MAY - AUG 2015 #10

Science for life

Agrosystems and sustainable production

As the population grows, the planet does not. It will only be possible to produce enough food for all with integrated systems

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Ministry of Agriculture, Livestock and Food Supply

BRAZILIAN GOVERNMENT BRASIL

FROM MALTHUS TO BIOTECHNOLOGICAL ADVANCES

While scientific advances have so far been able to dribble the predictions made in the eighteenth century by the British economist Thomas Malthus – that population grows faster than food production –, a new concept, now in vogue in livestock production and agriculture, promises long life to the balance between food supply and demand. This, despite significant estimates of growth of Earth's population until 2050.

This concept is sustainable intensification, which can be translated as producing more, with increased efficiency and diversification in the same space while managing soil and water resources in a sustainable manner. As a practice, sustainable intensification has been presented as a viable alternative so that mankind can continue to produce food and reach record rates of productivity, protecting the environment and reducing harmful effects of human actions on the planet. The details can be verified in the cover story in this issue of XXI – *Science for life* magazine.

As it is a finite resource, water is also the topic of the interview with the agricultural engineer Luís Henrique Bassoi. He shows us that agriculture is not the villain of the water crisis, as it is usually pointed out. Bassoi brings data on irrigation and water resource management.

Agribusiness research also signals good tidings with health care. Plants, animals and microorganisms can be used as biological factories for the production of molecules with high added value, acting in a positive way in treatments against cancer, AIDS and hemophilia, among other diseases. Brazilian researchers and American and British partners have shown that genetically modified soybeans are efficient and viable biofactories for large-scale production of cyanovirin, a protein that has the natural ability to bind itself to sugars, preventing the multiplication of the HIV virus in humans. Spanish researchers, with the help of their Brazilian counterparts, have developed transgenic rice containing the HIV molecule in their DNA. This is an example of agriculture reaffirming itself as an ally of the pharmaceutical industry. To better understand this partnership, the story on page 46 is worth reading.

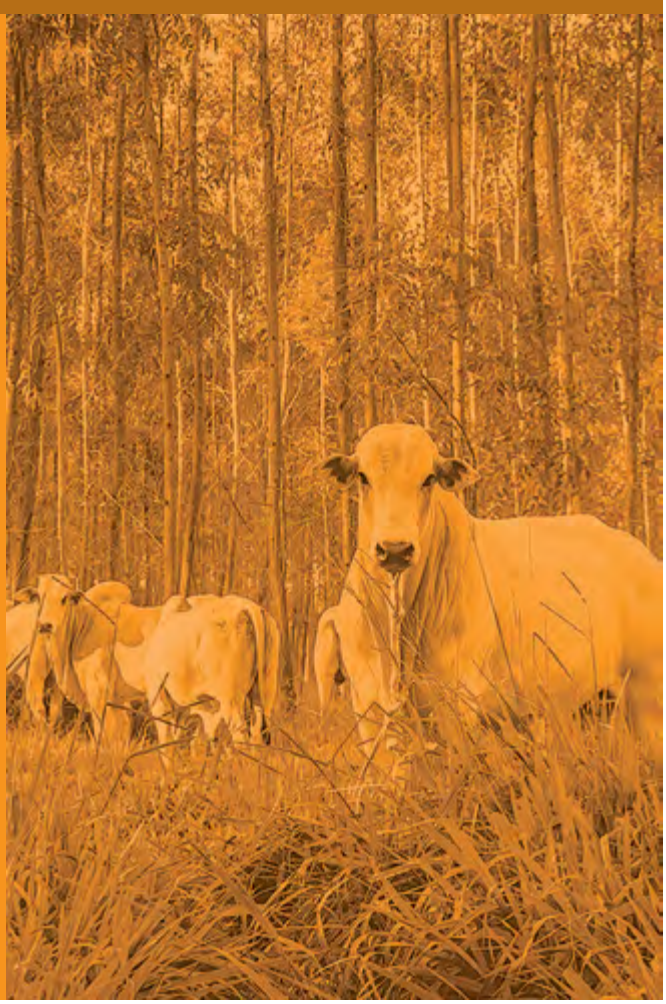
Scientists are sure that these advances open prospects for better quality of life for the population. But the ordinary citizen is not always convinced. New technologies still generate distrust, in particular those resulting from biotechnological processes, as Adriana Brondani, from the Brazilian Council for Biotechnology Information (CIB), wrote in an article for this issue commenting on recent opinion polls. Democratization of knowledge is indeed a necessity, and it was a great stimulus for us in this issue of the XXI – *Science for life*.

Elephant grass (*Pennisetum purpureum*) and African oil palm (*Elaeis guineensis*) reveal new possibilities of use. Elephant grass can supply boilers and generate energy. It also serves as raw material for cellulosic ethanol, also known as 2nd generation ethanol. African oil palm bunches have nanofibers with such high mechanical resistance as to mimic certain metals. Researchers want to test them as reinforcement for natural rubber. Check out these discoveries in this issue.

Enjoy your reading!

—— *The editors*

The agricultural engineer Luís Henrique Bassoi states that agriculture is not the villain of the water crisis, as it is sometimes considered, and presents data on irrigation and water management.



Sustainable intensification is a viable alternative so that humankind can continue producing food and reaching record yield rates, preserving the environment and reducing the effects of its actions on the planet. Details can be seen in this special article.

XXI
Science for life

CEO
Maurício Lopes

Executive Directors
Ladislau Martin Neto
Vania Castiglioni
Waldyr Stumpf

This publication is responsibility of Embrapa's Secretariat for Communications

Head of the Secretariat for Communications
Gilceana Galerani

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Tatiana Martins

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Robinson Cipriano

STAFF PAGE

Editors
Marita Féres Cardillo
Fabio Reynol
Gabriel Pupo Nogueira

Graphic project
André Scofano and Nayara Brito

Design
Fernando Jackson, Gabriel Pupo Nogueira, Luciana Fernandes, Lucio Cavalcanti and Maurício Camarão

Cover
Gabriel Pupo Nogueira

English translation
Tikinet Edição Ltda., Marcela Bravo Esteves and Mariana de Lima Medeiros

Revision
Marcela Bravo Esteves and Mariana de Lima Medeiros

SCIENTIFIC CONSULTANTS FOR THIS ISSUE
Antônio Vander Pereira, Elíbio Rech, João Kuthcouski, Lourival Vilela, Maria José Amstalden Sampaio, Paulo Galerani, Vitor Del Alamo Guarda, Vanderley Porfirio da Silva.

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Ministry of **Agriculture, Livestock and Food Supply**

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FASHION COTTON

Photo: Sérgio Cobel/Embrapa

In April 2015, the colored cotton produced in the semi-arid was a stellar attraction at the fair "1,618 Sustainable Luxury", in Paris, France. The event is known for presenting global initiatives aimed at sustainable consumption. In Paraíba state, Brazil, 80 families grow colored cotton in dryland/upland systems, without chemical fertilizers or synthetic insecticide. As it is naturally colored, the fiber does not require the use of chemicals to dye the fabric, and saves 83% of water in the fabric finishing process compared to artificially colored fabrics. These features make the product very attractive for companies interested in the so-called "green fashion". The colored cotton is as old as white cotton. Many wild species were found as far back as 4,500 years, but their short fibers were not suited for spinning. Genetic improvement conducted by Embrapa Cotton resulted in varieties of colored lint suitable for the textile industry. The shades range from light green to light, dark and reddish brown. Researchers now want to achieve a blue-colored cotton variety. For that purpose, they turn to biotechnology to transfer the gene that provides that color to the cotton fiber. •

— By Edna Santos

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http://guide.1618-paris.com/selection-natural-cotton-color
https://www.embrapa.br/algodao

MORE PRODUCTIVE CANOLA

Research conducted by the Brazilian Network for Canola Pollination assessed the impact on bees in canola crops in Rio Grande do Sul, Brazil. Studies were carried out during canola flowering in three cities of Rio Grande do Sul: Esmeralda, Estrela and Guarani das Missões. The methodology included three comparisons: open crops (natural process of pollination), covered crops (free of bees) and manual pollination flower by flower. The assessments identified more than 38 species of pollinating insects. It was found that the honeybee *Apis mellifera* is the most abundant and important species, representing, on average, 76% of the crop pollinators. According to the researcher Betina Blochtein, from the Pontifical Catholic University of Rio Grande do Sul (PUC-RS), the results were surprising: the free visitation of bees increased the productivity of canola from 17% (hybrid Hyola 420) to 30% (Hyola 61). The greater presence of bees increased the number of silique (pods) and the weight of canola grains. Essentially, the study indicates that pollination not only enhances the grain yield of the crop, but also contributes to uniformity and precocity of the formation of siliques.•

— By Joseani M. Antunes

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http://www.polinizadoresdobrasil.org.br

FRUIT WITHOUT FUNGICIDES

Fresh fruit, free of residue from agrochemical contaminants and with greater shelf life and trade life, is what a new post-harvest treatment technology developed by the team coordinated by researcher Daniel Terao, from Embrapa Environment, have promoted. It is a combination of processes that uses hot water sprayed at higher temperatures, followed by cooling with ozonated cold water jets to interrupt the thermal process. The fruit also undergo exposure to UV radiation (UV-C) in controlled doses for each species, considering fruit variety, contamination, and the use of specific yeasts and natural plant extracts with residual effect for protection against rottenness during extended storage. The combination of processes occurs on the conveyor belt and ensures the efficient control of fungi and pathogens that attack fruits and cause rottenness. The new model is considered economically viable and technologically safe to promote the transition from control of rot and harmful microorganisms, a procedure performed currently based on fungicides and agrochemicals, to a system that leaves no residue in the treated fruits. It can ensure greater participation of Brazilian production in foreign markets, especially Europe – final destination of approximately 70% of the fruit exported by Brazil.•

Photo: Marcos Vicente/Embrapa

— By Marcos Alexandre Vicente

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http://www.embrapa.br/meio-ambiente

WORLD CONGRESS

Photo: Gabriel Faria
Art: Luciano Mendes / Maurício Camarão

Feeding a growing world population, with increasingly limited resources and spaces, is one of the biggest challenges of the agricultural and livestock sector. Focusing on this problem, the world's foremost experts on the subject will meet in Brasília from July 12 to 17 to discuss solutions during the World Congress on Integrated Crop-Livestock-Forest Systems (WCCLF). The Congress will include 31 lectures by representatives of universities, research institutions, and international bodies from the five continents. Agricultural systems such as those that integrate crop production with livestock and forestry in the same space, in addition to increasing the volume and diversity of products, also provide important environmental services such as carbon sinks and the refilling of aquifers and groundwater. The event is organized into three topics – technology, environment and social economy – and will create a final document that will be submitted to the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21), scheduled for the end of 2015. The Congress will be held at the Ulysses Guimarães Convention Center, in Brasília, Brazil, and will include the third International Symposium on Integrated Crop-Livestock Systems. Check the special article about sustainable intensification on page 14.•

— By Fabio Reynol

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http://www.wcclf2015.com.br/?lang=pt

MORPHINE EFFECT

Photo: Claudio Bezerra/Embrapa

Embrapa Genetic Resources and Biotechnology and the University of Brasília (UnB) have identified for the first time protein fragments (peptides) in coffee with an effect that is similar to morphine, as they present analgesic and anti-anxiety effects. The characterization of these molecules is part of the doctoral thesis of the student Felipe Vinecky, who developed it in the framework of the graduate program in Molecular Biology at the University of Brasília (UnB) and Embrapa Genetic Resources and Biotechnology, coordinated by the researcher Carlos Bloch Júnior. The peptides were identified when Felipe was searching for coffee genes associated to improved product quality, as part of a project jointly developed by Embrapa and the French Agricultural Research Centre for International Development (Cirad). •

— By Fernanda Diniz

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https://www.embrapa.br/recursos-geneticos-e-biotecnologia
http://www.ib.unb.br/

ACCESS TO KNOWLEDGE

The Embrapa website is the best one ranked among research institutions of Latin America, according to the World Web Ranking of Research Centers. The survey developed by the Consejo Superior de Investigaciones Cientificas (CSIC – Spanish Higher Council for Scientific Research) measured the quality and relevance of the knowledge production available to the public at 8,000 websites of research centers. The goal was to promote electronic access to content for the academic community. In the world ranking, Embrapa appears in the 28th position, the second among agricultural research centers, behind the Japanese Agriculture, Forestry and Fisheries Research Council. The ranking uses four indicators: visibility (number of external links pointing to the site); site size (number of pages); number of "text-rich files" (*.pdf, .ps, .doc, .docx, .ppt*) available; and relevance measured by the quantity of publications and number of citations in Google Scholar, a search service for scientific databases.•

— By Marcos Esteves

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http://research.webometrics.info/en/Latin_America
www.embrapa.br

TRUTHS AND MYTHS ABOUT WATER IN AGRICULTURE

By Fabio Reynol

The recent Brazilian water crisis has raised questions about water management in all sectors. Agriculture was cited as one of the pivotal problems, since it uses about 70% of the consumed water. The agricultural engineer Luís Henrique Bassoi says that the issue is not so simple. According to him, the agricultural sector is not responsible for such waste and can even generate a greater volume of water.

Interview photos: Camila Santana/Embrapa

Graduated at the Escola Superior de Agricultura Luiz de Queiroz of the University of São Paulo (Esalq-USP), Bassoi has a master's degree in Irrigation and Drainage at the São Paulo State University (Unesp), campus Botucatu; a PhD in Nuclear Energy in Agriculture (USP) and a postdoctoral degree in Irrigation and Drainage by the University of California, Davis, United States. He is currently a researcher at Embrapa Tropical Semi-arid, in Petrolina, Pernambuco, and Professor of graduate programs in Agronomy of the Faculty of Agronomic Sciences (FCA) at Unesp Botucatu and in Agricultural Engineering in the Federal University Vale do São Francisco (Univasf), campus Juazeiro, Bahia. Bassoi coordinates the Irrigated Agriculture portfolio of Embrapa, instance that gathers all research, development and technology transfer projects of the company regarding the topic, and also outlines strategies that overweigh the challenges related to irrigated agriculture.

XXI - Agriculture has been pointed out as the villain of the water crisis since it uses 70% of the available water. Do you agree that this percentage corresponds to reality?
Bassoi - This is an average estimated using global data and corresponds to different situations of water use in agriculture. It does not necessarily match the national average, and there are variations between regions. However, we still need specific studies to get to a number for Brazil – 70% is an average with which researchers work today.

XXI - Why does the sector consume so much water?
Bassoi - The term "consume" is not very appropriate for this context, in my opinion, as it gives a connotation that agriculture and livestock withdraw water from sources leaving it unavailable, which is not at all true. What happens is that only a small part of this water becomes "unavailable" to return to the nature: the water that will be used by the plant or animal to "manufacture" agricultural products such as the grains rice, corn and beans, or milk and meat, for example. The largest portion of water used in crops remains in the hydrological cycle, as we learned in school. Part of the water penetrates the soil, renewing the groundwater supply, another part of the water returns to the atmosphere by evaporation of the water in the soil surface and by plant transpiration, and yet another part is drained to water fountains. Note that this is very different from withdrawing water from a river for industrial production or urban use, in which some effluent must be treated to return to the environment. Because of all this, I prefer to say that the agricultural and livestock sector consumes electric energy and fertilizers, but uses water to produce.

XXI - What is the importance of irrigation?
Bassoi - First, it must be said that in certain areas it is impossible to produce without irrigation, as in the semi-arid. In the semi-arid it is impossible to achieve commercial agriculture that generates employment, income and development without irrigation. In general, the production of an irrigated area can be up to three times greater than a non-irrigated area, depending on culture and site. Therefore, irrigation is directly linked to the amount of food, fiber and bioenergy that we want to produce. Conservationist measures must be adopted to increase the availability of water and help agriculture to use it well, instead of closing the taps of rural areas, as has been proclaimed lately.

XXI - What are the consequences of closing the taps of rural areas?
Bassoi - All producers use water, whether they are small, medium or large. And agribusiness covers all groups. Smallholders who market their production are also part of the agribusiness and will be the first to suffer if they cannot use water. Given this fact, it is possible to realize that without water there will be no production, income or employment for those working in rural areas, and there will be no agroenergy, fibers and especially food for those who live in the cities. Think about the production of vegetables, for example, which are crops that depend on daily irrigation. Without water, these products will be the first to disappear and to become more expensive. The impact on the national economy would also be terrible because of the influence that agribusiness has on the Brazilian gross domestic product (GDP). I must emphasize: we are not only referring to large producers: smallholders, related to essential crops, such as some vegetables, fruits and our precious beans, will also suffer if water is cut from rural areas. »

XXI - What is the responsibility of the agricultural sector in the water crisis?

Bassoi - The water crisis is the result of two factors. The first is the occurrence of rain below the expected in recent years. Since 2010, according to data from weather-related institutes, the average rainfall recorded in the country is below the historical average in various parts of Brazil. There was also an aggravation between the end of 2014 and beginning of 2015, when there was an atmospheric blocking, as reported by the Observatory on the 2014-2015 Crop Year [https://www.embrapa.br/agua-na-agricultura/observatorio-safra-2014-2015]. The other factor is the lack of planning, which could help to face this problem even with the declining rainfall indexes.

XXI - How can we solve this issue?

Bassoi - First we need society's awareness, as a whole, concerning the fact that we need to use water better. It is important, for example, to control the water consumption preventively rather than use it as the last measure. We must ration while we have water. After it is over there will be nothing to ration. Preventive measures are less expensive and less traumatic.

XXI - How do you evaluate irrigation in Brazil?

Bassoi - Brazil uses little irrigation. This is because some regions still require infrastructure of water and electricity distribution. In addition, training and technology transfer for irrigation are not widely available. Today, the country has nearly six million irrigated hectares, but we have the potential to get close to 30 million hectares, that is, the area could be five times bigger. An expansion like this also would result in the expansion of agricultural and livestock production and productivity, and the consequent increase in the supply of fiber, bioenergy and food, whether for human and animal consumption, or for processing and industrialization. It must be remembered that Brazil plays an important role as a food supplier not only for the domestic market, but to the whole world. The country is one of the main actors in food and agricultural raw materials supply to the world. Irrigation will help to improve this scenario. It is time to question: what will be the cost of not using irrigation? The biggest burden will be giving up Brazil's agricultural vocation. We have land and solar energy in abundance, and also availability of water, but it is necessary to rationalize the use of natural resources and invest in efficiency. Without water there is no agriculture. The national irrigation policy (Law 12,787, 2013) should aid the planned increase in irrigated area and agricultural productivity, and encourage the capacity-building and training of human resources for the practice of a rational and efficient irriga-

"Brazil has nearly six million irrigated hectares, but we have the potential to get close to 30 million."

tion. The entire society can reap great benefits from it.

XXI - Even with a regime of reduced rainfall is it possible to have irrigation water?

Bassoi - Even with a reduction in the water supply, it is possible to obtain good productivity. Losses in times of water scarcity are inevitable. For many parts of the country, there is little rain forecast for the first half of this year, so it is possible that there will be crop failure. However, with planning and the adoption of technologies that promote the efficient use of water, it is possible to reduce losses. For example, the judicious application of water, considering factors such as the crop type, amount of water in the soil, crop evapotranspiration, among others. Precision agriculture, which is reaching more supporters in Brazil, can also assist the irrigation management, which is nothing more than the use of criteria to define the amount and time of irrigation. Precision agriculture takes into account variations in soil and plant in the agricultural area. Thus, in some parts of this area smaller or larger amounts of water can be used, instead of applying the same amount in the whole area. This helps saving water and increases the efficiency of water use.

XXI - Are producers trained to irrigate?

Bassoi - We can find many producers who are qualified. Yet we know that the number must be

"...with planning and the adoption of technologies that promote the efficient use of water, it is possible to reduce losses."

increased. There is great demand for irrigation training in Brazil. Localized irrigation (drip and microsprinklers), for example, has increased mainly in fruit tree orchards, but there is still much expansion to be done. The subsurface drip irrigation has been used with good results in sugarcane and coffee plantations, for example. The central pivot allows the efficient irrigation of large areas, something essential for crops that require large-scale production, grains for example, to be profitable. Such good news about irrigation need to be spread.

XXI - How can farms collaborate with the rural and urban water supply?

Bassoi - Rural properties can be water producers. Basically, to produce water is to adopt conservation practices that increase the amount of water that infiltrates into the soil. In simple terms, this is achieved when maintaining the maximum amount of water on the property without letting it seep out. Thereby, water ends up seeping into the ground, renewing the groundwater that supplies a reservoir, a stream, a river, that is, any local water source. These measures are known: use of terraces and "small dams", maintaining vegetation atop hills, around water sources, on a riverbank (riparian forest) etc. These measures also minimize erosion. The water crisis has also shown the importance of reservation, which is the saving of water with a reservoir. Until now, it was seen as a practice with greater »

importance in regions where there was little rain, such as the semi-arid. We are seeing now that even regions that have regular rainfall regime also need to have a water reserve. In rural areas, water reservoirs can be constructed so that the water can be used by one or more farms, especially during droughts. This can decrease the water withdrawal from fountains that are also used for urban or industrial supply. But it is important to note that all sectors should use water rationally. It is a collective responsibility of the entire civil society.

XXI - In your opinion, why do we have to invest more in reservoirs in Brazil?
Bassoi - It is an important issue that deserves more discussions. There is a wrong idea about reservoirs, because a lot of people consider that they could lead to water shortages for those who are further down the road, that is, downstream. This needs to be better explained to the population. By making use of integrated management and planning, it is possible to build reservoirs without causing water shortages for other users. This requires studies to determine the appropriate locations for reservoirs, the amount of water to be retained, outflow, the purpose of reservoir and other aspects.

XXI - Do international examples of water management exist?
Bassoi - In California, United States, people have been living for a long time with low hydric availability, big population, and most of the agriculture is irrigated. A wide network of reservoirs and canals ensures water supply for all users. The population has daily access to information on local or regional news, or on websites, about the level of the reservoirs. The population is informed by authorities about the need for the rational use of water in all sectors. Other good examples are Spain, Australia and Israel. Once again I reinforce: the key to success in this matter is planning and integrated management of water resources.

"...it is possible to build reservoirs without causing water shortages for other users."

XXI - What is the integrated management of water resources?
Bassoi - A common situation can illustrate this. If the water of a river or reservoir is used for power generation, irrigation and urban supply, there must be a common agreement related to how and when each sector requires water, as well as to establish the limits, and in case of a crisis, determine the sectors that will have priority. There is also the issue of sustainable management of water resources, which is basically the need of maintenance of quantity and quality of the water. The Brazilian federal law 9,433, 1997 (water law) addresses this matter. •

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Observatory on the 2014-2015 Crop Year:
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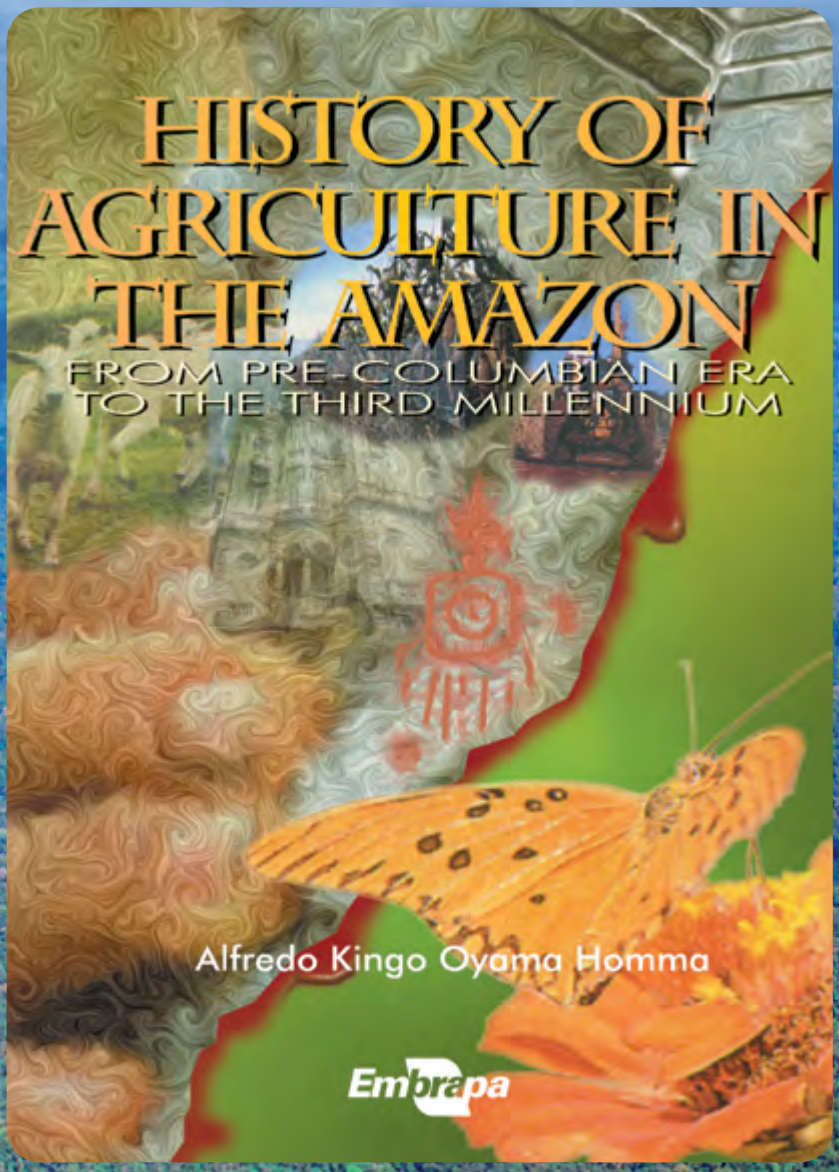

"The edition *History of agriculture in the Amazon: from Pre-Columbian era to the third millennium*, written by the researcher Alfredo Homma, aims to challenge readers to this extremely necessary and urgent debate about the Amazon's future."

Maurício Antônio Lopes
President of Embrapa

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AGRICULTURAL GROWTH AND RESPECT FOR THE PLANET

Agriculture can increase production while protecting the environment – that is the focus of sustainable intensification

By Fabio Reynol
Art: Gabriel Pupo Nogueira

Living on Earth for 200 thousand years, humans have always benefited from the abundance of resources. From our ancestors, cave dwellers, to the current residents of cities, today we can produce more than we need. But how long will this last? A strong sign that the days of abundance are numbered appeared in the 18th century. In 1798, an Anglican minister realized that the increase in food production was much slower than population growth. With the data observed at the time, he made a basic projection of the evolution of the "number of people versus food production", and predicted that the two curves would intersect at some point from which starvation would be inevitable for a good part of humanity. The results were published in his "An essay on the principle of population", written by the British Economist and minister Thomas Malthus. Demography obtained then a classic study, and the world, a latent concern.

Malthus did not live long enough to realize that his prediction would not come true so soon, especially because he had not considered key variables such as scientific and technological advances that increased food production. However, it is true that there is a limit, and we are approaching it. Unlike population, which is always growing, arable lands, resources and supplies are finite.

We have to consider that, in the countryside, food shares space with wood production for furniture; biofuel, that eases the demand for petrol oil; and also fibers for the clothes we wear or for the paper of this magazine, just to name a few examples. To blur the picture, human action modified the planet and its climate, creating one more challenge to agricultural activity.

This panorama ended up motivating the emergence of a new concept of agricultural production based on two pillars. First, it is necessary to make the most of what the Earth can offer us. »

Why depend on a soybean monoculture, for example, if we can produce in the same area several products like meat, wood, corn and sorghum, in addition of soybeans themselves? Diversification not only increases production capacity but also gives more financial security to the producer, who stops relying on a single product.

Increasing production is important, but it is not everything. One also needs to guarantee that the environment will be kept in condition to provide resources, remain with preserved natural areas, and even help to mitigate the effects of human action on the planet's climate. Thus we have the second axis of the concept: sustainability.

The meeting of the two philosophies coined the term "sustainable intensification", something that involves conservation practices, integration of different production systems in the same area, concepts involving agricultural and environmental sciences, and greater interdisciplinarity in agronomic studies. "Some years ago it was strange idea thinking about a pasture or a crop with trees in the middle of it. Today things have changed", says researcher Vanderley Porfírio da Silva, from Embrapa Forestry. He recalls the early days of the development of integrated systems (see the text *A seed of more than two decades*, page 34).

One of the biggest boosters of sustainable intensification is the role of agriculture and livestock in mitigating the effects caused by greenhouse gases (GHG). "The industry has the ability to neutralize or immobilize these gas emissions", says Eduardo Assad, a researcher from Embrapa Agriculture Informatics. However, to this end, he says it is necessary to find the balance between production and sustainability. "It is possible to raise 30 head of cattle per hectare per year. However, to neutralize the gases emitted by them, we will have, at a maximum, between one and 1.5 animals per hectare per year", he exemplifies.

The main idea in this case is to neutralize the GHGs emitted by cattle, especially methane (CH_4), eliminated by ruminants by eructation, the technical name for "burping". Assad notes that the Brazilian livestock sector has been the target of international criticism – this sector is considered harmful to the environment since it throws huge amounts of methane into the atmosphere. According to him, the trend is of increased international pressure to the point of turning this issue into non-tariff barriers that the country will have to face. "Brazilian beef will have to certify its origin and attest that it was produced in conditions that respect the environment", he forecasts. An

Photos: Thinkstock/Embrapa

answer to the problem would be integrating livestock to cropping, forestry (planted trees) or both, in the so-called integrated crop-livestock-forestry systems (ICLF).

In addition to access to the international market, what else would the producer gain? A lot, according to Assad. "First, this diversifies production and opens possibilities to produce other products besides meat. Then the producer may receive funds for environmental services or sell credits in the carbon market", he explains. Environmental services are paid by government programs to producers who adopt specific conservationist practices. An example is the Reforestation Program, in the state of Espírito Santo, which pays farmers who recover areas of native vegetation. The Low-Carbon Agriculture program (ABC Plan), coordinated by the Brazilian Ministry of Agriculture, Livestock and Food Supply, works towards the same goals. In addition to providing lower interest credit, the ABC Plan allows the use of up to 35% of the financed amount for the recovery of permanent preservation areas and legal reserves (learn more about the ABC program on page 28).

WATER PRODUCTION

According to Assad, it is also interesting for governments. The recovery of natural areas opens a new market niche: the production of native plant seedlings. Moreover, conservation practices also mitigate another crucial problem: the water crisis. "A great advantage is that the water will reappear preventing erosion, conserving soils, rivers and lakes, and facilitating water infiltration in the soil. Such practices renew the groundwater supply and increase the volume of water available", he states.

Integrated systems allow one to increase a pasture's stocking rate, which is the maximum number of animals that can be sustainably kept in an area. A simple pasture, without integration, is able to maintain 0.4 animal per hectare/year to neutralize gas emissions. If the pasture is integrated with agricultural production, the number rises to 1.5 animal/ha/year and if the integration involves planted forests, the producer can maintain up to 2.5 animals/ha/year without danger of emitting GHGs in excess. "Trees have large capacity to neutralize and fix carbon in the soil and in its aerial biomass, which increases stocking rates while reducing the greenhouse effect", says Assad.

Another positive aspect is that trees provide shade for the pasture, and give thermal comfort to animals, thus increasing productivity. "The thermal difference between sunny and shaded areas can reach 10°C", says the researcher, stressing that this comfort influences production. »

Photo: Sebastião José de Araújo/Embrapa

INTEGRATION IN THE CERRADO

THE OPENING OF THE BIOME FOR AGRICULTURE IN THE 1970s MOTIVATED THE CREATION OF THE FIRST PRODUCTION SYSTEMS

In the early 1970s, Brazilian agriculture still had a lot of growing to do. Importing meat, rice and beans, Brazil at that time sought to bring agricultural activity to Cerrado, a biome known for its poor soils and difficulty of cultivation. One of the first species to be planted in the agricultural frontier was upland rice. As it is a rough plant, this rice demands low fertilization and dispenses with liming. When intercropped with forage, rice leaves the field ready for cultivation, as it corrects the acidity of the soil, reduces the incidence of termite mounds and promotes a longer vegetative development of grass, keeping it green in the dry period.

Considering all of these advantages, the Barreirão System was created in the state of Goiás for the intercropping of grains and forages (see the infographic on page 20), and is used until nowadays for the rehabilitation of pastures. João Kluthcouski, researcher from Embrapa Rice and Beans, tells us more about it: "The Barreirão represented the beginning of integrated systems. Until then, no one thought about systems to rehabilitate pastures", he says, stating that the very concept of rehabilitating pastures was strange for the sector. "There were then about 20 million degraded hectares. Today this area is five times larger", he compares. Barreirão is considered an ICL system, a system that integrates crop and livestock production.

Another challenge faced by Kluthcouski was the practice of cattle breeders at the time, accustomed to considering livestock as an extractive activity. "The common practice four decades ago was of clearing an area for pasture to be used to exhaustion, and

when it was degraded, another area was cleared to continue the same process. Today, this practice has no place", says the researcher who believes that the mentality in the country has changed in recent years.

After the Barreirão, research efforts developed the Santa Fé, a system that also intercrops grains and grass, this time with the aim of guaranteeing cattle feed during the drought period. In addition, Santa Fé produces cover crop, plant remains of the already harvested cultures, left in the field as organic matter for the next crop. The technology of planting without removing previous crop remains, which is called no-till farming, provided other important advantages such as soil conservation, maintenance of carbon in the field and reduction of the temperature on the soil surface. The most common practice was to clear the land by removing the stubble and leave the land exposed. No-till farming has proven to be so important in mitigating the effects of greenhouse gas emissions that it was adopted as one of the practices advocated by the Brazilian government's ABC Plan.

"With the Santa Fé, it was possible to keep the land producing 12 months a year. The producer can have a crop of soybeans, a mid-season corn harvest and raise cattle in the same area. If one of them does not do well, another may be able to pay the costs, and the risk of losing money will be considerably reduced", celebrates Kluthcouski.

After the Santa Fé, a new version of the system that incorporated legumes like dwarf pigeon peas (*Cajanus cajan*) was created, with the intention of improving cattle feed. It was called Santa Brígida system and it provided cattle with a pasture of better nutritional quality. Later, other systems were developed focusing on different production demands. "There is no more reason for the Brazilian farmer to have degraded pasture; there are technologies, incentives, and economic and environmental advantages to adopt these systems", assures the Embrapa researcher.

He tells that the synergy between integrated cultures promotes impressive results in production. When intercropping grain production with brachiaria grass, for example, the producer improves the quantity of organic matter in the soil, and the stubble generated reduces the effects caused by off-season dry spells. In addition, this grass reduces the incidence of diseases caused by fungi in the soil. It was proven that corn or soybean crops planted after the brachiaria have a better production, according to Kluthcouski. Likewise, the next pastures had more quality. "A soybean plantation usually prepares the ground for a high-quality pasture", he points out.

A LEAP IN FOOD PRODUCTION

The researcher observed that one of the biggest obstacles to the implementation of the systems is the attitude of some cattle breeders. Considered by many investors as a secondary activity, livestock does not receive due attention, according to Kluthcouski. Curiously, what has changed this posture is the expansion of crops such as soybeans. "After leasing pasture areas for soybean producers, cattle breeders receive back a rehabilitated pasture, an improvement in the livestock production is observed and they become more aware of the care the pasture needs", he explains.

The potential of Brazilian agriculture with the degraded pasture is gigantic. Kluthcouski evaluates that if the 100 million degraded hectares the country has today were rehabilitated with grain plantations, Brazil would triple the current production of crops like corn and soybeans. "It would be so big a production that there would be no market in the world to absorb it today", he calculates. However, thinking about a future scenario in which the planet could have as many as 9 billion inhabitants in the year 2050, this possibility may be essential to feed such population.

"The integrated systems will be the biggest leap in food production that the planet has ever seen, precisely because it is happening in a tropical region that has the best conditions in the world to produce food, especially Brazil and some South American countries", the Embrapa researcher completes. »

Photo: Thinkstock/Embrapa

INTEGRATED

From soil and water

1

Barreirão

Grass intercropped with annual crops to rehabilitate pastures.

2

Santa fé

Grains intercropped with grass for animal feed during the dry season, and soil coverage for no-till farming.

3

No-till farming

Sowing on the remains from the previous crop, without tilling the soil, and with crop rotation.

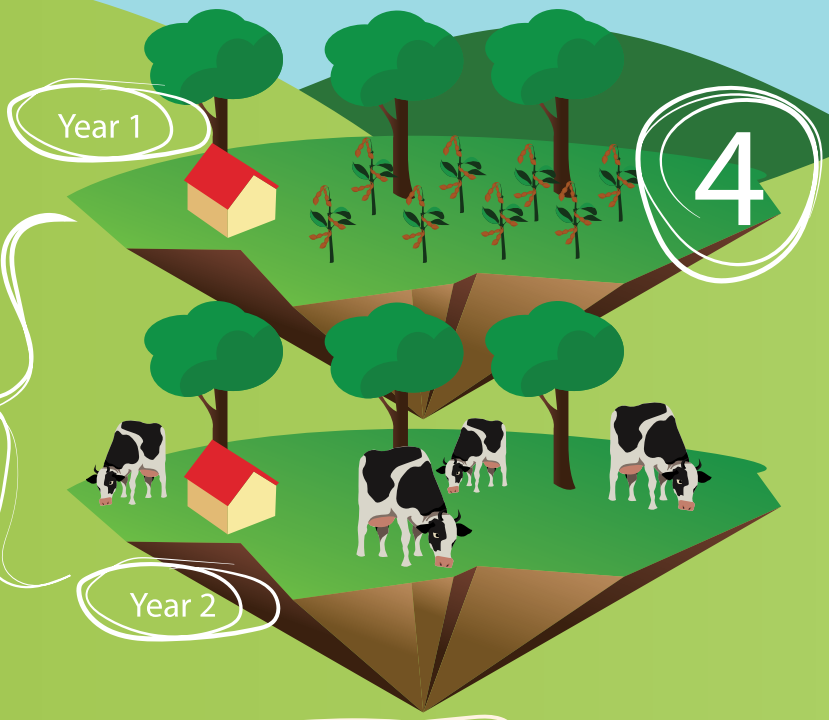
Infographic: Felipe Sousa

TECHNOLOGIES

conservation to animal welfare

Crop rotation

Cyclic and seasonally ordered alternation of different crops in the same area.



Sequential cropping

Repetition of two crops in the same area, yielding harvests and off-season harvests, and producing throughout the year, for several years.

Photo: Gabriel Rezende Faria / Embrapa

FORESTS IN THE COUNTRYSIDE

HOW TREES CAN IMPROVE PRODUCTION

By Katia Pichelli

Eight years ago, when putting trees in pastures seemed an outrageous idea, the condominium Pizzolato, in Saudade do Iguaçu, in the southwest region of Paraná, converted 10.2 hectares of pasture into a silvopastoral system, one of the ICLF technologies, associating the Jersey dairy cattle with a Bermuda grass (*Cynodon* spp.) pasture and trees of the *Grevilea robusta* species. The place comprises the properties of four families of smallholders who have invested in technology and organization for the success of the proposal.

Soon the results came: the afforestation of the pasture contributed to higher cattle productivity, especially due to the thermal comfort provided to the animals, and also promoted soil conservation, influencing pasture quality. The condo has become one of Embrapa's Technological Reference Unit (URT) in partnership with Emater Paraná Institute and the Paraná Agronomic Institute (Iapar).

The rural producer Eugênio Pizzolatto tells that, when the farmers in the condominium started breeding dairy cattle, he noticed that the animals suffered a lot with the heat. "Embrapa and Emater made the proposal to perform the experiment with an integrated system. We have embraced the cause and had success. The thermal comfort for the animals has increased milk production. The animals are grateful!", he celebrates, recalling that, at the beginning, their neighbors saw the technology with distrust. Today, the condo is a benchmark for the entire region and conducts field days to show the various stages and techniques used. The key to their success? "Get information to avoid mistakes. Technical monitoring is essential. And don't do business without calculating and planning", the producer teaches.

In 2014 they held their first thinning, that is, the selective cutting of trees with lower development than the others. The goal is to reduce competition among trees and allow the remaining ones to keep growing to produce good timber and good log yield, in addition to regulating shading to enable the pasture to grow.

The Emater-Paraná veterinarian and extension agent José Antônio Vieira has monitored the condo since the implementation of the system and attests the benefits of the technology. “During hot spells, the cattle find a rather cool, healthy microclimate and, in the winter, a microclimate 4 to 5 degrees warmer. The presence of trees in pastures also helps to prevent rain and frost, which are extreme events for cattle and pastures. In dry periods, the trees help to retain the moisture required for the development of grass”.

The first data from the condo analyzed indicated a 20% increase in the volume of milk produced. With regard to grevillea, the first trees thinned can be used for production of fine wood products such as wood strips. In the 10.2 ha, 2,200 trees were planted and, in the first thinning, 710 trees were removed, representing the harvest of about 110 m^3 of wood. This volume has already given farmers enough income for the purchase of a portable sawmill. There are still 776 trees that, if removed today, would represent a volume of 237 m^3. The expectation is that these trees remain in the system for at least another four or five years, providing for an increase in wood volume as well as a product with higher market value, since the type of wood produced may be sold to sawmills (furniture and frame manufacturers).

FOREST SCIENCE

Behind the results there is a lot of research. In an integrated system, the tree is a production component, so the species used must have genetic material known to be productive and adapted to the region. In addition, the integration must be very well planned, because it is often only possible to discover some problem after the trees are three or four years old, which may represent a great loss.

Although several forest species are used, the ones that are most planted today in ICLF systems in the country are eucalyptuses. Gradually, grevillea has also begun to gain ground. In fact, there is guidance towards the choice of species that have a market in the region where they are planted, since transport is a high-cost item in forest operations.

However, there is still little information on how these species behave in integrated systems. “There are important differences”, explains the Embrapa Forests researcher Vanderley Porfírio da Silva. “The main characteristics of the trees suffer changes depending on the type of spacing and planting conditions. When the trees are planted in a large, dense, continuous area of forest with tighter spacing, they behave in a way. But the spacing and conditions in integrated systems are quite different and they modify indicators such as, for example, branch thickness, growth ring thickness, average height, diameter, among others”, he adds.

A tree in monoculture tends to loose its branches naturally with more ease, but in an integrated system this is no longer the case. With more room to grow, the branches live longer and do not suffer from natural self-pruning, as expected. There is, therefore, much room for research, especially on genetic improvement and management, which can, among others, also offer options of new species for integrated systems.

Photo: Katia Regina Pichelli / Embrapa

Research on forestry, however, faces a peculiar challenge: the length of time to obtain responses. “The time length for research on crops or forage species that have annual life cycles, for example, is much smaller than the investigation of tree species, which have life cycles that are decades-long”, Porfírio compares.

The merging of different topics within a single space is the great innovation provided by the ICLF systems. Before them, the rural estate was seen as a sectional place in which each piece of land was intended for a certain type of activity. ICLF systems have brought a vision of integration which is being disseminated today. “This requires the ability to manage these components, understand the needs of each one of them, because resources such as water and electricity, for example, are shared”, explains Porfírio. Land use must be optimized; more products and goods must be produced simultaneously in the same land. »

THE CHALLENGES OF RESEARCH IN SILVICULTURE

The system needs to be refined and more research components need to be explored, in particular for forest management. It is not enough to simply plant trees. What will be the design executed? What will be the spacing between trees and between rows? How many rows of trees? In which period is it necessary to give more attention to each component? The basic premise to define the system is water and soil conservation, hence there is no "fixed recipe", and each case should be assessed based on its particularities. Opening more space for one of the components may end up harming others. A greater number of trees, for example, can damage pasture in terms of water resources. Focusing only on grains, on the other hand, can result in a weak investment in forest management, which will not provide the desired effects of shading or even the extra profit. It is a process of resource optimization, i.e. light, water, soil, nutrients, microclimate, between animals and plants, meeting the needs of each component.

The adoption of ICLF systems also helps to mitigate greenhouse gas emissions, one of the Brazilian commitments to mitigate climate change. The country currently has the Low-Carbon Agriculture Plan , associated with the ABC Program, which is a line of credit for farmers to adopt mitigating technologies, as is the case with the livestock-forest systems (see article on page 28). "The Plan has held training sessions throughout the country to help farmers adopt technologies that mitigate GHG emissions. ICLF systems are examples of such technologies. In addition to the benefits of the integration itself, ICLF systems encourage land-use planning, and this is crucial for sustainable agriculture", says Renato Vianna, from Emater/Seab Paraná and state representative of the ABC Program.

Forestry research also strives to understand the relationship between trees and carbon sequestration, so that there is a beneficial balance between carbon

Photo: Fabiano Bastos / Embrapa

sequestration, animal comfort and wood production. “Nobody will invest in something that has no returns. Clearly, today people have discovered that profit comes not just from the direct product itself, but also from indirect ones such as, for example, the image of the business”, says Porfírio. “If we have livestock and agriculture that are proven to be low-carbon, the product will be more valorized by the international market”, he claims.

There is still great potential for the adoption of ICFL systems from the forestry point of view. Since Brazil today presents a large set of degraded pastures and most of its wood consumption still comes from native forests, the systems that involve forests become a great business opportunity and contribute to the positive image of the sector. “Sustainable rural properties now work with short, medium and long-term components, and in the latter case forest production fits perfectly. Quality wood production is what the market needs and ICLF systems work within that perspective”, says Amauri Ferreira Pinto, state forestry production manager of Emater Paraná, who emphasizes that planting forest species with economic purposes is today one of the main components of income and environmental sustainability in rural properties, and also provides a high rate of return.

Diversification promotes greater economic security to the producer. An emblematic case happened in the northwest region of Paraná, in a period in which cattle farming went through major problems. “If it were not for the trees of the livestock-forest system, the producer would have abandoned livestock production. The trees paid the bills for a while, and producers remained in livestock production. Otherwise, they would have had to sell the dams, part of the herd, which could have ended their business”, recalls Porfírio. Therefore, ICLF systems are deemed to be resilient: when one of the components does not do well, the other can compensate for it. »

Photo: Kadijah Suleiman / Embrapa

SUSTAINABLE LIVESTOCK PRODUCTION IN THE AMAZON

By Renata Silva

The Don Aro farm, in Machadinho d'Oeste, Rondônia, is managing to solve serious problems related to degraded pastures, which affected not only the soil, but also productivity and income. The changes are occurring after the owner, the cattle breeder Giocondo Vale, bet on integrated crop-livestock-forestry systems (ICLF) to renew the pasture, rehabilitate the soil and thus improve productivity. With the renewed pasture, cattle began to consume less mineral supplement, and gains also occurred in the weaning, which can start at nine months of age. The cattle breeder reports that he also obtained great improvement in weaning weight, jumping from 7.29 to 8.5 arrobas (males), and from 6.51 to 7.7 (females), a 17.5% increase providing additional gains of around R$ 140 to 170 per head.

Currently he has 674 animals on the property and is producing new animals by crossing (British) Aberdeen Angus and Nelore breeds, rendering greater precocity for the slaughter and tenderer meat. The zootechnician from Embrapa Rondônia Elisa Osmari explains that the improvement in animal nutrition, through pasture rehabilitation via crop-livestock integration, is the cause for the excellent results achieved. "There is also the positive performance of the forestry component, because the existing trees in the Don Aro property provide suitable shading and greater thermal comfort for the cattle resulting from the European crossing, which has darker fur and greater susceptibility to heat", she states.

The cattle breeder began adopting the CL integration in his property assigning 96 acres for the intercropping of rice with the *Brachiaria ruziziensis* grass and did not stop there. The property's rice production in the 2012/2013 harvest was 9,700 bags of 50 kg each in 185 hectares. In the 2013/2014 harvest, using 385 ha, 20,050 bags were obtained. And for this year's harvest, Vale expanded production to 400 planted hectares. "Today my property has about 67% of the area for grain crops

or temporary pastures, and by December 2017 I will have 100% of the area used for mechanized production, with soil correction, and in integrated systems. We are working to accomplish that", says the owner, who has beef cattle as one of its main activities.

The crop-livestock integration adopted in the property is temporary, that is, an area is used for a few years with crops, then pastures, which in turn end up having its formation cost lowered because of the use of residual fertilizers. After harvesting the crop in the main cropping season, he also plants mid-season (second season) forage crops such as sorghum to feed the cattle. The goal is to have a high-quality pasture in the mid-season and, at the same time, ensure the production of whole grains for animal supplementation for females at the finishing stage. To do this, the producer is planting corn to be used as animal feed. As for the forestry component, planting is done in blocks, which are inserted within areas with grain crops or livestock.

The Don Aro farm is a sustainability model in the region. It is important to emphasize that Machadinho d'Oeste was among the 43 municipalities in the Amazon area that had the highest deforestation rates in the region, and was included in the actions within the Green Arc/Legal Land program (government), aimed at reducing deforestation in partnership with Embrapa and other institutions.

At the opposite side of the deforestation trend, Vale has been working with livestock for 25 years in almost 1,600 hectares of land, without the use of slash and burn and with sustainable practices. "Historically we have opted for 'zero fire' here in Don Aro. That is, we do not use fire in pastures and forests", he comments. The property has 42% of its total area covered by native vegetation; reforestation in blocks; and permanent preservation areas (PPA) duly registered at the *Cadastro Ambiental Rural* (CAR) (Brazilian Environmental Registry of Rural Areas) with the responsible institution.

The Don Aro farm is the first property of Rondônia to receive the certificate of adequacy from the Program of Agricultural Best Practices - Beef Cattle, coordinated by Embrapa. It is also the second in the Northern region to receive the Gold rating, for meeting 100% of mandatory items and 80% of the highly recommended items of the program - the tenth in Brazil in this category. The adoption of ICLF systems is not mandatory for the program, but it is a highly recommended item. Once he was aware of it, Giocondo Vale adopted the system and has no regrets. "At first, the production in an integrated system and the search for sustainability in a rural enterprise was practically unknown in our region. Today we are aware of the advantages of an integrated and sustainable production", he concludes.

With Embrapa's support and encouragement through the best practices program, the cattle breeder managed to better organize and structure actions in his property, going beyond the recommendations. The Don Aro farm is the first in the state of Rondônia to apply the Solid Waste Management Program, as well as the "Zero Waste" Plan. In addition to triple washing, a procedure to remove pesticides by washing containers three times, selective waste collection is performed in accordance with the legislation. Giocondo is also investing in the recovery of permanent preservation areas, by planting two thousand seedlings of native species and 11,000 seedlings of Brazil nut trees, the largest planting conducted by an individual in Brazil. "We are proving that it is possible to have a sustainable agricultural business, and be environmentally friendly, economically viable and socially fair", the producer argues.

The case of the Don Aro farm is a model for Rondônia. The advantages of ICLF systems for the country are proven by technical, economic, social, and especially environmental feasibility analyses. Their application in different biomes and the range of possible combinations between agriculture, livestock and forest, that is, either crop-livestock, crop-forest, livestock-forest, or crop-livestock-forest integrations, offer both the producer and the system great versatility, and consider cultural, economic and environmental components for better adaptation to the reality of each region. »

Photo: Thinkstock/Embrapa

Image: Nasa.gov

ABC PLAN

BRAZIL CUTS CARBON EMISSIONS FROM ITS AGRICULTURE

By Katia Pichelli

Brazil has promised to reduce by more than a third its greenhouse gas (GHG) emissions by 2020. But what does this have to do with farming? Agriculture and forest- and land-use changes are responsible for part of the Brazilian greenhouse gas emissions, and among the commitments made by the country there is a plan to cut GHG emissions from the agricultural sector by 133 million to 166 million tons of carbon equivalent between 2010 and 2020. For that purpose, among other actions, the public policy Sectorial Plan for Climate Change Mitigation and Adaptation for the Consolidation of a Low Carbon Economy in Agriculture, also known as the ABC Plan (– http://www.agricultura.gov.br/desenvolvimento-sustentavel/plano-abc), was developed by the Civil Cabinet of the Brazilian Presidency, the Brazilian Ministry of Agriculture, Livestock and Food Supply and the Brazilian Ministry of Agrarian Development, with the collaboration of government institutions, non-governmental organizations and the private sector.
The ABC Plan works with seven programs:

1. Rehabilitation of degraded pastures- this practice and the maintenance of pasture productivity contribute to mitigating greenhouse gas emissions;

2. Integrated crop-livestock-forestry (ICLF) systems and agroforestry systems (AFS) - contribute to the rehabilitation of degraded areas, as well as the maintenance and restoration of the forest cover. Trees are great carbon fixers, that is, they reduce and neutralize greenhouse gases emitted from production;

Photo: Gabriel Rezende Faria / Embrapa

3. No-till farming system - practice of leaving the stubble from the previous crop. Associated with conservation farming, no-till contributes to soil and water conservation, fertilization efficiency, organic matter content in the soil, reduction in the use of pesticides, mitigation of greenhouse gas emissions, and also contributes to soil resilience;

4. Biological nitrogen fixation (BNF) - instead of extracting nitrogen directly from the soil, the plant itself produces it through bacteria inside their root: the rhizobia. BNF reduces production costs, decreases risks for the environment by reducing greenhouse gas emissions, and also increases organic matter content (carbon sequestration) and improves soil fertility;

5. Planted forests - besides being a source of long-term income for the producer's family, they increase the wood supply for industrial, energy, construction and other purposes; they also reduce pressure on native forests and capture CO_2 from the atmosphere, reducing the effects of global warming;

6. Treatment of animal waste - proper treatment of effluents and waste contributes to a reduction in the emission of methane, one of the most potent greenhouse gases. It enables an increase in farmers' income, either due to the organic compound produced or through the generation of biogas-fuelled automotive, thermal and electrical power;

7. Adaptation to climate change - the previous items comprise strategies on how agriculture can help reduce GHG emissions, while adaptation has to do with technologies to assist agriculture to adapt to climate change. Depending on the scenario, there may be changes in the distribution of rainfall, temperature and other factors that directly influence the crop cycles and the vegetation, which can result in lower yields and lower quality products, which in turn could cause major losses in agriculture and jeopardize food security and the permanence of farmers in the field. The strategy is to invest more effectively in agriculture, promoting diversified systems and the sustainable use of biodiversity and water resources, supporting the processes of ecological transition, organization of production, ensuring income generation, research (genetic resources and improvement, water resources, adaptation of production systems, identification of vulnerabilities and modeling), among other initiatives. »

For the implementation of the activities established in the ABC Plan, a credit line was created, the ABC Program, to which farmers have access through projects submitted to commercial banks. State Managing Groups were created throughout the country to establish initiatives and to define state objectives and goals, observing each region's needs and opportunities.

In the 2014-2015 Agricultural and Livestock Plan, for example, R$ 4.5 billion were offered to the ABC Program for special credit lines. However, the farmers' adherence is still low, especially for ICLF initiatives. According to Elvison Nunes Ramos, coordinator of Sustainable Management of Production Systems of the Ministry of Agriculture, "because it is a more complex technology in relation to project elaboration and implementation in the field, it is a slow process, but with significant advances as the managing groups conclude their state plans". The ABC Program's goal is to expand ICLF systems so that they can be used in four million hectares. "ICLF systems are more complex to implement because they involve knowledge on forests, agriculture and livestock", adds Elvison. Considering such perspective, the ABC Plan also focused on the training of technicians and financiers to better understand ICLF systems and thus be able to prepare and analyze projects. About 20 thousand people have already been trained throughout the country to support the ABC

Photo: Thinkstock/Embrapa

Plan: technicians (70%), producers and students (30%).

In addition to the funding and training of the people involved, the ABC Plan also provides funding for research and monitoring of mitigation actions, with revisions and updates of the plan every two years.

UNDERSTAND THE COMMITMENT

Brazil has signed the United Nations Framework Convention on Climate Change, which aims at stabilizing greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous interference from human activities in the climate system. As a goal, during the Copenhagen Conference, which took place in 2009 (COP 15), the country took on the commitment of cutting between 36.1% and 38.9% of its projected greenhouse gas (GHG) emissions by 2020. This commitment has become the National Policy on Climate Change (Law 12,187, 2009), and the decree that regulates it (Decree 7,390, 2010) also includes the elaboration of sectoral plans.

A study published in *Science* magazine (June 2014) showed that Brazil has reduced 70% of the deforestation of the Amazon rainforest and cut CO_2 emissions into the atmosphere in 3.2 billion tons of CO_2 between 2004 and 2013. The work is signed by scientists from the Earth Innovation Institute, in the United States, and the Amazon Environmental Research Institute, in Brazil, and concluded that 86,000 square kilometers of forest were spared from deforestation, an area larger than the territory of Austria. »

Image: Thinkstock/Embrapa

KEEPING AN EYE ON THE EMISSIONS

To monitor the implementation and execution of the Plan, the Getúlio Vargas Foundation Center for Agribusiness Studies (GVAgro), in partnership with their Center for Sustainability Studies (GVces), created the ABC Observatory, with the goal of developing studies and promoting discussions about low carbon agriculture and the implementation of the ABC Plan. To learn more, visit: www.observatorioabc.com.br

In 2015, Embrapa will inaugurate the Multi-Institutional Laboratory for the Monitoring of the ABC Plan (LiM-ABC), a structure of 729 m^2 dedicated to gathering technical data from across the country related to low carbon-emitting agricultural practices. The building is located at Embrapa Environment, in Jaguariúna, São Paulo, and is the result of a R$ 4.4 million investment – R$ 2,4 million of which invested in equipment. The Ministry of Environment has funded R$ 2 million and the rest was invested by Embrapa.

Photo: Secom/PR

AGROFORESTRY SYSTEMS IN THE AMAZON REGION

FAMILY FARMING IS DEVELOPED IN HARMONY WITH THE FOREST

By Ana Laura Lima
and Izabel Drulla Brandão

The knowledge of the Amazon people allied with science is the key to overcome the challenge of sustainability. This is the premise of Embrapa for the development of research and technologies related to agroforestry systems (AFSs), in which agriculture and forest are uniting food production with the conservation of natural resources. This model of production is traditional in family farming systems in the Northeast region of Pará.

The AFSs associate agricultural crops or animals with forest species, simultaneously or in a sequence, and research studies the interactions within such systems. The models are varied and adapted to producers' needs –agroforestry intercropping of mahogany with black pepper; planted forests of *paricá* (*Schizolobium excelsum* var. amazonicum Ducke) of rapid growth, suitable for the production of plywood in a livestock-forest system; intercrop-

ping of eucalyptus with pasture; and agroforestry systems in lowland areas.

For dairy and beef cattle, integrated crop-livestock-forestry (ICLF) systems dispense with the need for clearing forest areas for new pastures, rehabilitate degraded pastures and provide comfort and a higher quality of life for the cattle.

Photo: Thinkstock/Embrapa

MORE EFFICIENT MITIGATION

Family farming is an alternative for the expansion of African oil palm in northeastern Pará. Embrapa performs research that integrates soybean crops with AFSs in the region. The results are positive and show that agroforestry systems integrated with oil palm have a positive influence on the carbon and nutrients cycle, as they are quite efficient in storing these components in the soil. In the analyzed area, in Tomé-Açu, it was found that the most diversified AFS with oil palm has accumulated 28% more carbon in the soil than the traditional AFS, and 23% more than the secondary forest.

"The economic, environmental and social benefits of the AFSs are countless", says researcher Osvaldo Kato, who gives some examples: diversification of agricultural and forestry production in the property; landscape restoration, reforestation and rehabilitation of degraded areas; increase in soil production capacity, food security and increased income for the farmer; environmental conservation and increase in flora and fauna biodiversity; reduction in deforestation, in forest fires and of impacts on global climate change.

TRADITIONAL KNOWLEDGE HELPS SCIENCE

Among the experiences that Embrapa has been studying in Pará there are initiatives of farmers who are considered experimenters or innovators by the researchers. From the traditional knowledge and observation of the forest, they develop systems with environmental, economic and social viability.

Pedro Araújo Ferreira, 46 years old, a farmer in São Domingos do Capim, in Northeastern Pará, transmitted his knowledge to researchers and extension technicians. He is a reference in Agroforestry Systems in the Monte Sião community, on the banks of Capim river. In his 66-hectares property, he manages only 18 hectares, which is the source of livelihood for his family (wife and five children), with the production of açaí berries, cocoa, banana and tree species that are native to the Amazon. No wonder his land has become a reference in Agroecology.

"The configuration of the species is random, only with a certain distance between them so there is no competition. One completes the other giving shade and food. I try to mimic the forest, and 100% of my production is organic, without the use of fire", the farmer explains. Pedro's story is guided by the desire to understand the forest, experiment and innovate. »

Photo: Priscila Viudes / Embrapa

A SEED OF MORE THAN TWO DECADES

By Fabio Reynol

Producing goodies as distinct as milk, wood, soybeans and corn in the same field was not usual for traditional agronomic research, normally dedicated to solving issues focused on specific species and themes. Therefore, the emergence of integrated production systems was also the result of a systemic scientific view built over the last decades.

In July 1994, Embrapa has coordinated the 1st Brazilian Congress on Agroforestry and the 1st Meeting on Agroforestry Systems in the MERCOSUR countries, in Porto Velho (RO).

The event was promoted by two of Embrapa's research centers, Embrapa Rondônia and Embrapa Forests. Both worked with integrated systems, but with different elements: the Northern Unit located in the state of Rondônia was investigating ways to make agricultural production in the midst of native forest viable, a concept called "agroforestry". The research center in the state of Paraná, on the other hand, was looking for ways to insert the planting of trees in crop areas.

The meeting in Porto Velho originated the Congresses of the Brazilian Society of Agroforestry, whose ninth edition was held in October 2013 in Ilhéus, Bahia.

Agroforestry research had been established in six Embrapa research centers, all located in Northern Brazil, in the states of Acre, Amapá, Amazonas, Pará, Rondônia and Roraima. "The concept promotes agricultural production without taking anything from the forest, fitting with it", explains the agricultural engineer Vanderley Porfírio da Silva, researcher at Embrapa Forests. At the time, agroforestry production systems were something new. "The commonplace was to have only crops or trees in an area, in the case of silviculture, and when trees were put in pastures, the goal was to provide animals with shade. No one had the idea that they could be a source of income", he comments.

Some of Embrapa's centers had developed systems for pasture rehabilitation (see infographic, page 20) and improved cattle feed. The innovation of no-till farming, according to Porfírio, has provided conditions for the establishment of the systems and, in 2006, the first experiments with silviculture in the Cerrado appeared. "Then ICLF systems left the Amazonian context to become part of Brazilian agribusiness", analyzes the researcher.

For him, the most notable occurrence for the project was the 1994 Congress. "It is very significant that, two decades later, Embrapa is once again at the forefront of a similar event, now with global reach. This story needs to be rescued and remembered to increase awareness of the challenges that have brought us to this current level of research", he concludes.

INTEGRATION OF RESEARCH PROJECTS

To guide and organize research on integrated crop-livestock-forestry (ICLF) systems and to better monitor the results obtained, in 2013 Embrapa created a portfolio to manage studies on this theme. This structure seeks to align research and technology transfer projects with the strategic objectives of the organization, and achieve greater efficiency in the use of infrastructure and professionals. The Chairman of the Steering Committee of the ICLF Portfolio is Lourival Vilela, one of the leading Brazilian researchers from Embrapa Cerrados.

The Portfolio is expected to gather all efforts concerning ICLF systems so that studies are convergent and complementary. It helps the obtained results to be more effective and brings greater benefits to users of this technology.

According to the Executive Secretary of the Steering Committee of the ICLF Portfolio and researcher from Embrapa Eastern Amazon Gladys Martínez, it is possible to better map the research conducted by Embrapa when the projects are gathered in a single platform.

"You begin to have a broad horizon of the research on integrated systems across the country and thus you can connect information. With the portfolio we see that several issues are or have been studied. But we have also observed a lot of gaps that must be filled", she explains.

The portfolio currently has 20 ongoing projects and 17 have already been completed. Among those in progress, 19 are related to research and development and 1 to technology transfer.

Altogether nearly R$ 15.6 million are being invested in actions on the development of technologies, more knowledge about the interactions between components, evaluation of the production process and development of sustainability metrics.

Most of these projects are transdisciplinary and multi-institutional in nature, combining different Embrapa Units and other research institutions.

THEMATIC LINES

The ICLF portfolio has three priority lines organized by themes: technology development, social economy and technology transfer. These lines meet the main challenges related to knowledge advance, fomentation and use of these complex systems, as well as the development of environmental, social and economic sustainability indicators to reveal the impacts arising out of the adoption of ICLF systems.

In the thematic line of technology, one finds research focused on the competitiveness and sustainability of integrated production systems.

This line also includes studies on the interaction between biotic and abiotic degradation of components, design of integrated systems in space and time, the management of components in integration, efficient use of inputs with emphasis to water, greenhouse gas dynamics, development of cultivars that are more suitable to ICLF systems, nutrient cycling, development of sustainability indicators, and energy conversion and balance in the systems.

The line dedicated to socioeconomics has the purpose of generating economic information for better understanding of the systems and to foster policies to support and promote the technology. This line comprises research focused on the development »

Photo: Fabiano Bastos / Embrapa

of standardized methods and tools for economic, social and environmental analysis, analysis of opportunity costs and appreciation of environmental services.

The line focused on technology transfer, on the other hand, organizes actions to disseminate the technology, making sure it will be available for producers. Capacity-building projects for technical assistance and rural extension agents, validation of technologies, implementation of Technological Reference Units, and communication and marketing are part of this research line of the portfolio.

In addition to the division into thematic lines, the ICLF portfolio seeks to organize regional research projects, promoting the interaction between research institutions and generating more accurate information for each biome.

"When you regionalize research, you are covering areas with the same problems and the same production conditions. With regionalization we will deal with our similarities and try to achieve the technology development or the way of working that is better suited for the region", explains the portfolio's secretary, Gladys Martínez.

Illustration: Rafe Braga

MULTIDISCIPLINARY RESEARCH

Research involving complex systems such as integrated crop-livestock--forestry integration requires multidisciplinarity and integrated efforts. It takes the expertise of a team with different specialties to study the interaction between the components and the effects of each on the others.

To make this possible, a heterogeneous team of researchers is working on the topic. Currently, more than 30 Embrapa Units are developing activities with integrated systems, and studies that also have the participation of scientists from partner institutions are common. Altogether, 609 people are working on these projects, and 518 are Embrapa's staff.

An example of the effort in the studies on ICLF system was the creation of Embrapa Agrosilvopastoral, in Sinop, Mato Grosso, in 2009. The Unit's main objective is to study integrated systems. To this end, it has a team of researchers working together on two major large-scale and long-term experiments. At the same time, other research unit was created in Palmas, Tocantins: Embrapa Fishing and Aquaculture, which has a thematic core team of 16 researchers and analysts that are specifically focused on integrated production systems for the region of Matopiba, considered the country's last agricultural frontier– covering agricultural areas in the states of Maranhão, Tocantins, Piauí and Bahia. In addition, researchers of other Embrapa Units collect data and develop research in

PARTNERSHIP TO PROMOTE ICLF SYSTEMS

By Fabio Reynol

To accelerate the adoption of integrated crop-livestock-forest systems by farmers, the ICLF Development Network was created in 2013, and it comprised Embrapa and six private companies: Cocamar, Dow, John Deere, Parker, Syngenta and Schaeffler. It is a public-private partnership (PPP) created in the light of the commitment to reduce greenhouse gas emissions made by Brazil at COP15, at the end of 2009 (see the text on ABC Plan on page 28). The network supports technology transfer on ICLF systems to farmers, promoting increase in income and sustainable production.

The network includes investments of approximately R$ 15 million – R$ 2.5 million of each private partner. Embrapa provides scientific knowledge and technical support for the diffusion of technologies. "It is a sum of forces in which intelligence [Embrapa] and muscle [private sector] are brought together to accelerate the progress of a sector", says Paulo Herrmann, president of John Deere and coordinator of the General Assembly of the Development Network. Currently, Embrapa's representative in the Assembly is the Executive Director of Research, Ladislau Martin Neto. The network also has a Steering Committee for tactical and operational actions, chaired by researcher Ronaldo Andrade, from Embrapa's Business Secretariat.

The main activities supported by the Development Network are linked to technology transfer actions through the dissemination of the best practices in integrated systems. There are about 200 Technological Reference Units distributed throughout Brazil, which work to test the technologies and disseminate them in their surroundings.

In addition to implementing, conducting and following-up on the reference units' activities, the network also supports lectures, courses, workshops, seminars and field days, with the aim of promoting the adoption of integrated systems in various regions of the country. There are hundreds of events held annually to promote the exchange of information between technicians and producers who wish to adopt integration.

"A great example of the events run by the ICLF Development Network is the field day at the Santa Brígida farm, in Ipameri (GO), which is already in its ninth edition and has become a national and international reference in the development of integrated crop-livestock-forestry systems", informs Herrmann. The initiative counts on the support of Embrapa Cerrados.

For the John Deere executive, ICLF systems represent the beginning of a radical change in the country. "It is the key for a revolution in tropical agriculture with more food production with environmental preservation. It proves that these two activities are not self-exclusive", he says.

these experiments that use more than 80 hectares.

"The ICLF approach has to be multidisciplinary because we are dealing with associated elements. The integration of the results is another challenge. Researchers must cross individual data to obtain greater complexity of information. The platform is integrated, the areas are multidisciplinary, and the analysis of the results has to be done in an integrated way. This is a huge scientific challenge", states the Head of Embrapa Agrosilvopastoral, João Flávio Veloso Silva.

Another characteristic of the research on ICLF systems is the long period required to obtain results. For tests with the agricultural and livestock components, at least five years are necessary so that the effects of the system can be verified. When the system also has the tree component, the time needed is even greater, reaching 20 to 25 years depending on the forest species used. •

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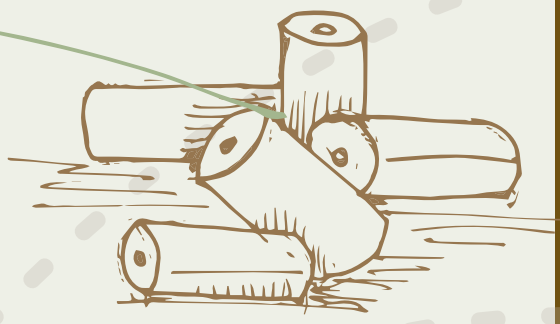


Elephant grass (*Pennisetum purpureum*) is an alternative to generate thermoelectric power and replace firewood.

By Vivian Chies
Art: Luciana Fernandes

The name of the current biggest land animal fits like a glove to elephant grass. The plant reaches the height of four meters just six months after sowing. With an African origin, it was introduced in Brazil in the late 1920s and is grown throughout the country, mainly in forage grass systems. Picked and chopped, it is offered as food to livestock, usually during the winter, when drought and cold leave animals without pastures. But such a production volume has also arisen the interest of another field: energy.

Elephant grass can supply biomass that, as it is burned, generates energy and steam that drives turbines and triggers generators. This is what Sykué Bioenergya, in São Desidério, Bahia, is doing, adding energy in the Brazilian transmission network. In the state of Goiás, some red ceramic industries, as an experiment, have used grass instead of wood in the ovens. The elephant grass can also become ecological firewood through a compression process that turns it into briquettes or pellets. Finally, it serves as raw material for cellulosic ethanol, known as 2nd generation (2G) ethanol. Like any plant, from its cellulose one can extract sugars, that, when fermented, originate biofuel that can fuel cars and even airplanes.

The background for the effort of institutions and companies in the development of technology of cultivation and processing of elephant grass for energy is the pressure for the adoption of less impactful solutions from an environmental point of view. The Conference of the Parties on Climate Change (COP-20), held in Peru in December 2014, pointed out the need for a reduction of 40% to 70% of GHG emissions by 2050, so as not to exceed the 2°C increase of average temperatures in the planet by the end of this century. The use of clean energy, such as from the use of elephant grass biomass, is on the list of investigated alternatives.

According to the researcher José Dilcio Rocha, from Embrapa Agroenergy, the insertion of elephant grass in the national energy network has a strategic role. First, this grass can be a tool for the decentralization of production, allowing the generation of electricity and the production of bioenergy in places where the construction of dams or traditional biomass cultivation is not possible. The Brazilian Ministry of Mines and Energy forecasts the need to increase the installed capacity of power generation in Brazil from the current 124.8 GW to 195.9 GW until 2023. “Sometimes the solution you need is not national, but regional”, says Rocha.

PRODUCTION PER YEAR

Various other plants, such as sugarcane and eucalyptus, are already or may be used for those applications. Then, why invest in elephant grass? High productivity is the first answer. The Embrapa Coastal Tablelands researcher Anderson Marafon says that, with two annual harvests, between 150 and 200 tons of fresh mass are drawn per cultivated hectare, which yields from 40 to 50 tons of dry mass.

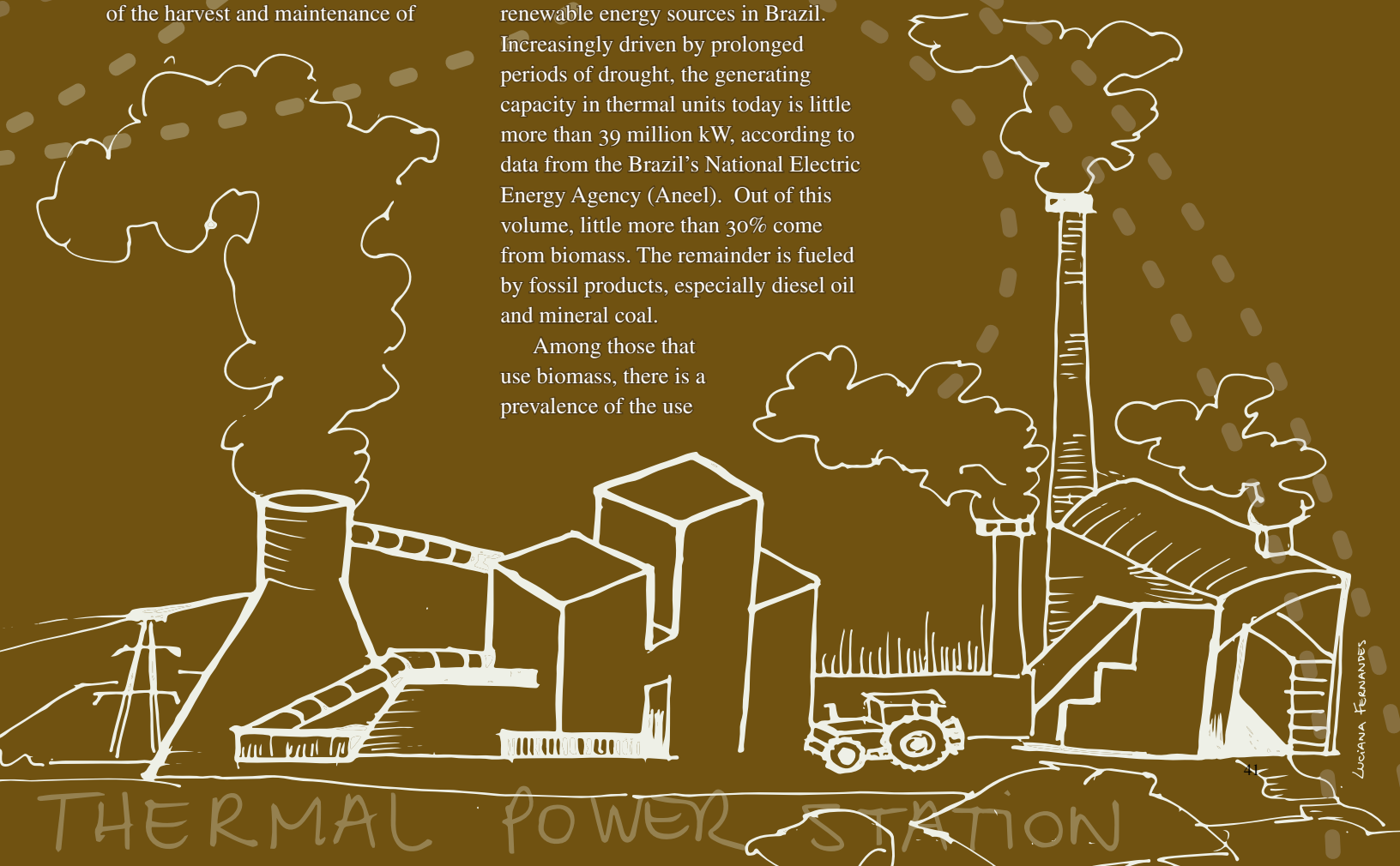
Studies show that, if the goal is to produce biomass for energy, the first harvest of elephant grass can be done six months after planting. For sugarcane, this period is three times longer and, for eucalyptus, it goes as far as seven years. In addition, elephant grass is a perennial species. If and only if it is well managed, a cultivated area with the grass can continue re-sprouting for many years. The possibility of mechanization of the harvest and maintenance of a continuous flow of raw materials throughout the year are other advantages pointed out.

In the production of bricks, tiles and other red ceramic products, some companies are beginning to experiment with replacing wood by elephant grass in the ovens. The Center of Alternative Renewable Energies of the government of Goiás is investing in the grass as biomass to supply the sector with energy, avoiding middlemen in the purchase of firewood and preventing the use of native wood. The Center's development manager, Victor Salomão de Pina, tells that a project to promote the use of raw materials, especially in the area of Anápolis, is under development. "The main challenge is to dominate the production chain and the lack of technical knowledge of those who want to use it", he comments.

Elephant grass could also broaden the participation and diversify renewable energy sources in Brazil. Increasingly driven by prolonged periods of drought, the generating capacity in thermal units today is little more than 39 million kW, according to data from the Brazil's National Electric Energy Agency (Aneel). Out of this volume, little more than 30% come from biomass. The remainder is fueled by fossil products, especially diesel oil and mineral coal.

Among those that use biomass, there is a prevalence of the use of bagasse – which mainly supplies the very own sugar mills that produce it with energy– and wood waste. Elephant grass already appears as fuel to two companies: one in Amapá and another in Bahia. The latter is the most emblematic experience of the use of elephant grass for energy purposes in Brazil. With an installed capacity of 30 million kW, Sykué Bioenergya began to put the project of transforming this grass into electricity into practice three years ago, when the first seedlings were planted in São Desidério, Bahia.

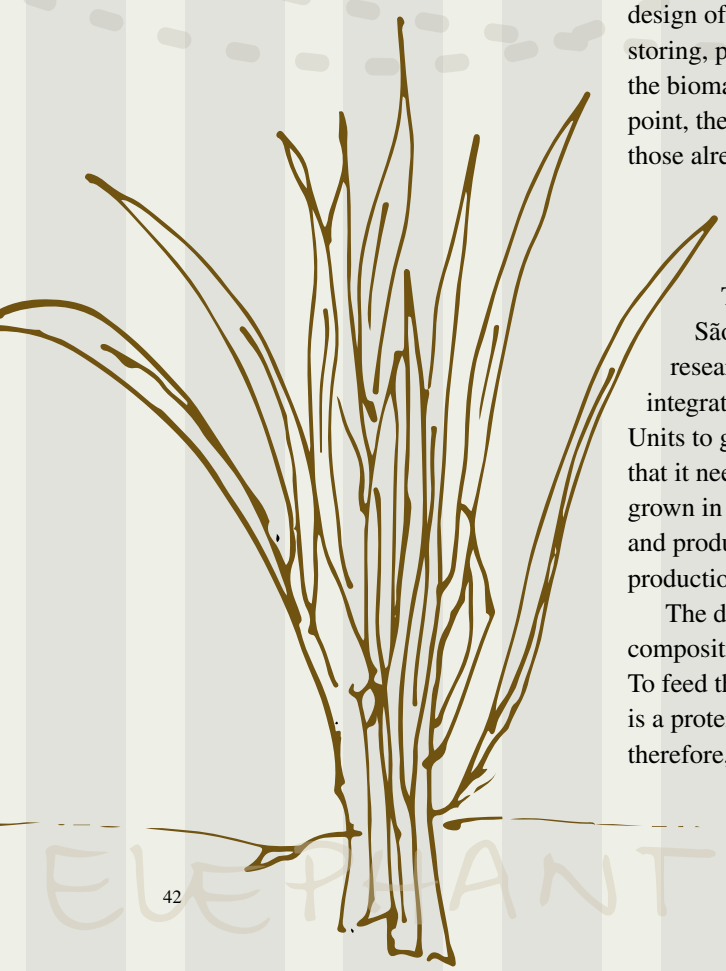
The project coordinator, Giovanna Rajoy, and the Sykué CEO, Carlos Taparelli, reveal that many difficulties are being encountered in the pioneering initiative. Inadequate seedlings, productivity that is lower than expected, high humidity and need for investment to be higher than initially planned are among the problems. Is there any firm intention »



to expand the use of elephant grass for energy generation? The decision will only be taken after a few years of experimentation.

Giovanna and Taparelli understand that knowing the production cycle better and establishing technological routes for other uses of the grass – ethanol, for example – are among the needs. The vice-president of technology and development of Dedini Indústrias de Base, in Piracicaba, São Paulo, José Luiz Olivério, reinforces that knowing the biomass that serves as fuel well is the most important factor for the good performance of a thermal project. "The wealth from the sugarcane is produced in the fields; the power plant has the role of not losing what the field produced", he informs.

The company of the countryside of São Paulo was responsible for planning and assembling Sykué's industrial plant. "That really excited us because it was an unprecedented challenge; at that time, no other facility known to produce electric energy from the elephant grass existed", says Olivério. The main restraint was the design of the structure for receiving, storing, processing and transporting the biomass to the furnaces. From that point, the project is quite similar to those already used for the burning of sugarcane bagasse.



IN THE FIELD

The challenges identified in São Desidério are subject of research being developed in an integrated way in various Embrapa Units to give the sector the answers that it needs. Currently, the grass is grown in small areas, using varieties and production systems that have the production of forage as target.

The difference begins at the composition of the desired material. To feed the cattle, what is desirable is a protein-rich biomass that has, therefore, a low carbon/nitrogen ratio. When the goal is to use the material as fuel, what is sought is the exact opposite. "This result was achieved only with management, increasing the range of cutting and reducing nitrogen fertilization", explains the researcher Francisco Ledo, from Embrapa Dairy Cattle (MG). In this Unit lies the corporation's elephant grass Active Germplasm Bank , comprising 120 varieties.

The first action of Embrapa to use elephant grass as biomass for energy purposes has been the evaluation of available varieties to identify the most suitable one. The researcher Antônio Vander Pereira, from Embrapa Dairy Cattle, clarifies that, although the development of specific varieties for this application is on the horizon of the work, there is no need to wait years for it. "The materials that we already have are highly productive and suitable for the energy production", he guarantees. Soon, technical recommendations should be released accordingly.

Actions for genetic improvement have also already started. With a project inserted at Embrapa's portfolio for the sugar-energy sector, the gene bank's accessions are being reassessed, seeking materials with desirable characteristics for future programs of cultivar development. "Our intention is to generate resources for the implementation of a specific project for power generation with elephant grass", says the project

leader, Juarez Campolina Machado. There is a network of research institutions participating in the tests, in four regions of the country: South, Southeast, Midwest and Northeast.

Embrapa Agroenergy is one of the Units that participates in this project, characterizing the biomass of pre-selected accessions, in partnership with the Multi-user Laboratory of Chemistry of Natural Products of Embrapa Tropical Agroindustry, Ceará. Using nuclear magnetic resonance, not only the composition is being investigated, but also the chemical structure of materials. Researcher Patricia Abrão, from Brasília, explains that knowing the levels of cellulose, hemicellulose and lignin is not enough to understand why a sample has better results than another in the ethanol production process, for instance. Finding out what the monomers that make up each of these structures are and the links between them informs the work of the breeders.

At Embrapa, there are also studies in which accessions from the gene bank are being genetically crossed, seeking materials with desirable characteristics for energy purposes. The goal is to obtain more productive new varieties, tolerant to pests and diseases and adapted to the different Brazilian regions.

LARGE AREAS

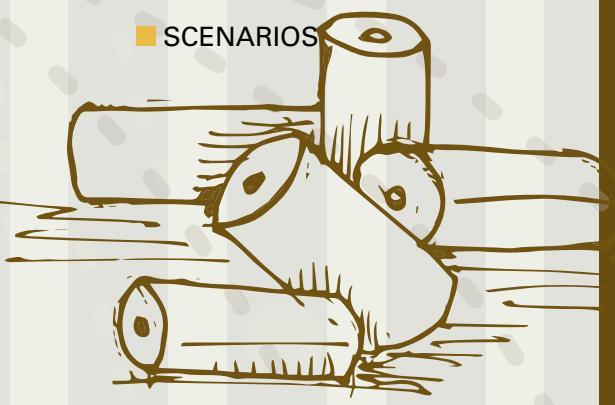
Another challenge is the development of production systems in large tracts of land. For the researcher Letícia Jungmann, from Embrapa Agroenergy, this is one of the main limitations, including harvest and post-harvest systems. Currently, elephant grass is grown as grass crops that take up small areas. When thinking of ethanol production or generation of bioelectricity, however, there is a need for a lot of material. Sykué has used 5,000 hectares to grow the grass; on its website, Florida Clean Power announced 500,000 hectares in Amapá for the same purpose.

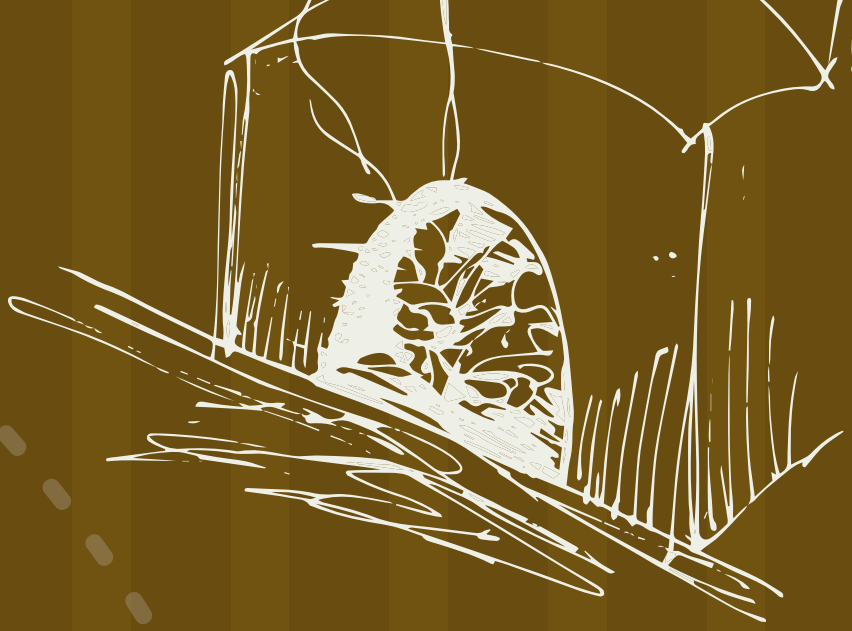
Pereira recalls that growing in extensive areas need appropriate management to deal, for example, with plant-health problems. It is also strategic for materials with additional cycles, with harvests at different times, to ensure dry matter production flow the whole year.

In the Execution of Research and Development Unity of Rio Largo (AL), of Embrapa Coastal Tablelands (SE), research involving the elephant grass production system is intended to provide an alternative source of biomass for the generation of bioelectricity in sugar and ethanol plants off season. In Alagoas, 25 plants process sugarcane and burn the bagasse to generate electric power.

The researcher Anderson Marafon highlighted two issues in the final step of the elephant grass energy production system: harvesting and reducing humidity. Two methods of sun drying are being tested: with the grass just cut and “laid” in the field, or with the material chopped and placed in the yard of the power plant. The latter has managed to lower the humidity from 70% to 50% after the fourth or fifth day of sun exposure.

Concerning the harvest, Embrapa’s tests seek efficient machinery. In the pastures, the material is harvested young and tender, a condition that is more suitable for animal feeding. To produce biomass for energy, the plant has to remain for about six months in the field. The grass, then, is more fibrous and tough and the typically used harvesters are not strong enough. »





BACTERIA AND ASHES TO INCREASE PRODUCTION

By Ana Lucia Ferreira

GRASS ETHANOL

While the team searches solutions for the improvement of crop production, in the laboratories of Embrapa Agroenergy, elephant grass is a raw material that has been tested for the production of cellulosic ethanol (2G) since 2009. The experiments began with the participation in a project led by researcher Marcelo Ayres, from Embrapa Cerrados (DF), to identify alternative sources of biomass for sustainable biofuel production. In this study, elephant grass was compared with other forage plants, sorghum, wood and sugar cane bagasse, among other plants with energy potential.

The researcher Silvia Belém from Embrapa Agroenergy claims that the elephant grass has adapted very well to the process, showing favorable characteristics. The glucose volume recovered was high, with the use of smaller quantities of enzymes. The results of this first experience made the research center choose this grass, as well as sugarcane bagasse, as raw material for a large project that is studying ways to optimize all phases of (2G) ethanol production.

The first studies Embrapa has undertaken with genotypes of elephant grass (*Pennisetum purpureum*) for biomass production with energetic purposes began in 1995, with a team led by researcher Johanna Döbereiner (1924-2000) at Embrapa Agrobiology. The multidisciplinary project involved other institutions and aimed at the development of a technology for the coal production to be used in the steel industry. Embrapa then identified the most appropriate varieties. "We evaluated more than 40 genotypes in soils extremely poor in nitrogen because we wanted a grass that, besides producing biomass, did not need much nitrogen fertilizer," explains the researcher Segundo Urquiaga.

Usually, when elephant grass is produced for livestock feed, it is necessary to use nitrogen fertilizers aiming at a plant with high protein levels, which is not necessary for biomass production. In the field, the researchers initially studied the behavior of plants in poor soils, selected those that demanded less fertilizer and then began to search for bacteria associated with elephant grass. "Using isotopic techniques, we were able to distinguish in the plant how much nitrogen came from the soil and how much came from the air through the bacteria naturally associated to it", says the researcher.

If the objective is to obtain a plant for biomass production that shall be used as an alternative to fossil fuels, using agricultural inputs that require a high level of non-renewable energy, like nitrogen fertilizers, for instance, would be a contradiction. The goal, after all, was to produce grass with environmental and economic sustainability. To this end, researchers from Embrapa Agrobiology also have searched different ways to increase grass production.

ASHES

One of the ongoing studies uses the ash derived from burning biomass as a source of nutrients for grass crops. According to Urquiaga, experiments with ashes from furnaces of potteries – in Campos, Rio de Janeiro, Brazil – proved to be a material as good

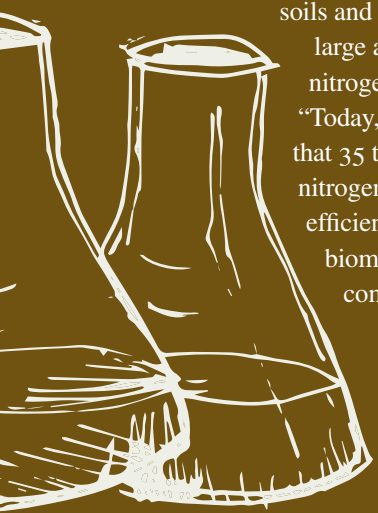
Photo: Daniela Collares/Embrapa

Silvia Belém, from Embrapa Agroenergy, observes a reactor during the production of ethanol from elephant grass

as a commercial fertilizer. "It is a source of high-efficiency phosphorus and potassium, and also of some micronutrients. Since Brazil imports more than 95% of the potassium used in agriculture, we need to think about how to recycle this nutrient", he adds.

The search for elephant grass varieties that are more efficient regarding biological nitrogen fixation has always been present in the studies. From the forty genotypes initially evaluated, six were pointed out by the researchers as more tolerant to poor soils and did not require large amounts of nitrogen fertilizers. "Today, it is known that 35 to 40% of the nitrogen in the more efficient varieties for biomass production comes from the air, that is, from biological nitrogen fixation", emphasizes Urquiaga.

The aim of the research was to further increase this efficiency using inoculants. Researchers have identified nitrogen-fixing bacteria associated with elephant grass and now work for production of a bacterial inoculant (natural biofertilizer). The product would be able to increase the production of the grass with low cost and without the need of applying large amounts of nitrogen fertilizers.



LARGE SCALE

For the researcher Segundo Urquiaga, agronomic issues concerning the production of grass for energetic purposes are virtually resolved, and only some adjustments to production sites are still necessary. But he highlights that large scale production is a difficult process. "We do not have seeds and that hinders the production in large areas", he explains.

Elephant grass spreads through vegetative multiplication, like sugarcane. To plant one hectare of the grass, six to eight tons of culms are necessary. If well managed, the production takes about 90 days and is enough to plant ten hectares. And for another 90 days, they could meet the needs of a hundred hectares. Considering this proportion, to reach the necessary to plant in 1,000 hectares, over one year is required.

Urquiaga believes that the production of seeds is the solution to this problem. In this sense, an ongoing project at Embrapa Beef Cattle seeks to obtain a hybrid variety to produce botanical seeds to enable the planting of the grass. "This will definitely solve the problem of planting in large areas", he concludes.

BIOLOGICAL FACTORIES

Plants and animals are means for the production of molecules with high added value

Photo: Thinkstock/Embrapa

Photo: Thinkstock/Embrapa

By Fernanda Diniz
Art: Lúcio Cavalcanti

The evolution of genetic engineering over the last three decades allowed many molecules with high added value to be identified by scientists around the globe. These molecules have the potential to be applied in different sectors of the economy, such as health, energy agriculture and the industrial sector.

However, in the midst of so many discoveries, one question was bothering scientists. How to produce these molecules on a large scale and in an economically viable way? The answer to this question is in living organisms: plants, animals and microorganisms can be used as biofactories or biological factories for the production of molecules with high added value on a large scale and low cost.

When it comes to science and, mainly, to living things, everything is very peculiar and, in most cases, there are no generalizations. This means that for each molecule identified it is necessary to study the best biofactory to produce it on a large scale and with costs that make the process attractive to the market.

That is exactly what happened in the case of cyanovirin, a protein extracted from the blue-green algae (*Nostoc ellipsosporum*) with natural ability to bind to sugars and preventing the multiplication of the HIV virus in the human body. The positive effects of cyanovirin against AIDS had already been proven since 2008, from tests conducted with monkeys by the United States National Institute of Health (NIH). However, viable means to produce the protein on a large scale still needed to be found.

After tests with bacteria, yeast and tobacco plants, the team at Embrapa Genetic Resources and Biotechnology, coordinated by the researcher Elíbio Rech, managed to show that genetically modified soybeans are an efficient and viable biofactory for the large-scale production of cyanovirin.

According to him, the studies are being carried out with soybeans due to the great knowledge that the scientific community already has about the species, but the research can be made with other plant species. “Plants, in general, act as incubators of molecules and in the future will be biofactories for drugs”. Moreover, according to Rech, the advantage of using GMO soybeans for the production of drugs is mostly economic. “The savings are 40 times greater in comparison with experiments done on animals. In addition, Embrapa has patents for genetic modification of soybeans worldwide, which allows scientists greater freedom to handle the crop”.

UNPRECEDENTED RESULTS

The unprecedented result, with the partnership of the American Institute and the University of London, was published in the *Editors choice* section of the *Science* magazine (see “Browse” at the bottom of this article). This magazine, published by the American Association for the Advancement of Science (AAAS), is one of the most prestigious in its class, with weekly circulation of 130,000 copies, and besides online visitors, it is estimated that it has one million readers worldwide.

The research began to be developed in 2005 and is based on the introduction of cyanovirin in genetically modified soybean seeds for large-scale production. Rech, one of the authors of the article, says that tests were carried out with other biofactories such as tobacco plants (*N. tabacum* and *N. benthamiana*), bacteria (*E. coli*) and yeast (*S. cerevisiae*). However, the only biofactory that proved to be a viable option for the production of cyanovirin was the seed of GM soybeans, because it allows the protein to be widely spread in the proper amount. Allied to this is the »

benefit of low-cost investment required in the production of the raw material for the extraction of the molecule.

Regarding the potential of soybeans as a biofactory, or biological factory, for the production of cyanovirin, in the abstract of the article published in *Science*, the scientists who wrote the article claim that "roughly, if the GM soybean is planted in a greenhouse that is smaller than a baseball field (97.54 m), it is possible to provide enough cyanovirin to protect a woman 365 days a year for 90 years".

The next step is the large-scale production of soybean seeds to isolate cyanovirin and start the post-clinical studies phase. Rech emphasizes that the genetically modified seeds will not be planted in the field. They are grown under controlled conditions within greenhouses.

During the next stages of development, scientists will also have the collaboration of scientists from the Council of Scientific and Industrial Research of South Africa (CSIR).

FREE ACCESS TO TECHNOLOGY

In addition to being innovative, the research has a strong humanitarian component and, therefore, developing countries with high rates of AIDS infection, such as some in Africa, for example, will have license for production and internal use, free of royalties. The continent remains the most affected by the disease, with 1.1 million dead in 2013, 1.5 million new infections and 24.7 million Africans infected. South Africa and Nigeria top the list of most affected countries. In Latin America, with 1.6 million HIV-positive people in 2014 (60% of which are men), the most troubling country is Brazil, where the number of people newly infected with the virus rose 11% between 2005 and 2013, a trend opposing global figures, which showed a fall in the same period. In Asia, the countries which have the highest contamination are India and Indonesia, where infections have increased 48% since 2005.

PRODUCTION OF MEDICINE

The use of plants, animals and genetically modified microorganisms for the production of medicine is part of a technology platform with which Elíbio Rech has been working since the 1990s. The studies for the production of biopharmaceuticals are advancing, coordinated by Embrapa Genetic Resources and Biotechnology, and which involve other research units within Embrapa, research institutions and universities in Brazil and abroad.

The biopharmaceuticals, or biological medicines, as they are also called, are obtained by sources or biological processes, from the industrial employment of microorganisms or genetically modified cells.

In addition to the cyanovirin, the team coordinated by Rech also works with antigens as NY-ES01 and Hormad1, important elements for cancer diagnosis, with growth hormone, among others. The more advanced research consist in the development of transgenic soybean plants with antibodies against breast cancer, and transgenic plants and animals containing a protein called factor IX that can assist hemophiliacs.

"Precisely because they are able to express molecules of high added value with low costs, the biofactories or biological factories are viable options for the production of inputs, such as drugs and fibers that are interesting for the industry", states the researcher.

Today, many substances such as insulin are synthesized by traditional processes, which use bacteria or animal cells modified in culture. But Rech stresses that the process has limitations, such as the maximum size and the restricted amount of produced molecules. The intention of Embrapa's

group is to develop, from already domesticated plants, a diversified technology platform to produce a greater variety of molecules of industrial and pharmaceutical interests, with low cost, higher efficiency and in a sustainable way.

The process works as follows: plant cells are genetically altered to receive specific genes and they act as bioreactors for the production of a specific substance. The plant transformation process begins with the introduction of the gene inside the seed through a liquid medium. After the gene insertion, the assessment and selection of plants that are producing the substance is made according to what was proposed by the research.

"Transgenic seeds are stable, can be perpetuated for generations, and have the advantage of being easy to store and have millions of cells to serve as biofactories", says Rech. "The leaves, on the other hand, are temporary: they produce proteins during a period of up to seven days".

In the research Unit, the plants are grown in greenhouses, in which temperatures are rigidly controlled – also, there is plenty of water and light, and security systems that allow only authorized persons to enter. They are tobacco varieties and GMO soybeans with anti-cancer antibodies, growth hormones and anti-HIV molecules encoded in their DNA.

"These plants are not medicinal, neither they can be used for therapeutic purposes; they act as incubators for the production of molecules", explains the scientist. And he complements: "The plants are used only to produce a specific medicine. The molecule is inserted and, as it is multiplied through seeds or through vegetative propagation, a significant amount is achieved and then purified. These plants don't enter the food chain under any circumstances".

Rech emphasizes that the intention now is to take the research out of the laboratory – and for this the partnership with the private sector is essential. "We showed that the concept works, but we need to combine the work of molecular biologists with the work of engineers, attract the private initiative to scale up the process and take it forward, transforming a technological asset in real innovation, something that is not simple in Brazil", he points out. "This is a demand from society, a potentially lucrative area that can attract the interest of companies to apply our results". »

Photo: Adilson Werneck/Embrapa

BREAST CANCER PREVENTION

Breast cancer is one of the diseases that most afflict the female population worldwide. Each year, 182,000 women are diagnosed with breast cancer and, out of these, 43,000 die. Despite being an illness with great chances of cure when detected early, it is still the worst threat to Brazilian women, since it is the female malignant tumor with highest incidence and mortality rates in the country. Over the past 20 years, according to data from the National Cancer Institute (Inca), breast cancer mortality has grown about 60%. The incidence rate of cancer in Brazil was estimated at 40.7 cases per 100,000 women and mortality for 10.3 of them.

Genetic engineering can be a promising path for the prevention and cure of this disease and, therefore, Embrapa, Campinas State University (Unicamp) and the University of Brasília (UnB) have made efforts to develop transgenic soybean varieties with antibodies against breast cancer. These varieties will be used for the production of drugs that will act in the prevention and diagnosis of the disease and will also have therapeutic potential, even with advanced stage cancer.

FACTOR IX

The research aims to develop transgenic plants and animals capable of producing factor IX, a protein responsible for blood clotting. It is a partnership between Embrapa, the University of Brasília (UnB), the São Paulo School of Medicine (Federal University of São Paulo - Unifesp/EPM) and the Support Hospital of Brasília. Hemophiliacs do not produce this protein and, therefore, when they get injured, blood clotting speed is much slower, making them more susceptible to hemorrhage.

The research is also being developed under the coordination of researcher Elíbio Rech, and aims to use soybean plants and animals like biofactories for production of factor IX in a large scale and with lower costs. Currently, hemophiliacs control the absence of factor IX with medicine.

PHARMACEUTICAL INDUSTRY

Brazil is the fifth worldwide consumer of medical drugs and Brazilians spend no less than ten billion dollars per year with them. It is a very high number regarding the global industry, which moves roughly 350 billion of dollars annually. Biotechnology is emerging as an important ally in this scenario. The use of genetically modified plants and animals as biofactories for the production of safe medicine is a stimulus so that they become more accessible to the population.

ADVANTAGES OF BIOFACTORIES

- They produce genetically modified protein, identical to the original ones, with little capital investment, resulting in safe products for the consumer;
- Ease of storage and transportation;
- Cheaper medicine and large-scale production;
- They assist in the study of functions of molecules from the Brazilian biodiversity;
- Greater value is added to agricultural products;
- They unite agribusiness and the pharmaceutical sector.

The turnover of biotechnology in pharmaceutical industry worldwide has grown a lot in the last few decades, and today reaches approximately ten billion dollars per year. Biotechnological products are rapidly developing and today they represent ten percent of new products currently on the market. Rech believes the Brazilian scenario in ten years will be fully influenced by biogenetics.

Embrapa's expectation when investing in biopharmaceuticals research, as explains Rech, is to put these drugs in the pharmaceutical market with lower costs, since they are produced directly in plants, bacteria, or milk. There is evidence that the use of biofactories can reduce the costs of producing recombinant proteins in up to 50 times.

The researcher explains that plants produce genetically modified proteins that are identical to the original ones with little capital investment, resulting in safe products for consumers. In addition, they represent a way to produce cheap medicine in a large scale, as they are not subject to contamination, avoiding spending on the purification of organisms that are potentially disease-causing in humans. Not to mention the ease of storage and transport.

BIOTECHNOLOGY AND BIODIVERSITY

In addition to being an important instrument for the production of pharmaceuticals, the biofactory technology can also contribute to the study of molecules from the Brazilian biodiversity.

Embrapa develops a systematic work of gene collection from the Brazilian biodiversity, and many of these genes have good potential for use in agriculture and health, due to medicinal properties of their products. The technology will enable the discovery of the functions of these genes with greater speed and efficiency.

Biofactories for the production of pharmaceuticals provide even more value to Brazilian agribusiness, as they add value to plants, animals and microorganisms.

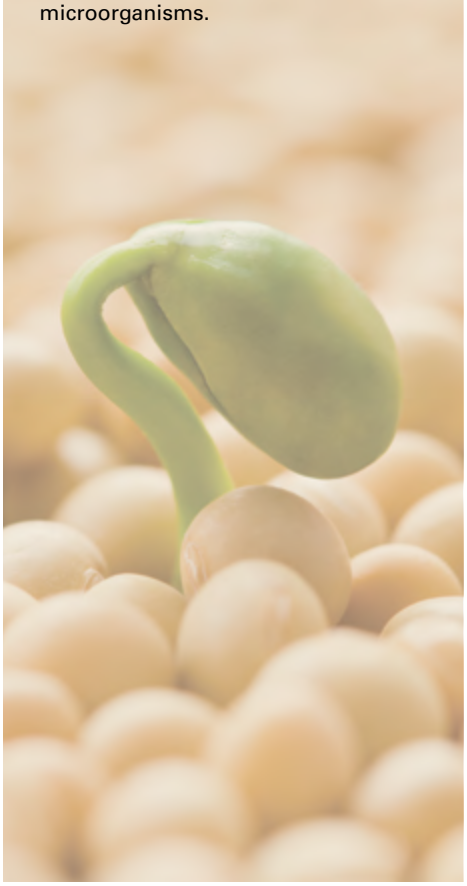


Photo: Thinkstock/Embrapa

SCIENTISTS BREED ANTI-AIDS MOLECULE IN RICE

By Irene Santana and Fabio Reynol

Photo: Thinkstock/Embrapa

Following this same trend of research with cyanovirin, the researchers Teresa Capell and Paul Christou of the University of Lleida, in Spain, found a viable means to produce the 2G12 antibody, a protein that neutralizes the AIDS virus. They developed transgenic rice containing the anti-HIV molecule in its DNA, thus reproducing it in a large-scale and economically viable way. That makes this rice a possible biofactory of the molecule, and have already aroused the interest of the pharmaceutical industry.

The research article was released in April in the *Plant Biotechnology Journal*. "This is the most important scientific journal in the Biology area after *Science* and *Nature*", says the researcher Elíbio Rech, who took part in the research.

According to Rech, the studies were coordinated by the Spanish University researchers, and the Brazilian participation consisted in the analysis of the modified rice and in measuring the quantity of 2G12 protein present in it. "It is a sign of the quality of Brazilian research, since the results of the study were analyzed only by Embrapa's team", boasts Rech. These analytical studies were conducted through mass spectrometry methods performed by researcher Andrew Melro Murad, from the same Embrapa Unit.

"We used state of the art mass spectrometers to measure the composition of the rice", tells Murad. In addition to the amount of molecule, he also assessed the genetically modified rice protein structure in comparison to conventional rice. The Embrapa researcher found 2G12 antibody levels between 1.8% and 2.4%. Elíbio Rech explains that those are positive values. "Above 1% we can consider the potential economic viability of the production of this molecule", he explains.

THE METHOD

To use rice as biofactory for the protein, the researchers took the pathogenic bacterium *Agrobacterium tumefaciens* as a vector. In this method, the bacteria are genetically engineered, a harmful gene is extracted from it, and the molecule that needs to be reproduced is placed. After being multiplied in the laboratory, the bacteria is cultivated with plants tissues. In this process, the bacteria insert their DNA in the plant, along with the desired molecule. From that tissue, new plants with the molecule are generated.

The team led by Rech, when reproducing the cyanovirin protein – also used to fight AIDS – adopted another method to introduce the molecule in the plant's DNA, called bioballistics. The process consists in the use of gold or tungsten microprojectiles accelerated at high speeds – exceeding 1,500 km/h – to introduce, via bombardment, the DNA of interest in *in vivo* cells and tissues.

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http://bit.ly/biofabricas1

http://bit.ly/biofabricas2

NANOFIBERS OF AFRICAN OIL PALM

They are crystal clear and have high mechanical strength. The challenge is to increase the scale and efficiency, and also test their application as reinforcements for other materials.

By Vivian Chies
Collaboration: Raquel Pires
Art: Fernando Jackson

Photo : Daniela Collares/Embrapa

Unlike the traditional tale of the scientist depicted as a researcher who spends a great deal of time alone in the laboratory to "conquer and fix" the world, daily routine tends to be much more stimulating. It is full of surprises and conflicts. For researcher Leonardo Fonseca Valadares, from Embrapa Agroenergy, the laboratory routine is versatile, motivated by challenges and long-term learning. "The routine is not boring. The work has several stages: one day you are planning, the other executing, then dealing with data, and after that arguing about the results. When a conclusion is reached, new ideas arise to plan new experiments and new projects. It is a very dynamic process".

Leonardo is head of a research that begun in April 2012 with the aim of extracting cellulose nanofibers of African oil palm bunches. African oil palm (*Elaeis guineensis*) is a plant with the potential to integrate the biodiesel production chain, thanks to its high productivity. It can yield up to six tons of oil per hectare. Soy, for example, generates between 500 and 600 kilos in the same space. However, for each ton of oil, 1.1 ton of empty bunches remains, which can be used for soil fertilization. The goal is to obtain greater added value from the crop using this material.

In the laboratory, the work begins with the extraction of cellulose by purification processes, which yield a material very similar to paper. The next step is the extraction of nanofibers. "The nanofibers of empty bunches have nanometric thickness. We use microscopes to see and characterize them", explains Leonardo.

It is already known that the nanofibers of African oil palm bunches are crystal clear and have high mechanical strength, comparable to certain metals. Embrapa Agroenergy wants to test it as reinforcement for natural rubber. The difficulty has been the low amount of nanofibers obtained and a sequence of extractions that is necessary. First, the cellulose, which is a fraction of the material itself, is cleansed. Then, only the nanofibers are separated, yielding an even smaller portion. "We had expected to achieve a larger quantity, but we realized it is not going to be easy".

To increase the scale and the yield is the next stage of the work that, in addition to continuing in the laboratory, must begin to also be developed in the area of Embrapa Agroenergy's pilot plants. Testing the application of nanofibers as reinforcement for other materials than natural rubber is also in the plans of the staff.

Optimizing the process to ensure that the conditions and costs are compatible with industrial reality is the challenge to be overcome if the intention is to insert the product in the market. Leonardo explains that, in the early stages of development, in the laboratory, the best reagents and supplies are used, in the amount needed to reach the result. Then the studies to adjust the processes begin so as to reach the appropriate scale, conditions and costs.

For the researcher, the achievements go beyond scientific results. They are also in the adaptation of laboratories, in the contact with other researchers, personal self-development, observation of the development of the students, and the coexistence with people from other areas. And from this interaction arose a new trend: the enzymatic route.

The process of obtaining nanofibers can be done using acids or enzymes. Since they are produced by microorganisms, enzymes have low toxicity and are easy to handle and dispose of. The final disposal of effluents from acid processes, on the other hand, requires neutralizing so that bodies of water are not affected. In addition, the handling of acids is more dangerous, both in laboratories and industries. "As I had no experience in that area, I never thought we could get nanofibers using enzymes, but we did", says Leonardo Valadares, who, as a chemist, had worked mostly with inorganic substances.

For Leonardo, all research is surprising. Even with planning, there is no guarantee that a particular result will be achieved. In this research, there was also the risk of the nanofibers not being extractable. But the scientist was very surprised to find out that they are extremely long and thin because of the characteristics of the raw material itself. This gives differentiated properties to the product.

In a laboratory, obtaining products different from those predicted is not necessarily negative. "There is no such thing as a mistake. There is a result. And you will try to find out how you got to it", says Leonardo. When he was a student, "a reaction 'went wrong' and clotted inside a balloon. I thought it was awful, it was not what was expected". The professor, with decades of experience, did not condemn the result. On the contrary, he drew attention to the fact that the material was resistant to solvents, something unexpected. "The resistance to solvents was then analyzed deeply and became the topic of the thesis and of the publication".

The conversion of biomass into energy and several chemicals products and materials is at the heart of the work of Embrapa Agroenergy. But, until joining the Unit, in 2010, Valadares worked with different materials (clay, for example). The young researcher liked the change of area. "We do not create nanofibers, they are within the plants. Nature is a source of inspiration for every scientist". •

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http://www.embrapa.br/agroenergia

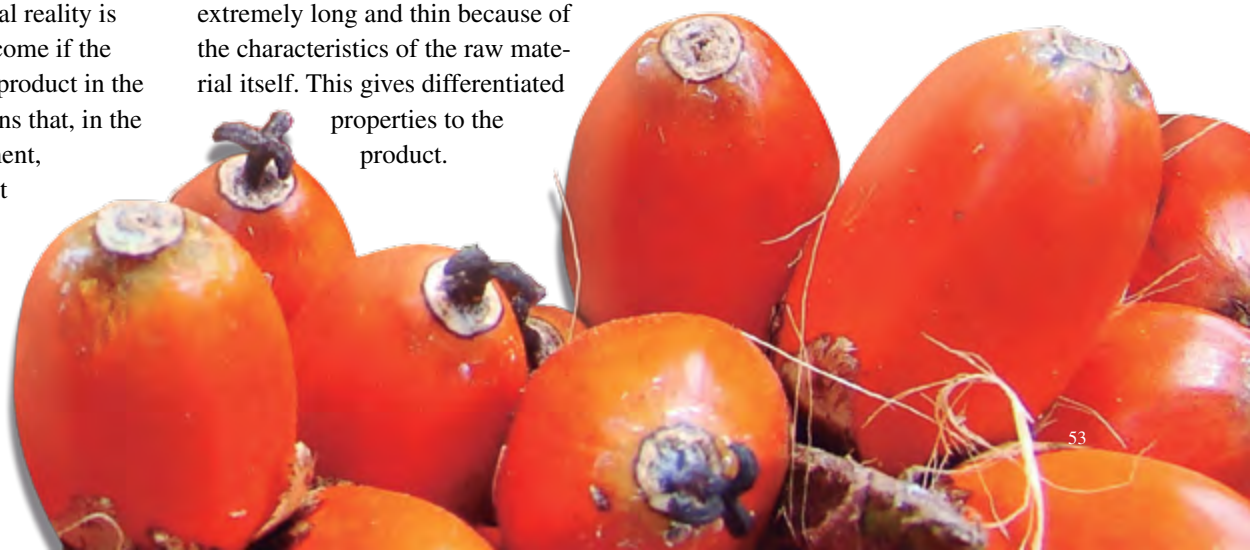


Photo : Siglia Regina dos Santos Souza/Embrapa

DEMOCRATIZING SCIENTIFIC KNOWLEDGE

Photo: CIB

Adriana Brondani

Adriana Brondani has a PHD in Biological Sciences from the Federal University of Rio Grande do Sul (UFRGS), and is executive director and spokesperson for the Council of Information on Biotechnology (CIB).

Operating areas:

Biochemistry, Molecular Biology, Scientific Communication.

By Adriana Brondani

Published in January 2015, a public opinion poll conducted by the Department of Agricultural Economics at Oklahoma State University, USA, found that 82% of respondents were in favor of labeling foods obtained through genetic engineering. In the United States it is not mandatory to provide this information on the label, and this question raises heated debates. In Brazil, a decree of 2003 provides that all foods or ingredients with the presence of genetically modified organisms (GMOs) – above 1% in the final composition of the product – must be labelled.

New technologies can generate distrust, especially those who break paradigms, as is the case of biotechnology. In the case of GMOs, as they are innovations which results in food, the mistrust can be even higher. However, this concern corresponds in fact to a real danger? The same study may help us consider this question. According to it, 80% of people also agree that all food containing DNA must be labeled. Well, virtually everything we eat, be it vegetables, legume, fruits or meats, fresh or processed, contains DNA. Moreover, the presence of the "molecule of life" in foods has no relation with transgenics. Long before the creation of genetically modified (GM) foods, human beings always ingested plants and our DNA never mixed with that of vegetables because of it, for example.

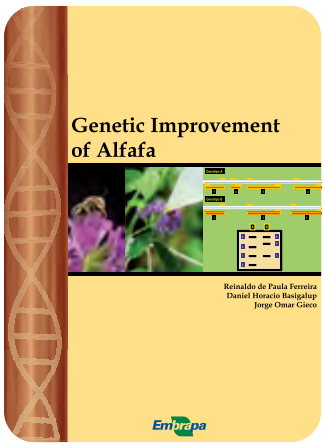
The percentage of the public who agrees with the labelling of GMOs is practically equal to the one that supports that the same procedure should be performed with foods that contain DNA. This is an indication that a large part of the population does not know what GMOs are. Moreover, it suggests that the public is not fully aware that all living things contain DNA, and there is nothing to be feared. Although the existence of this molecule was discovered only in the last century, it is not a human creation. This finding poses a challenge: the need to communicate scientific themes clearly and with accessible language, aiming to contribute so that society can be more informed to make decisions.

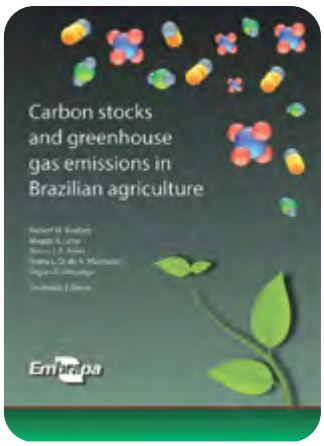
Another paper published in January 2015 by the *Science* magazine, with data collected by the Pew Research Center, reveals that there is much work to be done. The research showed the difference between the opinion of the academic community and the general public about some themes.

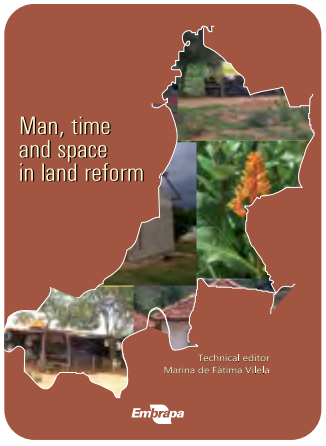
Specifically about GMO foods, 88% of scientists believe that they are safe; while among the general public that index is only 37%. Assuming that the access and the understanding of knowledge are some of the reasons for this discrepancy, who is responsible for democratizing such information? The answer surely involves several stakeholders, but it is necessary to highlight the key role that the press and opinion makers have.

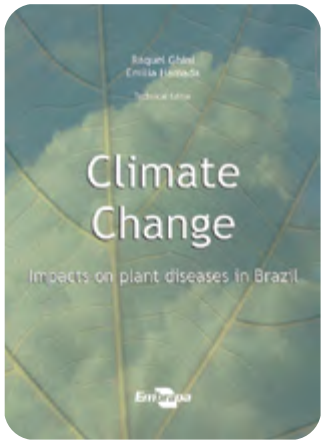
Current research warns of existing obstacles in the communication of complex issues. However, the studies have also demonstrated that, through exchanges mediated by opinion facilitators and makers, it is possible and urgent to democratize information on technological advancement.

Genetic improvement
Carbon stocks
Climate change
Biotechnology









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