	Maximum	▲	▲	▲	▲	▲	▲	▲	▲	▲
		Mean	▲	▲	▲	▲	▲	○	○	○	▲
		Minimum	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Air humidity	Maximum	▲	▲	▲	▲	▲	○	▲	▲	▲
		Minimum	▲	▲	▲	▲	▲	○	○	○	▲
	Precipitation		▲	▲	▲	▲	▲	○	○	○	▲
	Strong surface winds		▲	▲	▲	▲	▲	○	○	○	▲
	Fires		○	▲	○	○	▽	○	○	○	▽
Extreme events	Heat waves		▲	▲	▲	▲	▲	▲	○	▲	▲
	Cold waves		▲	▲	▲	▲	▲	○	▲	○	▽
	Droughts		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Consecutive dry days		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Heavy rainfall		○	○	○	○	○	○	○	○	○
	Natural disasters		▲	▲	▲	▲	▲	○	○	▲	▲
Soils	Availability of soil water		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Erosion		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Fertility		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Water quality		▲	▲	▲	▲	▲	▲	▲	▲	▲
Biological factors	Pollinators		▲	▲	▲	▲	▲	○	○	○	▲
	Plant diseases		▲	▲	▲	▲	○	○	▲	▲	○
	Animal comfort		▲	▲	NA	▲	NA	○	NA	▲	▲
	Biodiversity conservation		▲	▲	▲	▲	▲	○	○	○	▲
Socioeconomic factors	Productivity		▲	▲	▲	▲	▲	▲	▲	▲	▲
	Socioeconomic gains		▲	▲	▲	▲	▲	▲	▲	▲	▲

Acronyms: CLFI = crop-livestock-forest integration, AFS = agroforestry system, CFI = crop-forest integration, LFI = livestock-forest integration, PF = planted forest, CLI = crop-livestock integration, NT = no-till system, RDP = recovery of degraded pastures, Restore = restoration of native vegetation and degraded areas, NA= Not applicable, ▲ = Increase, ▽= Decrease, ○ = No change, ? = Unknown.

CONSIDERATIONS

This Working Paper presented evidence that the strategies and actions offered by the ABC Plan and Planaveg create the most suitable and resilient conditions for growth and development of crops, pastures and livestock. Consequently, there are many benefits, which range from regional environmental conditions, production systems, and the socioeconomic and cultural profile of the farmer. These conditions are more relevant if we consider a real scenario of climate change that we are already facing, and which will continue to get worse in the coming decades.

In recent years, research has sought solutions for sustainable development by studying the impacts of climate change that support measures to adapt to current and future changes in climate. Although various advances have been made in Brazilian research to develop and/or test cultivars and breeds adapted to climate change, they are still insufficient. Brazil, a culturally multifaceted country of continental proportions, still lacks the technology, strategies and investment to meet the needs and demands of different types of farmers and regions.

The known effects of good management and soil and water conservation practices that form the basis of low-carbon agriculture, together with the practices of recovery proposed by Planaveg, have a positive effect on the maintenance of biodiversity, on the availability and quality of water and on the incidence of natural disasters, primarily due to a reduction in landslides and flooding. They are promising systems that are expanding in Brazil. In the medium and long term, it will be possible to observe their adaptive capacity to climate change.

The results discussed show that the integrated systems are a sound and effective approach for Brazilian agriculture to adapt to the climate change underway. They present lower risk because they are diversified, with characteristics resembling the natural environment, and serve important functions. They keep water in the soil, possess biogeochemical cycles of greater richness and magnitude, sequester carbon, protect pollinators, increase and diversify production and income and therefore possess greater resilience to climate change.

In the Crop-Livestock-Forest Integration (CLFI) system, the presence of trees has proven effects on the health of crops and animals, by reducing the spread of diseases, providing thermal comfort and gains in productivity. This practice is directly related to the proposals for recovery in Planaveg.

Forests planted with native and exotic species, ecological restoration and agroforestry systems ensure the water cycle and supply of water and food for the rural and urban environment and maintain the flow of water courses, avoiding processes of erosion and silting, whose risks increase with an increase in intensity and frequency of extreme rainfall events. The use of trees in the agricultural system is an important source of income and stability for the rural enterprise and plays a fundamental role in reducing deforestation in native forest areas, in addition to sequestering CO_2.

The recovery of native vegetation and degraded areas is fundamental to restore the equilibrium of the rural landscape and environmental sustainability. However, environmental compliance is still seen as a burden for farmers, given the cost of restoration and reforestation, when it should be considered an investment and key part of the financial sustainability of their enterprises. Knowledge must be gained about the possibilities of economic exploration of legal reserves and permanent preservation areas, as well as financial return on investment in the restoration of degraded areas and native vegetation.

For financial agents, the security of transactions and instruments used to monitor activities are very important; in this sense, initiatives are being proposed, as in the report by Network of Central Banks and Supervisors for Greening the Financial System (NGFS), presented in April 2019.

Indicators from the matrix of impacts and resilience proposed in this Working Paper can be used by financial institutions, investors and insurance companies in the analysis of agriculture, forest, agroforestry and low-carbon projects. In risk analyses for agriculture, for example, unanticipated variation in productivity and income due to climate (hail, excessive rainfall, drought, windstorms, temperature) and/or biological (pests, diseases, unsuitable cultivars, loss of pollinators, etc.) factors can be considered.

It is also important to show the farmer that he/she is the greatest beneficiary of ecosystem services and this is why he/she should value them for different types of actions (for example, restoration of degraded areas, conservation of native vegetation remnants, implementation of good agriculture practices, etc.). All these actions can be incorporated in the analyses of risk for investors, insurance companies, and financial institutions and, once quantified, can contribute to reducing interest rates or premiums based on the reduced risk of the investment and financing. Moreover, the additional revenue obtained from the economic exploration of the legal reserve and the use of low-carbon technologies will make the business model more attractive for potential investment and financing.

In this sense, an effective monitoring system for the financing of future low-carbon, forest and agroforestry projects on a large scale should be evaluated by investors and financial agents, thus avoiding mistakes made in other credit lines.

In addition, the risks of climate change need to be widely disseminated. It is important to note that, up until now, society has been unaware of the amount invested per ton of mitigated carbon and ignores the fact that participation in the ABC Program, in its eight years of existence, is still very low in relation to the traditional loan program (Plano SAFRA).

There are many challenges, which can be approached as business opportunities. There are tools and knowledge, skilled professionals, methodologies and relevant legal frameworks for this transition. The present study, as well as the entire scope and scientific evidence collected here, is an important instrument for changing paradigms in the agriculture and forest production sectors, as well as for investors and decision-makers. The continuation of this structuring, together with effective actions on different fronts (economic, academic, extension, legal, etc.), is paramount and urgent.

Training, scientific research and technology, qualification of specialists and financial agents, extension activities and broad dissemination should all be intensified so that actions to adapt Brazilian agriculture to climate change can be expanded. This is fundamental to maintain Brazil's leading national and international role in agriculture and food production.

RECOMMENDATIONS

- Expand and encourage, with the support of technical assistance and rural extension services, integrated production systems;
- Incorporate the value of the ecosystem services stemming from low-carbon production systems and restoration in the cash flow of a farm for the analysis of investment risk and bank financing, given that, for reimbursable resources, the analysis of risk directly affects the cost of capital and the size of the spread of the financial agent and, consequently, impacts return on investment and the ability of the borrower to pay;
- Encourage insurers and reinsurers to consider the risk of losses avoided due to the adoption of climate change adaptation practices;
- Concentrate efforts to quantify, through indicators, the potential to adapt to climate change of the different actions of the ABC Plan and Planaveg;
- Place ABC Plan and Planaveg actions on the country's development agenda and view these actions as an investment and not a cost;
- Increase investment in low-carbon practices and restoration of ecosystems through the reallocation of resources from the Plano SAFRA;
- Consider food security in public policies for the agriculture sector, in addition to the economic value of production and overall commercial advantages; and
- Increase investment in research, technology, and innovation, training and capacity building, and improvement and dissemination of the adaptation strategies based on the ABC Plan and Planaveg.

ACRONYMS

AFS – Agroforestry System

BFN - Biological Fixation of Nitrogen

CFI – Crop-Forest Integration

CLFI – Crop-Livestock-Forest Integration

CLI – Crop-Livestock Integration

EbA - Ecosystem-based adaptation

GHG – Greenhouse Gases

IPCC – Intergovernmental Panel on Climate Change

IS – Integrated Systems (CLI, CFI, CLFI and LFI)

LFI – Livestock-Forest Integration

LR – Legal Reserve

NDC – Nationally Determined Contribution

NT – No-till

PPA – Permanent Preservation Area

RDP – Restoration of Degraded Pastures

GLOSSARY

Agroforestry System (AFS): a system that uses a large diversity of plants, managed to serve the vital needs of the community (food, health, clothing, housing and shelter) and that involves itinerant cultivation, traditional systems open to the market and intercropping of perennial trees, bushes and palms (BECKER, 2010; CASTRO et al., 2009).

Arroba (@): Standard unit of measure for weighing cattle carcasses. In Brazil, an arroba is equal to 15 kg. For cattle, it is the weight of the carcass, considering only the meat and bone, measured in kilograms. The yield of the carcass depends on the percentage of fat, sex and breed and, in practice, an average yield of 50% is used.

Bank spread: difference between what the banks pay for funds and what they charge to loan those funds to a private individual or corporation. In the value of the bank spread, the value of taxes such as IOF and CPMF are included.

Benefit: a term adopted in this Working Paper for the co-benefits of actions of mitigation to climate change.

Co-benefits: a term adopted in specialized literature for the additional benefit of mitigation actions, in other words, that beyond the benefit of a direct reduction in emissions, with a view to sustainable development.

Double-crop: refers to the crop, planted after the main harvest, which is traditionally less productive, due to the lower availability of rain during the crop cycle. The most common crop combinations for harvest-interim harvest planting are: soybeans-corn, in the Southeast and Central-West, and soybeans-wheat in the South of Brazil.

Integrated Systems (IS): systems that involve integration of agriculture activities in the same area. These include crop-livestock-forest integration (CLFI), crop-livestock integration (CLI), crop-forest integration (CFI) and livestock-forest integration (LFI).

Land sparing effect: the effect of adopting appropriate technologies in agriculture systems that provide increased productivity and financial gains and, consequently, allows less land to be used over time.

Legal Reserve (LR): an area located inside a rural farm or plot, designed to ensure the sustainable economic use of natural resources of the rural farm, aid in the conservation and rehabilitation of ecological processes and promote the conservation of biodiversity, as well as shelter and protect wild animals and native plants (EMBRAPA, n.d.).

Nationally Determined Contribution (NDC): a document that records the commitments and contributions proposed by the Brazilian government to comply with the Paris Agreement.

Permanent Preservation Area (PPA): a protected area, covered or not by native vegetation, with the environmental function of preserving water resources, the landscape, geological stability and biodiversity, facilitating the gene flow of flora and fauna, protecting the soil and ensuring the well-being of human populations (Embrapa, n.d.). As a general rule, there can be no economic exploration of forest resources on PPAs and the suppression of vegetation can only be authorized for the reasons provided for in law, in other words, when in the public interest, social interest and low impact, which includes, among other alternatives, agroforestry exploration and sustainable forest management practiced on small properties or rural family plots (EMBRAPA, n.d.).

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NOTES

1. In Hansen et al. (2013), tree cover is defined as all the vegetation measuring 5 m or more in height.

2. Cabruca is the regional designation given to the cocoo crop area under the shade of a thinned native forest.

3. Available at: http://www.projetoverena.org.

4. Available at: https://www.webambiente.gov.br/.

5. Available at: http://scafforragem.cppse.embrapa.br/scafforragem/.

6. Available at: https://www.mainstreamingclimate.org/ngfs/.

7. The Jevons paradox, also known as the rebound effect, occurs when technological progress or government policy increases the efficiency with which a resource is used (reducing the amount necessary for any one use), but the rate of consumption of that resource rises due to increasing demand. It was described by the English economist William Stanley Jevons in the book The Coal Question, which points to advances made in the efficiency of steam engines, which allowed them to consume less coal to produce the same amount of energy, but, nevertheless, ended up raising the total consumption of coal due to greater demand (Jevons, 1866).

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