Technologies for Climate-Resilient Smallholder Agriculture

Sharing practices from Brazil with Africa

IFAD
Investing in rural people

Adaptation for Smallholder Agriculture Programme
ASAP

In partnership with:

Brazil Africa Institute

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Introduction

Context

Improving rural livelihoods and promoting food security are two connected challenges in the agriculture sector across low-income climate-vulnerable countries, most of which are located in the Global South. Over 70 per cent of the world's poorest people – 1.4 billion women, children and men – live in rural areas and greatly depend on agriculture and related activities for their livelihoods. In some parts of the world, extreme weather events, such as droughts and heavy rainfall, are already affecting food security through decreases in crop production and quality and increases in crop pests and diseases.

Substantial efforts to tackle these challenges have been made by state and private-sector institutions in Brazil, which is a major agricultural producing country and a global reference in terms of South-South cooperation. Over the past few decades, Brazil has taken challenging development experiences and transformed them into valuable knowledge to be shared with nations of the Global South through development-oriented programmes, in which African countries have been key partners and/or beneficiaries.

There is great potential for agricultural technology transfer and adaptation between Brazil and Africa, in light of their similar environmental, climate and social conditions. In spite of local particularities, the two regions face similar development challenges, such as poor infrastructure (transport and energy, for instance), low educational levels and weak governmental support. These common features create interesting opportunities for South-South collaboration through technology transfer in several areas, including agriculture, climate change mitigation and adaptation, and value chains development.

The development, exchange and adaptation of technologies is part of the international development agenda, as explicitly set out in Sustainable Development Goal (SDG) 17 on partnerships for development. Targets 17.6, 17.7 and 17.8 aim to "Enhance … South-South and triangular regional and international cooperation on and access to science, technology and innovation", "Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries" and "Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries", respectively.

Drawing on its fundamental goal of promoting rural development, as well as its significant experience in South-South and triangular cooperation (SSTC), the International Fund for Agricultural Development (IFAD) commissioned the present catalogue with the goal of mapping good technologies and management practices in order to promote climate change adaptation and mitigation for smallholder agriculture in Africa. The report showcases both technologies and providers, presenting 11 case studies in which technologies were used in smallholder farming in Brazil in line with all the 17 SDGs.

Selecting and compiling agricultural technologies and management practices is a complex task, as the knowledge of such processes, seeds, tools and techniques often comes from different sources and so this knowledge can have different impacts. One can proceed with a demand-oriented approach – focusing on the technology user – or a supply-oriented approach – with the technology developer guiding the process. A balance between these approaches tends to produce the best result.

This catalogue compiles innovative and high-impact technologies, as well as arrangements and policies, in Brazil (supply-side). While a demand analysis has not been carried out, the technologies presented here are those suitable for family farmers, which are defined in Brazil as small properties with income from agricultural activities where family members make up the majority of the labour force. Family farmers account for 80 per cent of rural farms in Brazil (around 4.5 million farms) and about 33 per cent of Brazilian agricultural gross domestic product. This study focused on priority value chains in Africa: sorghum, millet, cowpea, rice, maize and soybean; cassava, fruit and vegetables; tree crops (cocoa, coffee, cashew and oil palm), and; protein production: livestock (poultry, goats and cows), fish farming and dairy.

This catalogue should contribute to improving rural livelihoods, enhancing exchanges between Brazil and Africa, and promoting SSTC. Stakeholders in Africa can consult it to determine the technologies that are suitable in their geographical contexts. Carefully adapting a technology is key if it is to be used in a new setting, hence why some organizations prefer the concept of technology exchange over technology transfer.

Agroecological Zones

This study prioritized technologies suitable for or adoptable in regions in Brazil that have similar edaphoclimatic characteristics to regions in Africa. An analysis of Africa's agroecological zones was first conducted (Figure 1) and these were later correlated with those of Brazil. Agroecological zones are areas with specific natural characteristics that make them suitable (or not) for certain agricultural activities. They are defined to serve as a basis for policies and strategies for the development of the agriculture sector, as well as to guide decision makers in the establishment of public policies in agricultural development programmes.

According to the Brazilian Agricultural Research Corporation (Embrapa), agroecological zoning is a technical-scientific tool based on the potentialities and environmental vulnerabilities of a particular region, especially the behaviour and characteristics of the climate, soil, vegetation and geomorphology, with a focus on the suitability of lands for agricultural use. It takes into account the social and economic characteristics of each region. Figure 1 illustrates the common agroecological zones in Brazil and Africa. As all of the technologies analysed in this catalogue are considered in terms of Brazilian biomes, this report includes a simplified comparison between these two types of zoning, namely agroecological zones and biomes (Table 1). This facilitates the identification of which technologies would be better adapted to each region of Africa.

Figure 1: Ecological zones in Brazil and Africa

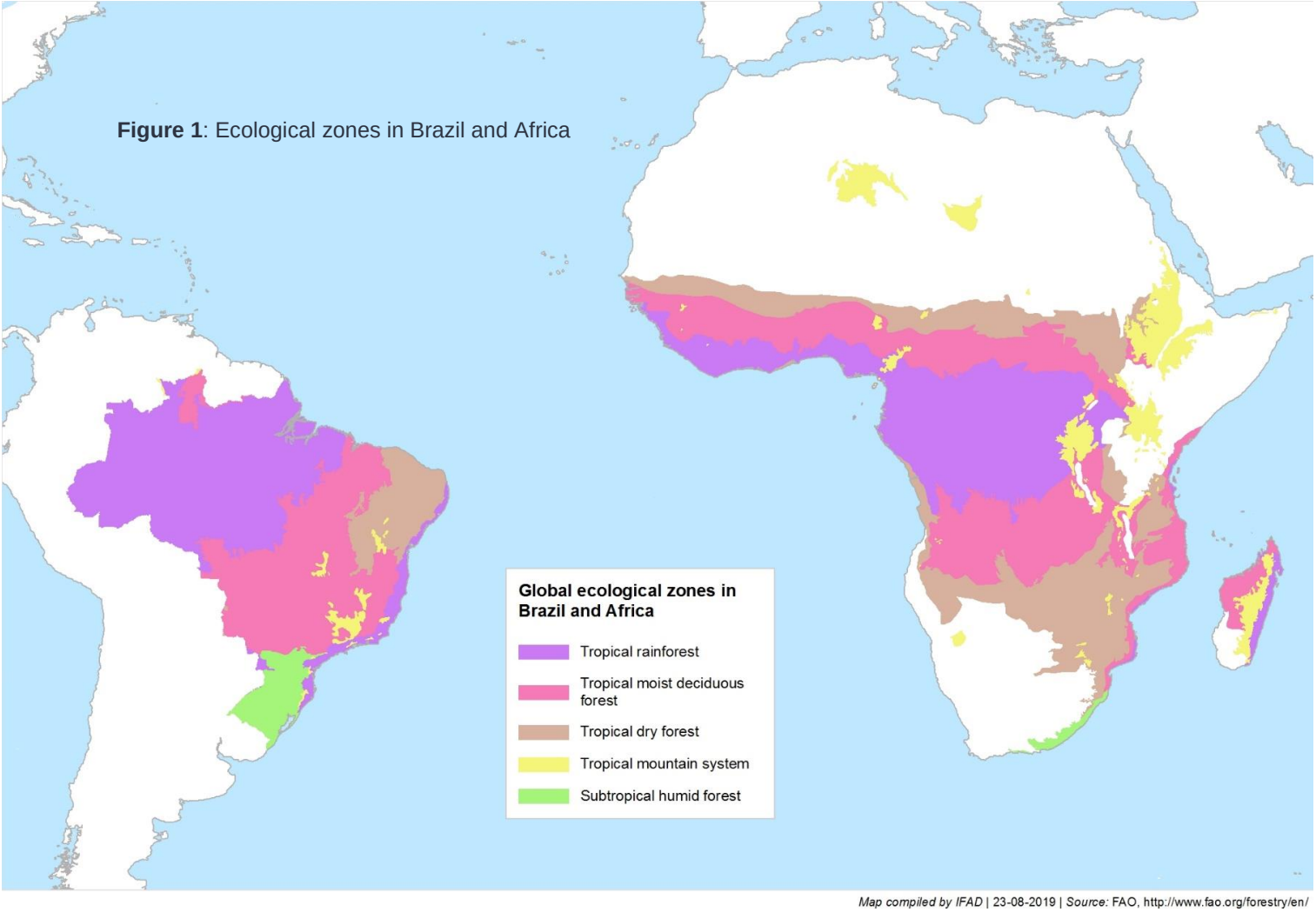

Table 1: Correlation between Brazil's biomes and Agroecological zones (source: FAO)

Agroecological zones in Brazil	Brazilian biomes	Main climate characteristics
Tropical rainforest	Amazon and Atlantic Forest	Summer with high precipitation levels and high temperature; often with short dry period in winter
Tropical moist deciduous forest	Cerrado (savanna)	Wide area with rather high rainfall but a pronounced dry season
Tropical dry forest	Caatinga	Rainfall varies between 500 and 1,000 mm or less, with a dry season of five to eight months; high temperature throughout the year (mean temperature of the coldest month greater than 20° C)
Subtropical humid forest	Atlantic Forest	Lower temperatures in winter (mean temperature of the coldest month less than 15° C) and rainfall evenly distributed throughout the year. However, rainfall decreases from the north (1,000 to 2,500 mm) to the south (600 to 1,000 mm)
Tropical mountain system[1]	Small areas in Cerrado, Caatinga and Atlantic Forest	Precipitation varies greatly but the region is tropical throughout, with a low annual range of temperature

[1] Owing to the small size of this zone in Brazil, we did not consider it in this catalogue.

Methodology

Hundreds of agronomic technologies in Brazil have previously been identified as potentially beneficial for African contexts.[2] This report is novel in that it the screening of technologies focused on climate adaptation and mitigation, which resulted in 11 technologies being selected that represent diverse types and value chains for potential use in West and Central Africa.

The research took the following criteria into consideration:

- ✓ farmers' profiles, with a focus on smallholder farmers and special attention being paid to young people and women as these groups make up a considerable proportion of African farmers, the potential new users;
- ✓ the use of reliable sources of information, such as research centres and universities;
- ✓ the current use and positive impact of technologies;
- ✓ the adaptability for regions with climate and soil conditions similar to those of Africa.

The methodological approach used for this research is summarized below:

1. Literature review for an initial quick screening of technologies and to define the key characteristics to be presented in the portfolio.
2. Compilation of research centres and contacts to create a list of centres in Brazil and other countries where information can be found about agricultural technologies. Emails were sent to these centres requesting information on relevant technologies.
3. Technologies portfolio (long list), including all long-listed technologies (around 70); it covered a brief description of the impact, scope of use in Brazil, target audience and technology developer (the type of organization and its context, when relevant) of each technology.
4. Technologies summary (short list), including a selected number of technologies (11); for each, a more comprehensive description was given, highlighting those cases in which simple low-cost technologies were successfully implemented and had significant impacts, with a description of how each was implemented.

The choice of the final technologies considered their relevance for Africa's context. As this study aims to promote the benefits of sustainable development, each technology listed below includes an analytical correlation with certain SDGs and their targets through the "SDG impact" section. For easy reference, a complete table of all SDGs and targets is available in the Annex. Furthermore, this catalogue has taken into consideration low-income and marginalized social groups as potential beneficiaries of the adoption of the technologies listed below.

[2] See Laura Antoniazzi, et al. *Technologies in Brazilian Agriculture and Potential for Cooperation with Africa* (Institute for International Trade Negotiations, 2013), https://bit.ly/2Ur1bga

Elements of Study

Among the technologies selected, the following categories were addressed: water, genetics, production systems, reforestation, post-harvest systems, feed, capacity-building and information and communications technology (ICT).

The 11 technologies chosen for this study are those most adaptable in Africa, according to the following elements:

- ✓ original technology name in order to facilitate finding new data, if needed (English/Portuguese);
- ✓ organization responsible for the publication of the report/article and/or development of the technology;
- ✓ crop activity (value chain);
- ✓ category (type of technology);
- ✓ brief description of the technology (e.g. what it is and how it works);
- ✓ whether the technology relates to adaptation and/or mitigation of climate effects;
- ✓ positive impacts (economic, social and environmental) in terms of yield increase, better use of inputs, greenhouse gas (GHG) mitigation or other areas (value proposition);
- ✓ primarily applicable agroecological zones based on the regions where the technology was developed or implemented (Brazilian biomes);
- ✓ SDG impact (goals and targets);
- ✓ year and place of development;
- ✓ target audience (farm profile and farm or community level);
- ✓ scale of current adoption (number of farmers and hectares) and enabling environment;
- ✓ costs and necessary investments in order to implement the technology;
- ✓ diffusion strategy (how the technology was spread);
- ✓ technology developer and intellectual property status (ownership);
- ✓ possible adaptation measures and necessary conditions for successful implementation;
- ✓ possible negative impacts due to its implementation and/or after effects (if any) and points to be observed;
- ✓ references.

Because Africa is so large, this study prioritized technologies suitable for or adoptable in regions with low precipitation levels (arid and/or semi-arid regions). In Brazil, the Cerrado and Caatinga biomes represent those agroecological zones with more similar conditions to African drylands.

1. One Land & Two Waters

Access to water for food production in semi-arid zones

Original technology name

One Land and Two Waters Programme (P1+2): “Access to water for food production” (*Programa Uma terra e duas águas (P1+2)*)

Organization responsible

Embrapa Semi-arid (Embrapa Semiárido)

Crop activity (value chain)

Multiple

Category and value chain

Water

Figure 2: Brazil’s semi-arid zone

Photo: Bmleite1

Description of technology

This social programme aims at ensuring water and land access by low-income families living in semi-arid rural areas. The programme provides families with enough water sources for either food and animal production or human daily needs, building technologies to improve water harvesting and management, as well as land use.

The goal of the programme is to teach people how to farm in a more sustainable way, taking into consideration the semi-arid context. The technologies adopted by P1+2 are simple, cheap and easy to apply by male and female farmers. The programme uses several types of structures for capturing water for food production and it currently uses seven different structures: (i) tank cisterns for drinking water (16,000 litres); (ii) underground dams (for crop irrigation); (iii) small surface dams (“*Barraginhas*”, which are semicircular in depth to bring moisture into the soil for crops); (iv) stone tanks (for community uses); (v) boardwalk cisterns (“*cisternas calçadão*”, which are 200m^2 concrete slabs for water harvesting with 52,000-litre reservoirs); (vi) “*Barreiro-trincheira*”, long, narrow, deep tanks that are dug into the ground; and (vii) popular water pumps (BAP in its original Portuguese acronym).

The programme uses low-cost, bottom-up, long-term measures, including an educational component. These community-based technologies create better conditions for farmers to strengthen their production systems, generating food and nutrition security. This food production system follows agroecology principles (no agrochemicals or chemical inputs). The result is diverse and healthy food production intended primarily for family consumption and the sale of any surplus produce.

Climate change impact

Adaptation

SDG impact

- ✓ **1** (1.4, 1.5, 1.a)
- ✓ **2** (2.4)
- ✓ **3** (3.3, 3.9)
- ✓ **6** (6.1, 6.4, 6.a)
- ✓ **12** (12.2)
- ✓ **13** (13.1, 13.2)

Technology developer and intellectual property status

Articulação Semiárido Brasileiro (ASA) and Embrapa centres – with no property rights

Year of development

2007

Primarily applicable agroecological zones

Semi-arid regions

Target audience

Rural communities in semi-arid regions

Positive impacts/value proposition

The system collects rainwater to improve rural livelihoods in semi-arid areas by increasing water availability and thus strengthening food security. Therefore, it contributes to increasing smallholders' income and empowering rural populations and local organizations. Families become more resilient to droughts, retaining their capacity to produce food for local consumption and income generation. Instead of migrating, families are encouraged to stay in rural areas with no need for external relief (such as water carts). A significant drop in infant mortality has been observed after the construction of cisterns, as have subsequent health benefits.

Scale of current adoption and enabling environment

This water harvesting technology was developed and diffused within a broader programme in the Brazilian semi-arid region, including social mobilization and technical solutions covering 980,133 km^2 and 1,135 municipalities. Through the P1+2 programme, more than 160,000 families gained access to water for food production in the Brazilian semi-arid region from 2011 to 2016. P1+2 has built 9,000 cisterns, 420 underground dams, 302 stone tanks and 208 popular water pumps, as well as several underground rainwater tanks ("*barreiro-trincheira*").

Embedded in the historical efforts to reduce local rural exodus, the broad P1+2 programme also aims to promote health, the use of agroecological

Costs and necessary investments

Cisterns are relatively cheap technologies; those for drinking water (16,000 litres) cost around US$828, while those for agricultural production cost US$2,670 on average. The Brazilian federal government is the main funder of the programme and its technologies, with US$66.7 million spent in 2017.

Several other institutions have funded cisterns and activities, such as Fundação Banco do Brasil (US$34.7 million spent on 12,000 cisterns for agricultural production and US$48 million spent on 80,000 drinking water cisterns), Banco do Nordeste, Sebrae and Petrobras, among others.

techniques and farmers' rights to land, water and seeds for the production of culturally appropriate food. Local community organizations have been brought together in networks and aligned with public policies.

Diffusion strategy

All activities are focused on developing farmers' technical capacity. Community organizations, municipalities and other local institutions are responsible for registering families, using data from a federal registry of low-income citizens. Priority is given to families with children up to 6 years old and headed by women. Once part of the programme, beneficiaries attend training sessions on water management for agricultural practices and bricklaying.

Possible adaptation measures and necessary conditions

The programme was developed and implemented through a partnership between grass-roots organizations and governmental institutions. Therefore, programmes aiming to use similar technologies must shape their implementation strategies to their cultural and institutional contexts, as well as to current public policies in force across the territory in question.

Possible negative impacts

There are no direct negative impacts. However, if the producer does not follow the procedures of use, water may be wasted.

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2. Smallholder Maize Multiplication

An economic alternative to produce one's own seed and improve maize yield and quality

Original technology name

Maize varieties for multiple uses (including multiplication) (*Milhos Especiais – Variedades e Multiplicação para a Agricultura Familiar*)

Organization responsible

Embrapa Maize and Sorghum (Embrapa Milho e Sorgo)

Crop activity (value chain)

Maize

Category (type of technology) and value chain

Genetics

Figure 3: Cultivar BR 473 – yellow grain

Photo: Marco Verch

Description of technology

These cultivars are special varieties of maize that can be produced and multiplied on farms, generating seeds for several years. Cultivars BR 451 (white grain) and BR 473 (yellow grain) are high in protein and thus are good for both human consumption and animal feeding. Both are early varieties. The sweet varieties are Superdoce (BR 400) and Doce cristal (BR 402), while BRS Ângela (white grain) is a maize popcorn. Requiring little technical assistance, these varieties can be cultivated for self-subsistence and for commercial purposes, and farmers can store seeds for several years, as they will maintain their characteristics over this time.

Climate change impact

Adaptation

SDG impact

- ✓ **1** (1.5)
- ✓ **2** (2.1, 2.4, 2.5, 2.a)
- ✓ **13** (13.1)
- ✓ **15** (15.6)

Technology developer and intellectual property status

These cultivars recommended to smallholder farmers were all developed by and are the intellectual property of Embrapa and, therefore, they are lower in price than other cultivars. Smallholder farmers can buy them at lower prices than other farmers.

Year and place of development

The BR 451 and BR 473 varieties were launched in 1998 and 2004, respectively. Seed multiplication has been successfully practised by farmers for several years.

Primarily applicable agroecological zones

These cultivars can be used in multiple regions, namely in all those that have suitable soil and weather conditions for maize production.

Target audience

This technology targets smallholder farmers who want to store seeds for several years as well as to improve maize yields and production while maintaining good nutritional quality for feeding cattle or for their own consumption.

Positive impacts/value proposition

These high-yield and high-protein varieties can improve the quality of human nutrition and increase cattle-based income. As they are highly nutritious varieties, these grains contribute to fattening animals when other food items are not available or affordable. In addition, these cultivars can be used in multiple regions because, as smallholders can produce their own seeds, genetic purity is maintained simply through isolation. This maintenance of genetic purity without the need to buy other varieties contributes to farmers' independence.

Scale of current adoption and enabling environment

According to Embrapa, there are more than 470 maize varieties, of which over 290 are genetically modified organisms and around 180 are conventional. In Brazil, these maize varieties have long been used by family farmers across the country for commercial or subsistence purposes, providing a source income as well as good profits and quality food for cattle. It was not possible to estimate an accurate adoption scale.

Costs and necessary investments

According to Embrapa Maize and Sorghum and partners that sell maize seeds from Embrapa (especially the seeds listed above), the average price of these maize varieties is between US$1.1 and US$1.6 per kilogramme (sold in bags of 20 kg, which are sufficient to plant 1 hectare). Furthermore, additional costs such as soil and crop management need to be considered in this practice.

Diffusion strategy

Embrapa, in partnership with industries and suppliers, promotes field days for smallholders and other interested farmers. Embrapa and partners have released several publications about this technology and regularly provide technical assistance for agricultural producers.

Possible adaptation measures and necessary conditions

Any region with favourable soil and weather conditions for maize cultivation can use these varieties. The price for adopting seed multiplication has to be considered, as do soil and management practices, based on the region and the farm's condition.

Possible negative impacts

Owing to the genetic variability of seeds, farmlands are subject to crop diseases and pests. These could affect the seed quality, in turn affecting the grain yield and production.

References

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3. Cassava Short-Cycle Cultivation

Enabling producers to have an alternative crop to sell during the cassava cycle

Original technology name

Intercropping cassava with other crops with short cycles (*Consórcio de mandioca e outras culturas de ciclo curto*)

Organization responsible

Embrapa Cassava and Fruits (Embrapa Mandioca e Fruticultura Tropical)

Crop activity (value chain)

Cassava

Category (type of technology) and value chain

Production system

Figure 4: Cassava and upland rice intercropping

Photo: Oka Mitsunori / JIRCAS Library

Description of technology

In this technology, cassava is planted in double-row spacing: 2 metres between rows and 0.6 metres between plants. The amount of space between rows allows short-cycle crops to be planted in these areas (beans, groundnut, maize, yams, etc.). By doing this, the cassava crop benefits from the fertilizing of the annual crop (both the fertilizer and straw), the need for weeding is reduced, small machines can still be used in the gaps, harvesting costs are reduced and the soil is more covered, thus improving the soil quality and also avoiding erosion and soil degradation. Furthermore, this technology provides an opportunity for smallholders to produce another crop in their lands, thus increasing potential profits and providing another food intake option.

Climate change impact

Adaptation and mitigation

SDG impact

- ✓ **1** (1.5)
- ✓ **2** (2.1, 2.3, 2.4)
- ✓ **12** (12.2, 12.4)
- ✓ **13** (13.1)
- ✓ **15** (15.3)
- ✓ **17** (17.7)

Technology developer and intellectual property status

Various arrangements/models of intercropping with cassava are available for free on Embrapa's website without intellectual rights for implementation.

Year and place of development

This production system (cassava with another crop) was first developed in 1981, but since then more types of intercropping have been developed and used.

Primarily applicable agroecological zones

Regions that have good environmental and soil conditions for cassava and a potential second crop

Target audience

Smallholders seeking to increase crop yields and income

Positive impacts/value proposition

Economic benefits**:** This technology reduces harvesting costs because the root is straighter and thus easier to pluck. Having an additional crop on the land increases crop production without an increase in the size of the field and hence increases the value of the field. Moreover, an additional crop ensures more agricultural stability for the farmland and for farmers' income.

Environmental benefits**:** Owing to the low soil capacity of cassava farmlands, the short-cycle crop plays a key role in soil protection, including by increasing soil cover, organic matter and nutrition. Moreover, intercropping increases the water stored in the soil, decreases the likelihood of erosion, increases carbon sequestration and reduces the effects of pests on crops.

Food security**:** Farmers can combine proteins (beans) and carbohydrates (cassava) to have multiple food intake options.

Scale of current adoption and enabling environment

According to Embrapa Cassava and Tropical Fruit, cassava in Brazil's northeast region has been produced mainly through this intercropping practice. The main crops used with cassava are peanut, maize, cowpea, beans and watermelon. The selection of the second crop depends on the region, soil conditions, farmers' preferences and management needs.

Costs and necessary investments

According to Embrapa (2003), the cost of intercropping cassava and beans over 1 hectare without soil management is US$1.07/kg bean seed, US$4/kg cassava root for planting and US$1.87/man/day for cassava + bean planting. Costs may vary depending on the period of evaluation and the region.

Diffusion strategy

Embrapa Cassava and Tropical Fruit has published articles and manuals concerning the possible arrangements and models of this practice. In addition, field days and technical assistance are also used to spread this technology.

Possible adaptation measures and necessary conditions

- ✓ Evaluation of potential crops that could be used in intercropping with cassava in each region
- ✓ Adaptation of each crop to soil and weather conditions
- ✓ Conditions for smallholders managing the potential second crop
- ✓ Assessment of the crop's potential benefits for the producer
- ✓ Technical assistance to help farmers correctly manage the new crop alongside cassava

Possible negative impacts

Without appropriate previous analysis to correctly choose the species to be intercropped, there might be negative interactions between cassava and the second crop. If that is the case, non-adaptation between crops can lead to the suppression of one of the crops, even cassava. Furthermore, farmers may not have the appropriate conditions and/or enough technical knowledge to grow a certain crop, which could affect her/his cassava intercropping system. Finally, if a previous analysis of possible markets for the crops is not carried out, the producer may lose produce because (s)he may not be able to sell it.

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4. Integrated Biosystems for Food Production

Ensuring the self-sufficiency of small properties

Original technology name

Sisteminha – integrated biosystems for food production (*Sisteminha – biossistema integrado para produção de alimentos*)

Organization responsible

Embrapa Middle North (Embrapa Meio Norte)

Crop activity (value chain)

Multiple (fish/poultry/vegetables/fruit)

Category (type of technology)

Production system

Figure 5: Fish tank with a Sisteminha submersible pump

Photo: Archive of the Government of Tocantins state

Description of technology

The Sisteminha is an integrated food production system consisting of rotating the production of fruit, vegetables, poultry, small animals (e.g. pigs and guinea pigs) and fish, with nutrients being recirculated as part of the fish farming using a submersible pump installed inside the fish tank. It is based on four principles: (i) miniaturization, (ii) replicability, (iii) production scheduling and (iv) food and nutritional security, which is particularly appropriate for family farmers. The system is geared towards sustainable development, as it makes functional links between agriculture, livestock, food processing, waste management and water use, while eliminating the environmental impacts caused by the conventional implementation of these activities.

Climate change impact

Adaptation and mitigation

SDG impact

- ✓ **1** (1.5, 1.b)
- ✓ **2** (2.1, 2.3, 2.4)
- ✓ **6** (6.3)
- ✓ **11** (11.a, 11.c)
- ✓ **12** (12.a)
- ✓ **13** (13.1)
- ✓ **15** (15.9, 15.c)

Technology developer and intellectual property status

Embrapa Middle North. Technical details on how the system works are available for free at Embrapa's website (there are no intellectual rights for

Year of development

Developed in 2011/2012 and patented in 2013 by Embrapa Middle North in Piauí state, Brazil

implementation), including a report on the operation of the submersible pump for fish tanks.

Primarily applicable agroecological zones

This technology can be used in multiple agroecological zones and is particularly appropriate for semi-arid regions and isolated areas owing to the main objective of the technology (to increase food production for subsistence). In Brazil, it can be adapted for all biomes: Amazon rainforest, Cerrado (savanna), Atlantic Forest, Caatinga, Pampa and Pantanal.

Target audience

Residents and/or producers of urban, peri-urban and rural areas, including *quilombolas* communities,[3] indigenous people and family farmers who seek to increase the amount of food produced in small areas – between 100 and 1,000 m^2 – for subsistence and, if possible, to increase their incomes through any surplus food produced.

Positive impacts/value proposition

(i) diversifying crops and increasing food production for small farmers or regions; (ii) improving the quality of life of farmers through increased availability of organic and diverse food, enabling producers and their families to access all of the food groups necessary for a nutritious and balanced diet; (iii) reducing expenses through the water recirculation system; and (iv) being highly adaptable, as the tanks and other structures are easily constructed using materials found in the surroundings of local properties.

Scale of current adoption and enabling environment

Embrapa Middle North is currently operating in the states of Piauí, Maranhão, Ceará and Minas Gerais. However, the system is being adapted for various properties in different regions throughout the country, and it could be used throughout Brazil and abroad. In addition, some countries in Africa are also receiving support to implement the system through a marketplace platform. It has become a public policy solution in Brazil, where public institutions plan to install more than 3,000 systems.

Costs and necessary investments

Costs vary between US$120 and US$1,335, according to the size of the area to be converted for the system and the materials to be used, as well as the technical assistance provided to producers to correctly implement the system, without losses and extra expenses.

Diffusion strategy

Embrapa delivers courses on this system in universities and other educational institutions, as well as among municipal, state and federal agencies that express an interest in applying this system as a public policy. This technology has won several awards, which has increased its visibility.

Possible adaptation measures and necessary conditions

Farms must be at least 100 m^2 and have water available to supply the aquaculture tanks (fish farming). Each tank should contain between 6,000 and 8,000 litres so that fish production (starting from 30 kg of fish after 90 days) and the subsequent fertilizer production (through animal waste) are sufficient to

[3] *Quilombolas* are descendants of Afro-Brazilians who escaped slavery (abolished in 1888 in Brazil) and founded community settlements to live in freedom. Today, these settlements, called *quilombos*, are officially recognized by Brazil's Government.

maintain the system.

Residues from fish farming and other types of animal husbandry are used for fertilizing and maintaining the area in which fruit and vegetables are grown, avoiding industrial fertilizers and pesticides. An analysis is needed of the most suitable species of poultry (and small animals), fish, vegetables and fruit for each region.

Possible negative impacts

Producers may face challenges in marketing their products in remote areas. Areas with severe water shortages are unable to install and maintain the system owing to the key role of the fish tanks (aquaculture) in the functioning of the system.

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5. Integrated Crop-Livestock-Forest

A solution to diversify production and increase the productivity of agriculture in a sustainable way

Original technology name

Integrated crop-livestock-forest (ICLF) (*Integração Lavoura-pecuária-floresta*)

Organization responsible

ICLF Network Association (public-private partnership formed by Bradesco, Cocamar, John Deere, Soesp, Syngenta and Embrapa). Others important agencies in Brazil related to ICLF are Embrapa Eastern Amazon (Embrapa Amazônia Oriental), Embrapa Beef (Embrapa Gado de Corte), Embrapa Livestock Southeast (Embrapa Pecuária Sudeste) and SENAR – National Rural Apprenticeship Service (Serviço Nacional de Aprendizagem Rural).

Crop activity (value chain)

Multiple (forest/livestock/crops)

Category (type of technology)

Production system/reforestation

Figure 6: Crop-livestock-forest

Photo: copyright-free under Creative Commons CC0

Description of technology

Integrated crop-livestock-forest (ICLF) is a sustainable production strategy that includes crop, livestock and forestry activities undertaken in the same area, aiming to increase synergies among the components in the agroecosystem and to increase the economic feasibility of farms, improve animal welfare and mitigate greenhouse gas (GHG) emissions. This system can be implemented through intercropping, either in succession or in rotation, so that mutual benefits are gained from all activities.

ICLF works by planting annual crops (rice, beans, maize, soybean or sorghum) and trees along with forage species (*Brachiaria* or *Panicum*). It can be used in different settings, combining two or three components in a single production system: crop-livestock (ICL) – mixed farming; crop-forest (ICF) – agroforestry; livestock-forest (ILF) – livestock-forestry; or crop-livestock-forest (ICLF) – agro-livestock-forestry.

Climate change impact

Adaptation and mitigation

SDG impact

- ✓ **1** (1.4, 1.5)
- ✓ **2** (2.3, 2.4)
- ✓ **6** (6.6), 8 (8.4)
- ✓ **12** (12.2, 12.a)
- ✓ **13** (13.1)
- ✓ **15** (15.1, 15.2, 15.3, 15.5, 15.b)

Technology developer and intellectual property status

Different arrangements/models are available for free at Embrapa's website and there are no intellectual rights for implementation. Case studies are available at the ICLF Network Association's website.

Year of development

This production system has existed since the 1950s, but gained popularity in the 1990s. Since then, several models have been developed based on the premise of the integrated production of livestock with forest and crops species to improve productivity and to promote greater efficiency in the use of natural resources.

Primarily applicable agroecological zones

Multiple. It is a very flexible system that can be adapted to different production settings. In dry regions, it is more difficult to cultivate forest species.

Target audience

Applicable to farms of all sizes and profiles, provided that soil and climatic conditions are not restrictive. ICLF can also be used in degraded areas, as it can be a way to recover soil conditions.

Positive impacts/value proposition

ICLF has multiple positive impacts for the environment, producers and society as a whole.

Economic benefits**:** (i) increasing and diversifying production; (ii) increasing farmers' income by augmenting production with grains, fibres, meat, milk, and wood and non-timber products; and (iii) providing economic stability through more diversified production and the subsequent reduction of risks and uncertainties.

Environmental benefits**:** (i) promoting environmental compliance when using the forest component; (ii) considering sustainable intensification of the soil and the reduction of pests, diseases and weeds; (iii) preventing the use of new areas for production owing to the intensification process; (iv) reducing GHG emissions while promoting carbon sequestration; (v) allowing a considerable reduction in the use of agricultural pesticides and other chemicals; (vi) improving agricultural practices; and (vii) improving animal welfare by improving their thermal comfort and providing a better environment through a more efficient use of natural resources.

Social benefits**:** (i) reducing labour seasonality and rural exodus; (ii) creating direct and indirect jobs; and (iii) improving the public image of farmers within society.

Scale of current adoption and enabling environment

A study carried out by the Kleffmann Group during the 2015/2016 harvest estimated that Brazil has over 11 million hectares of integrated agricultural production systems.

Costs and necessary investments

Studies show that the implementation costs vary between about US$1,900 and US$2,100 per hectare, depending on the crops, without considering the acquisition of animals, but considering technical assistance.

Diffusion strategy

The ICLF Network Association aims to accelerate the wide adoption of ICLF systems by rural producers as part of an effort to foster the sustainable intensification of Brazilian agriculture. The Network supports 107

Possible adaptation measures and necessary conditions

The species in each arrangement/model need to be compared with local species. When adapting the system and choosing appropriate fruit tree species, account should be taken of the site's climatic suitability, the demands of the consumer

technological reference units distributed throughout all Brazilian biomes and involving the participation of 20 Embrapa research centres.

Different ICLF technical cases have been published on Embrapa's website and other institutional sites in order to disseminate this information among producers (there is no intellectual property for implementation). Additionally, Embrapa and SENAR offer courses, events and field days for producers.

market and the experience of the producer. The capacity of producers to manage species and crops that they have not previously used (for example, the pruning of trees) would need to be improved. Owing to the complexity in terms of the implementation and maintenance of ICLF, as well as the need for greater investments, some producers may face difficulties in adopting this technology.

Possible negative impacts

Depending on local market access conditions, farmers may not find places to sell certain products.

References

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6. Savanna Agroforestry Horticulture

An irrigation system to improve food production

Original technology name

Agroforestry Systems (AFS) – The Filho System (*Sistemas Agroflorestais (SAFs) – Sistema Filho*)

Organization responsible

São Paulo's Agency for Agribusiness Technology (APTA) and the Agricultural Economy Institute (IEA) from São Paulo/Embrapa Cerrados

Crop activity (value chain)

Multiple (forest/livestock/crops)

Category (type of technology)

Production system/reforestation

Figure 7: Horticulture

Photo: feraugustodesign (pixabay.com)

Description of technology

The Filho System is an agroforestry system that optimizes farming lands by using the available space between the orchards, representing an intensive and economically viable form of land use with great potential for small producers. In this system, the available space between the lines of vegetables and fruits is used for the production of short-cycle crops, especially in the early years of exploration of the orchard in order to obtain productive intensification of the area. As well as other agroforestry systems, the Filho system contributes to restore forests, recover degraded areas and provide different ecological benefits.

The system's name (Filho) comes from the Portuguese abbreviation for "fruit growing integrated with crops and vegetables" (in Portuguese: "*Fruticultura Integrada com Lavouras e Hortaliças*"). It is an integrated vegetable production system of fruits, grains and vegetables in areas with varied irrigation. It is versatile, an efficient method of soil management and suitable for intensive production in small areas. It was designed to guide the conversion of orchards into areas for producing other crops, with the aim being to promote diversification and the intensive production of food in the Cerrado, which is the Brazilian biome equivalent to savannas.

Climate change impact

Adaptation and mitigation

SDG impact

- ✓ **1** (1.4, 1.5)
- ✓ **2** (2.1, 2.2, 2.4)
- ✓ **6** (6.4, 6.6), 8 (8.4)
- ✓ **12** (12.2, 12.a)
- ✓ **13** (13.1)
- ✓ **15** (15.1, 15.2, 15.3, 15.b)

Technology developer and intellectual property status	Year of development
Different arrangements and models are available for free at Embrapa's website and there are no intellectual rights for implementation. These models contain details of the irrigation and other systems used for planting, such as plant spacing, and the potential fruit and vegetable species that can be used.	The system was developed in 2008: small areas used a mix of different species of beans and banana in the Distrito Federal region. The system was officially launched in 2014 after the primary results of the test areas were received. Since then, publications about this system have been published on Embrapa's website.
Primarily applicable agroecological zones	**Target audience**
The system was developed for the Cerrado biome (which is equivalent to savannas) as a reference. However, since it relies on irrigation, it can be adapted to any other biome.	Family farms (small producers) and fruit growers who seek to intensify food production on their farms by adopting new field technologies

Positive impacts/value proposition

Like ICLF, agroforestry systems have many positive impacts, especially when used to restore degraded areas. In Filho's case, the production's intensification leads to efficient use of land, water, sunlight, fertilizers, raw materials and labour. It has the following benefits:

Economic benefits**:** increasing and intensifying production, which promotes and expands farmers' economic activities, depending on the potential within the region. A testing area of 400 square meters in Minas Gerais state demonstrated economic gains of R$2,054.67 and R$4,137.41 (about US$ 550 and US$ 1,100) in two agricultural years, representing an increase of 282 per cent in the added gross production value by family farmer in the second year of the system.

Environmental benefits**:** (i) promoting environmental compliance through reforestation of degraded areas, reducing the pressure to expand production into new areas; (ii) considering sustainable intensification of the soil and reducing pests, diseases and weeds; (iii) reducing GHG emissions, while promoting carbon sequestration; (iv) allowing a considerable reduction in the use of agricultural pesticides; (v) improving agricultural practices; and (vi) optimizing and intensifying soil nutrient cycling.

Social benefits**:** (i) reducing labour seasonality and rural exodus, allowing the population to settle in the region and for small producers to remain within the agriculture sector; (ii) creating direct and indirect jobs; and (iii) improving the public image of farmers within society.

Scale of current adoption and enabling environment

Farms surrounding Brazil's Distrito Federal region as well as in Minas Gerais state were used as pilot areas. The system can be adopted in any region with soil and climatic conditions favourable to the cultivation of fruits, grains and vegetables. In addition, farms must have enough water to ensure the irrigation system effectively instensifies crop production.

Costs and necessary investments

The costs of irrigation in fruit farming vary between US$4,000 and US$8,000 per hectare. The costs are influenced mainly by the species to be cultivated, the total size of the cultivation area and the technological level to be adopted.

Diffusion strategy

The system was developed owing to the need for a production model in regions with low rainfall indexes to ensure the sustainability of small production areas. Knowledge about this technique and other possible models is disseminated through online publications, events, courses and even field days with producers and communities interested in implementing it.

Possible adaptation measures and necessary conditions

The species in each arrangement/model need to be compared with local species. When choosing fruit tree species, the climatic suitability of the site, the demands of the consumer market and the experience of the producer should be considered. The capacity of farmers to manage species and crops that they have not previously used (for example, the pruning of trees) would need to be improved.

Possible negative impacts

There may be difficulty in marketing products in very isolated regions when surplus produce is created.

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7. Indigenous Seeding Reforestation

Social arrangement to strengthen seed collection and traditional communities' representation in the forest restoration chain

Original technology name

Direct seeding (*muvuca*) and the development of a seed network for forest restoration projects (*Semeadura direta (Muvuca de sementes) e o desenvolvimento de uma rede de coleta de sementes para projetos de restauração florestal*)

Organization responsible

Socio-Environmental Institute – ISA (Instituto Socioambiental) and Xingu Seeds Network

Crop activity (value chain)

Native tree crops

Category (type of technology)

Forest/restoration/capacity-building

Figure 8: Seed collectors from the Xingu region collecting native seeds at an indigenous territory in Southeast Amazon

Photo: Rogério Assis / ISA

Description of technology

This technique involves two technologies that are developed and applied together. The "*muvuca*" technique is a direct seeding technique for vegetation recovery projects that is considerably cheaper than planting seedlings, mainly owing to the lower cost of the main input (seeds versus seedlings) and the necessary maintenance in each of the techniques.

The *muvuca* technique consists of a mix of native forest and green manure species seeds that are seeded using farmers' regular machinery, such as spreaders, when possible, or manually. Short-cycle (up to one year) green manure species provide initial land recovery and enough shade for the establishment and growth of pioneer native trees, preventing the growth of exotic grasses and weeds. Along with short-cycle species, other seeded shrubs and vines that live up to three years begin their growth, allowing the long-growing native species to develop sufficiently, thus ensuring the recovery of the area.

Native seeds are collected by indigenous and local communities, who are organized within a network to promote capacity-building (specific training is given on safe collection and seed quality) and commercialization (information is given on demand, prices, etc.). The key to ensuring the economic feasibility of the network is ensuring synergy between the demand for seeds and the collection itself. Thus, the dialogue between the landowners (consumers) and communities (collectors) is an important pillar in the sustainability of this network.

Climate change impact

Adaptation and mitigation

SDG impact

- ✓ **1** (1.5)
- ✓ **2** (2.3, 2.4, 2.5, 2.a)
- ✓ **6** (6.6)
- ✓ **8** (8.1)
- ✓ **10** (10.2)
- ✓ **13** (13.1, 13.b)
- ✓ **15** (15.1, 15.2, 15.3, 15.8, 15.9, 15.a, 15.b)
- ✓ **16** (16.7)

Technology developer and intellectual property status

ISA (there are no intellectual rights for implementation), which is a non-governmental organization

Year of development

ISA started to implement restoration projects in 2006 through "*Y Ikatu Xingu Champaign*" (in the Kamaiurá indigenous language; "Save the Xingu's good water" in English). The seeds collection network was created a year later. It is located in the Xingu indigenous territory in the north of Mato Grosso state, which borders the Amazon and Cerrado biomes in Brazil.

Primarily applicable agroecological zones

The *muvuca* technique can be used in multiple agroecological zones, with good results achieved even in low-precipitation regions.

Target audience

Landholders who seek to restore degraded areas as well as rural settlements on a small scale; traditional communities and indigenous peoples are the target audiences of the native seeds network.

Positive impacts/value proposition

This technique has environmental, economic and social impacts. First, it significantly reduces implementation costs, as collaboration leads to more areas being restored and saves resources. Through better management practices and the restoration of degraded areas, seed source areas are preserved and the carbon stocks are increased, which guarantees the preservation of habitats for fauna and flora and improves communities' living conditions. The technique can also be adapted to the production of fruit and wood species for commercial purposes.

The development of a seed collection network increases cooperation between different communities, thus increasing their connections and representation in the community, and offering concrete household income opportunities, as well as opportunities for forest conservation and the retention of traditional knowledge.

The initial motivation for this programme was to improve water quality within the Xingu territory, as reforestation alongside rivers can prevent erosion and nutrient run-off, and decrease the need for agrochemicals.

Regarding carbon intake, the seed collection programme in the Xingu region resulted in a reduction of GHG emissions and removals of 9,485 tons of CO_2 equivalent, based on 181 hectares of restored areas.[4] In addition, 89 community members (41 of whom were women) gained qualifications and/or improved their

[4] ISA commissioned a carbon monitoring report audited by Imaflora (the Institute of Forest and Agricultural Management) and validated by CCB (Climate, Community and Biodiversity Standards) entitled *Carbon Nascentes do Xingu*. The report was carried out based on data collected from 2011 to 2017, accounting for GHG from 2011 to 2042 (30 years after planting).

knowledge as a result of the training given as part of the project's activities. Overall, 583 people (344 of whom were women) improved their livelihoods or income as a result of the project's activities.

Scale of current adoption and enabling environment

More than 5,000 hectares of forest restoration projects in the Cerrado and Amazon biomes were undertaken using native seeds of the Xingu Seeds Network. The native seeds collection network was responsible for producing over 175 tons of seeds, corresponding to more than US$750,000 income for the communities involved. After the success in the Xingu region, other places and communities are receiving support to develop regional seed networks. One example is the Vale do Ribeira Seed Network, in São Paulo state, where three *quilombos* have sought to create their own network. Another two native seed networks were established in Veadeiros Park (Cerrado) and around the Jirau hydroelectric dam (Amazon). At Veadeiros, 108 hectares were restored with 22 tons of native seeds (including grass seeds).

For successful implementation, knowledge about seeds and ecological restoration methods is needed, along with knowledge of the legal framework. For successful seed commercialization, the network must establish long-lasting connections with contractors and a fair price must be defined; the community must also be involved and seed commercialization must be aligned with demands.

Costs and necessary investments

Forest restoration costs vary, mainly according to workforce costs and seeds prices. A study[5] indicates that the costs of forest restoration using the *muvuca* technique vary from R$2,300 to R$3,600 (US$650 to US$950) per hectare depending on the region in Brazil, while the costs of using seedlings vary from R$8,000 to R$17,400 (US$2,100 to US$4,500). This technique can be implemented using common farming machinery or planting can be done manually, like with any other seed. Therefore, no specific tools or knowledge are required. A native seed network requires infrastructure, namely seed houses, laboratories for testing seed quality and transportation. The main costs are related to training collectors and farmers.

Diffusion strategy

ISA promotes capacity-building as part of a programme for collectors on how to collect, prepare and transport seeds. ISA acts as an intermediary between farmers (customers) and the seed collection network, communicating with both sides. Funding could also be gained through forest projects to improve carbon stocks. Today, there is a bottleneck in seed demand, as farmers have various legal requirements to comply with. ISA also publishes articles, reports and books, such as *Muvuca Guide* (*Guia da Muvuca*) and *Native seeds which connect the Xingu region* (*Sementes nativas que conectam o Xingu*).

Possible adaptation measures and necessary conditions

There first needs to be both a demand and incentives for forest restoration before this technique can be implemented. Local species must be identified and a network needs to be established that can offer sufficient seed supply for this technique. A seed network must be well connected and undertake community engagement, and it must have access to native vegetation areas for collection.

[5] Antoniazzi et al. "Restauração florestal em cadeias agropecuárias para adequação ao código florestal: análise econômica de oito estados brasileiros". Input and Agroicone, 2016. Retrieved from: https://bit.ly/2KYihvd.

Possible negative impacts

The need for large numbers of seeds means that it can be difficult to collect the required number for this technique to adequately maintain ecosystems. In terms of the seed network, the market does not necessarily remain stable over a long period owing to the changes in both supply and demand. In Brazil, even though environmental legislation requires that degraded areas be restored, it is still a fragile market, which depends on the contribution of non-governmental organizations. Forest restoration markets and activities are very dependent on national and international regulations and legal frameworks, and these have not been very stable to date. This may result in frustrations regarding expectations and variability in income generation.

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8. Fruits Solar Dryer

Simple technology to harness food outside its harvest time

Figure 9: Solar dryer model

Photo: Embrapa

Original technology name

IAPAR solar dryer for plants, fruits and roots (Secador solar IAPAR para hortaliças, frutas e raízes)

Organization responsible

IAPAR – Parana Agronomic Institute (Instituto Agronômico do Paraná)

Crop activity (value chain)

Multiple (food production)

Category (type of technology)

Machinery – post harvest (conservation)

Description of technology

Dehydration enables food to be preserved for a long time without refrigeration. It is a technique that has been used for centuries to preserve fruits, vegetables and even meat. IAPAR has developed a low-cost solar dryer for plants and roots. Easy and cheap to construct, it is a box with a black base that is protected by a thin net, so that the product does not touch the base. The drying or dehydration is done by sunlight that is absorbed by the cover and so, in turn, by the black base. The dryer must be built at an angle, ensuring an internal temperature of 45 to 60° C, with the dry air entering the box at the base and the humid air being released from the top. The drying process takes 24 to 72 hours, depending on the product. It is important to use a thermometer to check the temperature and then estimate the time for drying.

Brazil is a producer of fruits and roots, so this process is important for its farmers. The use of this technology assures food has a longer shelf life and increases the value of the final products.

Climate change impact

Mitigation

SDG impact

- ✓ **1** (1.4, 1.5)
- ✓ **2** (2.1, 2.3)
- ✓ **7** (7.a)
- ✓ **12** (12.3)
- ✓ **13** (13.1)

Technology developer and intellectual property status	Year of development
IAPAR (there are no intellectual rights for implementation)	Developed in 1980 by IAPAR
Primarily applicable agroecological zones	**Target audience**
The technique can be used in multiple regions, namely in those with dry conditions and a sufficient availability of sunlight.	This technology can easily be used in regions where smallholder farmers and communities with low incomes are common and where such farmers are isolated from markets. The producer can store products, ensuring the provision of food for a longer period, both for their own subsistence and for commercialization to generate income.

Positive impacts/value proposition

This technique involves drying food post harvest using sunlight. Without using electricity, it is possible to dry and even cook the food, and this technique may even eliminate some pathogens. Dehydration allows food to be preserved for a long time, without the need for refrigeration, interrupting the natural process of biological deterioration, bacterial activity, enzymatic transformation and oxidation. It preserves the main characteristics of food, namely its colour, aroma, flavour and texture. In this way, farmers are able to keep food for use beyond its harvest time, avoiding food loss. In addition to allowing for a richer diet and the use of regional fruits, dehydration can generate income for the producer and/or community through the sale of surplus produce.

Scale of current adoption and enabling environment	Costs and necessary investments
Solar dryers are one of the oldest methods for drying food. A great number of foods, such as fruits and meat, are dried using this method. It is very easy to use, as the only essential condition for the operation of the solar dryer (other than its correct construction) is the presence of sunlight, which must be controlled by manually adjusting the equipment. Due to lack of data, it was not possible to determine the current adoption scale.	Costs and investments will vary according to the prices and availability of the constituent materials: wood, polystyrene foam for thermal insulation, plywood sheets, sheet metal, a screen protector and a glass top.
Diffusion strategy	**Possible adaptation measures and necessary conditions**
IAPAR, as well as agronomists and specialists from extension and technical services, demonstrate, through publications (such as reports and factsheets), events, courses and even field days, how the solar dryer is built and installed, targeting producers and communities interested in the technology.	The solar dryer is constructed with simple materials such as wood, polystyrene foam and glass. However, the possibilities of adaptation need to be evaluated if these products are not available in certain regions. The solar dryer can also be adapted to the available space and conditions.

Possible negative impacts

If the dryer is not constructed using suitable materials and measures, and if the correct internal temperature is not maintained in the dryer – namely between 45 and 60° C – the dryer may not produce the expected results.

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9. Forage Palm for Livestock Feeding

A well-adapted plant alternative for dry and hot regions

Original technology name

Forage palm (cactus) (Palma forrageira)

Organization responsible

Embrapa Dairy Cattle and Embrapa Semi-arid (Embrapa Gado de Leite e Embrapa Semiárido)

Crop activity (value chain)

Livestock and milk production

Category (type of technology)

Feeding

Figure 10: Forage palm plantation

Photo: Cássio Moreira / Codevasf

Description of technology

Forage palm is a crop that is well adapted to the semi-arid climate (high temperatures and very dry). Forage palm can be used as feed for livestock and in milk production. The use of palm for animal feeding is already an established practice in several countries. However, its use in volume, with food quality control and management techniques, is increasingly being promoted. Different cultivars are adapted to their conditions and so require different management techniques and can be used for different types of feeding.

The technology on which Embrapa is working with several producers and sub-regions is related to the planting of certain palm cultivars and managing them in certain ways in intensified production systems to adapt to Brazilian semi-arid regions (particularly in the Caatinga biome) and planting different mixtures of them with other crops for animal feed. These initiatives have already created incomes and improved the accessibility to food for families living in regions where the climate is a challenge owing to low precipitation levels and long periods of drought, and so this technique represents an important tool in sustainable livestock management and regional development.

Climate change impact

Adaptation and mitigation

SDG impact

- ✓ **1** (1.5, 1.a)
- ✓ **2** (2.3, 2.4)
- ✓ **13** (13.1)
- ✓ **15** (15.3)

Technology developer and intellectual property status	Year of development
Embrapa studied the potential use of forage palm as animal feed, testing different varieties. The varieties were chosen based on the semi-arid and arid conditions in the regions where there is a low precipitation throughout the year.	The use of palm for animal feeding is already an established practice in several countries. However, its use in volume, with food quality control and management techniques, is increasingly being promoted. Embrapa Dairy Cattle and Embrapa Semi-arid are two of the most important agencies working with forage palm in the semi-arid region in Brazil. The publications of these agencies that were used for this study are from 2015 and 2016 and are focused on the production of forage palm at a larger scale for feeding purposes.
Primarily applicable agroecological zones	**Target audience**
Semi-arid and arid regions	Farms of all sizes located in semi-arid and arid regions that are seeking new feed possibilities for their animal production (sheep, goats, cattle and pigs)

Positive impacts/value proposition

This technique has an impact on livestock and milk production, as little external input is needed to produce feed for animals. By replacing more expensive feed ingredients with palm throughout the year, feed costs are reduced and use is made of the plant throughout the whole year. The inclusion of palm in feeding dairy animals reduces water consumption without affecting the quality of the milk and animal welfare. Palm plantations can help to preserve the Caatinga biome and, according to Nobel (2010)[6], some species can sequester the equivalent of 30 tons of CO_2 per hectare per year under suboptimal growth conditions.

[6] Nobel, Park S. Desert Wisdom/Agaves and Cacti: Co2, Water, Climate Change. New York: iUniverse, 2009.

Scale of current adoption and enabling environment

Since forage palm was brought to Brazil, it has been an important source of food and feed in arid and semi-arid regions, as is also the case in other regions around the world with similar climate characteristics. In Brazil's northeast region, it is cultivated at a large scale and used throughout the year, constituting one of the main crops used for dairy cattle and goat feed. It is estimated that Brazil's semi-arid region has over 500,000 hectares of palm-forage cultivated area (Moura, 2011)[7].

Costs and necessary investments

The costs of planting palm vary according to the level of management needed in terms of the soil and the inputs required. The main input is the seedling itself, called "*raquetes*" in Brazil ("rackets" in English). A 2017 study[8] with data from the Rio Grande do Norte state and in collaboration with Embrapa and the Agricultural Research Company of Rio Grande do Norte state (Emparn) estimated that the implementation costs for 1 hectare varied from about US$4,500 to US$13,500, depending on the acquisition prices of rackets. However, even with higher implementation costs, all the scenarios gave an internal rate of return above 40 per cent, considering irrigated and intensive production.

It is important to highlight the role that associations, producer cooperatives and technical assistance institutions play in promoting planting, reproduction and the distribution of seedlings (rackets) for reducing the total costs of the system.

Diffusion strategy

The main motivation for developing this technology, as well as its different forms of implementation, was the need to find new ways to guarantee the sustainability of agriculture activities in regions with sensitive climatic conditions.

In this context, different educational and research institutions, such as Embrapa and Emparn, have been conducting studies on the subject. The dissemination of this information is focused on smallholder farmers and cooperatives in Caatinga and some parts of the Cerrado biome in Brazil (semi-arid and arid regions). These organizations publish studies and disseminate knowledge through online publications, courses, events and field days for producers, with the objective being to present new alternatives and management practices.

Possible adaptation measures and necessary conditions

In ruminant feeding, palm can be used in a variety of ways; however, how it is used differs according to the circumstances, such as labour, facilities, machinery and material availability. It seems that forage palm should not be used as a single feed and instead should be used with other sources of nutrients. Thus, it is necessary to carry out analyses as regards the different types of feed available regionally.

[7] Moura, Magna S. B. et al. Aptidão do Nordeste brasileiro ao cultivo da palma forrageira sob cenários de mudanças climáticas. In: Simpósio de Mudanças Climáticas e Desertificação no Semiárido Brasileiro, 3., 2011, Juazeiro. Experiências para mitigação e adaptação; anais. Petrolina: Embrapa Semiárido, 2011. 1 CD-ROM. (Embrapa Semiárido. Documentos, 239). Retrieved from: https://bit.ly/2lJ9WTf.

[8] Dantas, S. F., Lima, G., & Mota, E. (2017). Viabilidade econômica da produção de palma forrageira irrigada e adensada no semiárido Potiguar. Revista IPecege, 3(1), 59-74. https://doi.org/10.22167/r.ipecege.2017.1.59

Possible negative impacts

If analyses on the most suitable cultivars for each region are not conducted correctly, pests and diseases might propagate across plantations and crops may even be lost. In addition, measuring the optimal amount of palm in the mix of animal feed is essential for ensuring the quality of meat and milk, as well as animal welfare.

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10. Climate-Smart Lamb Farming

A climate resilience programme for corporations operating in vulnerable areas

Figure 11: Goat breeding

Photo: copyright-free under Creative Commons CC0

Original technology name

Sustainable Smart Agro-climatic Module (MAIS – Módulo Agroclimático Inteligente e Sustentável) and the MAIS Lamb Module (MAIS Cordeiro)

Organization responsible

Adapta Group is a company created at the end of the Proadapta Sertão project to offer a specific corporate programme for the MAIS programme and its modules

Crop activity (value chain)

Goat/sheep

Category (type of technology)

Capacity-building/technical assistance

Description of technology

MAIS helps farmers' organizations (cooperatives, associations and private entities) to overcome climate challenges by implementing a technological package for sustainable agriculture among small producers. The MAIS programme consists of four main pillars: (i) a suite of climate-smart agricultural technologies and practices; (ii) a technical assistance programme for disseminating the production systems among farmers; (iii) a capitalization strategy, including credit, to implement the climate-smart agricultural system among farmers, and; (iv) a monitoring and evaluation process to understand farm development from a socio-economic and environmental perspective. The programme's goals are to increase farmers' productivity and efficiency, to reduce production oscillation owing to the effects of the climate and to restore ecosystem services and lower the environmental impact of farming activities.

The programme involves 20 production practices and technologies that can be divided into the following categories: (i) productive area (with livestock-forest-pasture integration); (ii) livestock (number of animals and best animal management practices); (iii) infrastructure (a management centre for sustainable intensification and to reduce animal heat stress); (iv) water security (wells, water cisterns and earth damns), and; (v) small-scale and low-cost machinery (to increase labour value and reduce manual work).

Climate change impact

Adaptation and mitigation

SDG impact

- ✓ **1** (1.5)
- ✓ **2** (2.4, 2.a)
- ✓ **12** (12.2, 12.8, 12.a)
- ✓ **13** (13.1, 13.3, 13.b)

- ✓ **6** (6.6)
- ✓ **8** (8.4)
- ✓ **15** (15.1, 15.2, 15.3, 15.5, 15.a, 15.b)

Technology developer and intellectual property status

Developed by *Adapta Sertão*, this is a project financed by the Multilateral Investment Fund (MIF) and the Inter-American Development Bank (IDB).

It is the intellectual property of the non-governmental organization Redeh, Onda Verde Consultoria, Instituto de Regeneração da Caatinga, MIF and IDB

Year of development

The programme has been tested and has been under development as part of the *Adapta Sertão* project since 2006. It has recently been refined and transformed into a more impactful business as part of the "*Proadapta Sertão*" phase funded by IDB and the Nordic Development Bank (NDF). The lamb module was published in 2016, focusing on areas related to the countryside (hinterland) of Bahia state.

Primarily applicable agroecological zones

Semi-arid and arid regions

Target audience

The MAIS solution is offered to small-, medium- and large-scale corporations (cooperatives, associations and private actors) to add climate resilience into their value chain. The MAIS lamb module is designed to assist those providing technical assistance in implementing the system on lamb production.

Positive impacts/value proposition

The programme promotes resilient agriculture so that farmers can overcome great periods of drought. Farmers who have been part of the programme have increased their income, food production and quality of life, as labour productivity has improved.

The MAIS lamb module makes lamb farming more economical and profitable, and it is adaptable for both small and large producers. It also seeks to make farms more resilient to climate change through actions that ensure adequate feed stocks for the herd and water security over prolonged drought periods of up to two years, and it works to recover pasture through partial afforestation and seeking immediate protection of the land as a Permanent Protection Area, as well as through implementing the Legal Reserve, namely the legal obligations under environmental law in Brazil.

Scale of current adoption and enabling environment

There are 100 goat farmers applying this programme in several municipalities of Bahia state. Experts visit producers on a monthly basis, providing technical assistance through various actions, including planning and organizing the productive areas, genetic improvement of the herd and the structuring and management of the animals, rotation and pasture recovery, strategic storage of water and food, mechanization of some activities, and productive,

Costs and necessary investments

The average cost of the MAIS solution ranges from US$60 to US$80 per month per farmer, depending on a variety of technical and economic factors. When implementing MAIS among farmers of the Bacia do Jacuipe county, the costs were R$2.5 million (US$667 million) and 250 farmers were engaged over three years, with the economic benefits reaching almost R$4 million. A cost-benefit analysis shows that the MAIS programme would generate benefits four to eight

economic and climate resilience monitoring.

times greater than the investments required to initiate the programme, when also considering additional increases in tax revenues, the use of trained technical experts and logistical cost reductions owing to production intensification.

Diffusion strategy

The programme and its technologies are disseminated via publications produced by funders (IDB and NDF). Prizes for community-based technologies with a climate aspect also form part of the communication strategy. The programme was awarded the Momentum for Change prize based on its success by the United Nations Framework Convention on Climate Change (UNFCCC). However, considering the private ownership of the programme, no broad large-scale dissemination is currently taking place.

Possible adaptation measures and necessary conditions

The main advantage of this production model is its great adaptability to each property. Each module can be scaled up or down depending on the area of the property and relative to the producer's expectation of profit.

Possible negative impacts

If a farm does not receive the necessary technical assistance, the system may not fit the needs of the property and, consequently, it will not generate the economic and social-environmental benefits expected.

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11. Forecast for Smallholders

Digital technology tool for disseminating agrometeorological data

Figure 12: Agroconnect platform

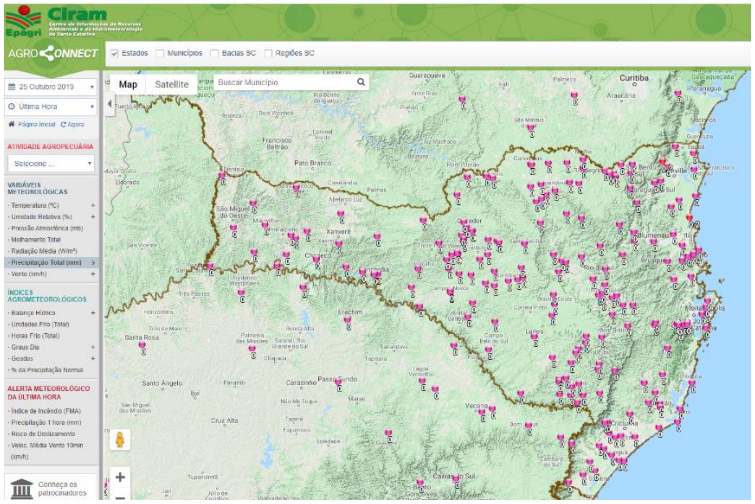

Photo: screenshot of Epagri/Ciram's Agroconnect
http://www.ciram.sc.gov.br/agroconnect/

Original technology name

Agroconnect – Agrometeorological information online (Agroconnect – Informações agrometeorológicas online)

Organization responsible

Epagri/Ciram – Santa Catarina's Centre for Information on Environmental Resources and Hydrometeorology, as part of the Agribusiness Research and Rural Extension Company of Santa Catarina

Crop activity (value chain)

Crops

Category (type of technology)

ICT

Description of technology

This is a free weather information service that warns farmers about conditions that are favourable to the emergence of crop pests and diseases. It functions as a tool to support the decision-making of producers. The platform is focused on the agricultural sector and provides information such as atmospheric conditions, time trends for the next few days, the likelihood of the development of disease in certain crops and phytosanitary alerts.

The system is supported by 234 automatic data collection stations situated across Santa Catarina (SC) state and neighbouring states in Southern Brazil (through partnerships with other institutions such as INMET – the National Institute of Meteorology) and one central unit that collects and analyses the data and feeds the system with hourly information.

In total, 42 crops are monitored and farmers receive alerts regarding the eight crops that are most common in the state: banana, apple, tomato, soybean, wheat, grape, onion and lettuce.

Climate change impact

Adaptation

SDG impact

- ✓ **1** (1.4)
- ✓ **2** (2.3, 2.4, 2.a)
- ✓ **12** (12.4, 12.8)
- ✓ **13** (13.1)
- ✓ **17** (17.8)

Technology developer and intellectual property status

Epagri – the Agribusiness Research and Rural Extension Company of Santa Catarina (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina)

Year of development

The new version of this technology was launched in 2016, but it took almost 10 years to reach the technological level it is at today. The system is a fusion of the different platforms that Epagri previously had concerning crop information, weather and geographic data, etc.

Primarily applicable agroecological zones

This technology is today used in the Atlantic Forest (rainforest and subtropical humid forests). To use this technology in drier areas, it may need to be adapted, particularly as regards the relevant meteorological data needed.

Target audience

This technology is suitable for all farm sizes, but it was developed with the intention of supporting small farmers who do not have sufficient resources to have a permanent manager or an agriculture expert working full time at their farms.

Positive impacts/value proposition

The software helps farmers to prevent possible diseases and so to optimize production and minimize the use of pesticides, which results in both economic and environmental gains. This is possible because, using the agrometeorological data of the system, producers are able to plan their field activities, such as a more efficient chemical controls in plantations.

Scale of current adoption and enabling environment

Since 2016, the platform has been accessed 430,000 times, with an average of 15,000 visits per month. Today, there are 105,000 users registered in the platform, including producers, agricultural experts and other professionals in the agribusiness sector.

One successful example is the number of apple growers in the state who use the software. About 90 per cent of these producers are registered on the platform and receive agrometeorological warnings and alerts.

The technology is used in Santa Catarina, as well as in some areas of the neighbouring states of Paraná and Rio Grande do Sul, and it could also be replicated for use in different conditions.

Costs and necessary investments

The cost of each station varies according to the complexity of the data that is collected; there are four different types of stations. Of the stations acquired in 2018, the costs ranged between US$6,941 and US$13,348 (R$26,000 and R$50,000).

The development of the software and the constant programming of the data represent the greatest investments, namely the development and maintenance of the central unit. Updating the database alone costs more than US$200,000 (R$750,000).

Epagri intends to develop a mobile application to accelerate and facilitate users' access. Currently, alerts are sent via email and the platform is accessed only through the website. The development of this new app should cost around US$26,695 (R$100,000).

Diffusion strategy

This technology is an online software through which producers can access real-time climatic information from all 234 stations concerning the 42 monitored crops. In addition, Agroconnect sends alerts about the eight main crops in SC state to registered farmers. As previously stated, the software is a fusion of other platforms, and this was done to centralize the information, thereby facilitating access to high-quality information by producers.

Possible adaptation measures and necessary conditions

This technology requires an agrometeorological monitoring network to be created for the collection of field information, which can be established through partnerships with other institutions. In addition, it is imperative to establish a central unit to collect and analyse these data and later disseminate them through the online platform.

Possible negative impacts

The software provides high-quality information; however, it is important that local analyses still be conducted on farms to validate any alerts that the system gives. In other words, the producer may consider the system as an indicator of whether problems are likely to appear on the farm, but it should not be the only indicator.

References

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Conclusions and Recommendations

Assessment on Impacts and Preferences

All technologies featured in this study have significant potential to be replicated in Africa. In addition to focusing on those technologies with climate mitigation and adaptation impacts, priority has been given to those with social and economic impacts, as these are particularly relevant dimensions in Africa.

However, the locations that will use these innovations and the technological level required need to be thoroughly evaluated, as does the level of interest among farmers and local organizations in implementing these technologies. Most of these technologies require a certain level of technical assistance, for both producers themselves and technical service professionals.

In addition, implementing some of these technologies will require the involvement of several institutions, such as in the case of the app for agrometeorological data as part of the Agrometeorological Data for Smallholders (technology 11). In such cases, effective implementation will most likely occur only in the medium to long term. For implementation in the short term, the less complex technologies are advisable, namely the Smallholder Maize Multiplication (technology 2) and the Fruits Solar Dryer (technology 8).

The technologies involving production systems for increasing the capacity for food production may, when used in the context of poverty, have transformational impacts. Therefore, even though they are complex, such technologies may be extremely useful, as they combine social, economic and environmental impacts.

Some of the technologies are actually packages of several others, which may be used separately. However, using the full combination of technologies in their specific arrangement can increase the effectiveness of the system.

Whether technologies are simple or complex, organizations must understand the market dynamics in the region in order to choose the most efficient technologies for their context. Understanding demand and other private-sector indications and preferences is crucial for agricultural development.

As regards the applicability of the technologies in this report to the agroecological zones in Africa, all are applicable in the tropical moist deciduous forest (which corresponds to the Cerrado biome) and most are applicable in the tropical rainforest (which corresponds to the Amazon and Atlantic Forest biomes) and the tropical dry forest (which corresponds to the Caatinga biome).

Tropical dry forests represent one of the most fragile ecosystems in Brazil and Africa due to their long periods of drought and low-density vegetation. Therefore, the agricultural activities in these regions are usually undertaken by families, as these regions do not attract professional and large farmers. Thus, technologies that provide technical assistance and require low investments, such as the Fruits Solar Dryer (technology 8) and the Climate-Smart Lamb Farming (technology 10), are of major importance in these regions.

All 11 technologies listed in this catalogue align with several SDGs, especially with SDGs 1 (no poverty), 2 (zero hunger), 12 (responsible consumption and production), 13 (climate action) and 15 (life on the land) in the context of smallholder farms (family farming). Only four SDGs are not directly related to these 11 technologies, which demonstrates the cross-cutting nature of the technologies as regards the SDGs. This shows how important implementing these technologies in African contexts can be in terms of achieving rural sustainable development.

Future Outlook

In addition to the 11 case studies listed in this catalogue, other successful approaches have been used in Brazil that are worthy of highlighting. The political and institutional framework in which these technologies were developed and applied must be taken into consideration. Brazil has a good track record in fostering low-carbon agricultural practices, and forests and agriculture are a top priority in the country's climate efforts. As a global leader in agriculture, Brazil follows a climate agenda that is closely aligned with its agricultural policies and legislation:

- ✓ **Incentives for environmental conservation linked to credit lines and nationally determined contributions (NDCs)**[9] (no-till, residue usage, land use planning, nitrogen fixing and integrated crop-forestry-livestock production systems): as part of Brazil's contribution to climate change, the country presented several agriculture and forestry activities in its NDC. This commitment was then integrated into public policies and official programmes, which provide strong incentives for farmers. Public credit with subsidies is one of the main agricultural policies resulting from this commitment.
- ✓ **Research into rural extension:** Brazil has a strong system in place as regards research into rural extension, with a track record of substantial impacts in the field. Embrapa uses technology packages and communication tools with the help of farmers' organizations to provide rural extension services and to provide farmers with appropriate knowledge and tools. Partnerships between Embrapa and state research organizations, as well as universities, also contribute to improving the understanding of farmers' needs and expanding their use of technologies.
- ✓ **Public policies for family farmers in Brazil:** there are specific governmental programmes in Brazil for supporting family farmers, meaning such farmers should be able to implement all of the technologies presented in this report. Below are a couple of examples of such programmes:
  - National school meals (PNAE) and food purchase (PAA) programmes that create strong markets for family farmers.
  - Comprehensive credit schemes, particularly for family farmers (including credit lines for mechanization and specific incentives for women and young people).

Below are a few suggestions of how climate-resilient development programmes could be improved in the future based on the technologies outlined in this catalogue:

- ✓ **Establish partnerships** (e.g. researcher-researcher, government-government, private sector-private sector or multi-stakeholder partnerships).
- ✓ **Ensure partnerships cover the entire transfer process** (i.e. adaptation, replication, dissemination, adoption, rigorous monitoring and improvement).
- ✓ **Create links between research, rural extension services and smallholder farmers** – this is crucial, but there is still a bottleneck in the large-scale implementation of successful technologies in Brazil. Several successful technologies are being implemented, but investments and coordination with the private sector are still largely needed.

There are several significant challenges in and opportunities for establishing Brazil-Africa strategic partnerships for agricultural and climate technology and policy transfer. There is also strong potential for transferring, adapting and collaborating on policy models. This report is intended to contribute to future exchange projects and to help in the adoption of these technologies, aiming to have a significant impact on the ground and on the global climate.

[9] NDCs are commitments taken by countries as part of the UNFCCC Paris Agreement on Climate Change (2015). These commitments outline how UNFCCC parties plan to reduce greenhouse gas emissions.

Annex – SDGs Correlation to Technologies [10]

	End poverty in all its forms everywhere	Directly related technologies
TARGETS	**1.1 –** By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day	
	1.2 – By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	
	1.3 – Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable	
	1.4 – By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	**1, 5, 6, 8, 11**
	1.5 – By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	**1, 2, 3, 4, 5, 6, 7, 8, 9, 10**
	1.a – Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions	**1, 9**
	1.b – Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions	**4**

[10] Source: United Nations Department of Economic and Social Affairs (UNDESA), Division for Sustainable Development Goals (DSDG). Retrieved from: https://sustainabledevelopment.un.org/

	**End hunger, achieve food security and improved nutrition and promote sustainable agriculture**	**Directly related technologies**
TARGETS	**2.1** – By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	**2, 3, 4, 6, 8**
	2.2 – By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons	**6**
	2.3 – By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	**3, 4, 5, 7, 8, 9, 11**
	2.4 – By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	**1, 2, 3, 4, 5, 6, 7, 9, 10, 11**
	2.5 – By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	**2, 7**
	2.a – Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries	**2, 7, 10, 11**
	2.b – Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round	

	2.c – Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility	

	**Ensure healthy lives and promote well-being for all at all ages**	**Directly related technologies**
TARGETS	**3.1** – By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births	
	3.2 – By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births	
	3.3 – By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases	**1**
	3.4 – By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being	
	3.5 – Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol	
	3.6 – By 2020, halve the number of global deaths and injuries from road traffic accidents	
	3.7 – By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes	
	3.8 – Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all	

	3.9 – By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	**1**
	3.a – Strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control in all countries, as appropriate	
	3.b – Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade-Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all	
	3.c – Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States	
	3.d – Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks	

	**Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all**	**Directly related technologies**
TARGETS	**4.1** – By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes	
	4.2 – By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education	
	4.3 – By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university	

	4.4 – By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship	
	4.5 – By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations	
	4.6 – By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy	
	4.7 – By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development	
	4.a – Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all	
	4.b – By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries	
	4.c – By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States	

	**Achieve gender equality and empower all women and girls**	**Directly related technologies**
TARGETS	**5.1** – End all forms of discrimination against all women and girls everywhere	

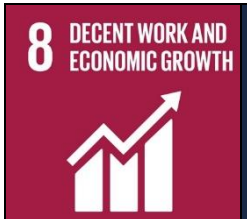
	5.2 – Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation	
	5.3 – Eliminate all harmful practices, such as child, early and forced marriage and female genital mutilation	
	5.4 – Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate	
	5.5 – Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life	
	5.6 – Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Programme of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences	
	5.a – Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws	
	5.b – Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women	
	5.c – Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels	

6 CLEAN WATER AND SANITATION	**Ensure availability and sustainable management of water and sanitation for all**	**Directly related technologies**
TARGETS	**6.1** – By 2030, achieve universal and equitable access to safe and affordable drinking water for all	**1**

	6.2 – By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	
	6.3 – By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	**4**
	6.4 – By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	**1, 6**
	6.5 – By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	
	6.6 – By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	**5, 6, 7, 10**
	6.a – By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	**1**
	6.b – Support and strengthen the participation of local communities in improving water and sanitation management	

7 AFFORDABLE AND CLEAN ENERGY	**Ensure access to affordable, reliable, sustainable and modern energy for all**	**Directly related technologies**
TARGETS	**7.1** – By 2030, ensure universal access to affordable, reliable and modern energy services	
	7.2 – By 2030, increase substantially the share of renewable energy in the global energy mix	
	7.3 – By 2030, double the global rate of improvement in energy efficiency	

	7.a – By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology	**8**
	7.b – By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support	

	**Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all**	**Directly related technologies**
TARGETS	**8.1** – Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	**7**
	8.2 – Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors	
	8.3 – Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services	
	8.4 – Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead	**5, 6, 10**
	8.5 – By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	
	8.6 – By 2020, substantially reduce the proportion of youth not in employment, education or training	
	8.7 – Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and	

	use of child soldiers, and by 2025 end child labour in all its forms	
	8.8 – Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment	
	8.9 – By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products	
	8.10 – Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all	
	8.a – Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries	
	8.b – By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization	

	**Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation**	**Directly related technologies**
TARGETS	**9.1** – Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all	
	9.2 – Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries	
	9.3 – Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets	

	9.4 – By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	
	9.5 – Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending	
	9.a – Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States	
	9.b – Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities	
	9.c – Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020	

	**Reduce inequality within and among countries**	**Directly related technologies**
TARGETS	**10.1** – By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average	
	10.2 – By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status	**7**
	10.3 – Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard	

	10.4 – Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality	
	10.5 – Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations	
	10.6 – Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions	
	10.7 – Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies	
	10.a – Implement the principle of special and differential treatment for developing countries, in particular least developed countries, in accordance with World Trade Organization agreements	
	10.b – Encourage official development assistance and financial flows, including foreign direct investment, to States where the need is greatest, in particular least developed countries, African countries, small island developing States and landlocked developing countries, in accordance with their national plans and programmes	
	10.c – By 2030, reduce to less than 3 per cent the transaction costs of migrant remittances and eliminate remittance corridors with costs higher than 5 per cent	

	**Make cities and human settlements inclusive, safe, resilient and sustainable**	**Directly related technologies**
TARGETS	**11.1** – By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	
	11.2 – By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons	

	11.3 – By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	
	11.4 – Strengthen efforts to protect and safeguard the world's cultural and natural heritage	
	11.5 – By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	
	11.6 – By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	
	11.7 – By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	
	11.a – Support positive economic, social and environmental links between urban, per-urban and rural areas by strengthening national and regional development planning	**4**
	11.b – By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels	
	11.c – Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials	**4**

	**Ensure sustainable consumption and production patterns**	**Directly related technologies**
TARGETS	**12.1** – Implement the 10-year framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries	

	12.2 – By 2030, achieve the sustainable management and efficient use of natural resources	**1, 3, 5, 6, 10**
	12.3 – By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	**8**
	12.4 – By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	**3, 11**
	12.5 – By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	
	12.6 – Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	
	12.7 – Promote public procurement practices that are sustainable, in accordance with national policies and priorities	
	12.8 – By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	**10, 11**
	12.a – Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production	**4, 5, 6, 10**
	12.b – Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products	
	12.c – Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities	

	**Take urgent action to combat climate change and its impacts, acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change**	**Directly related technologies**
TARGETS	**13.1** – Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	**1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11**
	13.2 – Integrate climate change measures into national policies, strategies and planning	**1**
	13.3 – Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	**10**
	13.a – Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible	
	13.b – Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities	**7, 10**

	**Conserve and sustainably use the oceans, seas and marine resources for sustainable development**	**Directly related technologies**
TARGETS	**14.1** – By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	

	14.2 – By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	
	14.3 – Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	
	14.4 – By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	
	14.5 – By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	
	14.6 – By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	
	14.7 – By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	
	14.a – Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	
	14.b – Provide access for small-scale artisanal fishers to marine resources and markets	
	14.c – Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS [United Nations Convention on the Law of the Sea], which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want	

	**Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss**	**Directly related technologies**
TARGETS	**15.1** – By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	**5, 6, 7, 10**
	15.2 – By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	**5, 6, 7, 10**
	15.3 – By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	**3, 5, 6, 7, 9, 10**
	15.4 – By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	
	15.5 – Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	**5, 10**
	15.6 – Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed	**2**
	15.7 – Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products	
	15.8 – By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species	**7**
	15.9 – By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	**4, 7**
	15.a – Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	**7, 10**

	15.b – Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation	**5, 6, 7, 10**
	15.c – Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities	**4**

	**Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels**	**Directly related technologies**
TARGETS	**16.1** – Significantly reduce all forms of violence and related death rates everywhere	
	16.2 – End abuse, exploitation, trafficking and all forms of violence against and torture of children	
	16.3 – Promote the rule of law at the national and international levels and ensure equal access to justice for all	
	16.4 – By 2030, significantly reduce illicit financial and arms flows, strengthen the recovery and return of stolen assets and combat all forms of organized crime	
	16.5 – Substantially reduce corruption and bribery in all their forms	
	16.6 – Develop effective, accountable and transparent institutions at all levels	
	16.7 – Ensure responsive, inclusive, participatory and representative decision-making at all levels	**7**
	16.8 – Broaden and strengthen the participation of developing countries in the institutions of global governance	
	16.9 – By 2030, provide legal identity for all, including birth registration	

	16.10 – Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements	
	16.a – Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and crime	
	16.b – Promote and enforce non-discriminatory laws and policies for sustainable development	

17 PARTNERSHIPS FOR THE GOALS	**Strengthen the means of implementation and revitalize the global partnership for sustainable development**	**Directly related technologies**
TARGETS	**<u>Finance</u>**	
	17.1 – Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection	
	17.2 – Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of ODA/GNI [Official Development Assistance / Gross National Income] to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries	
	17.3 – Mobilize additional financial resources for developing countries from multiple sources	
	17.4 – Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress	
	17.5 – Adopt and implement investment promotion regimes for least developed countries	

	Technology	
	17.6 – Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism	
	17.7 – Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed	**3**
	17.8 – Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology	**11**
	Capacity-building	
	17.9 – Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals, including through North-South, South-South and triangular cooperation	
	Trade	
	17.10 – Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through the conclusion of negotiations under its Doha Development Agenda	
	17.11 – Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020	
	17.12 – Realize timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organization decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market access	
	Systemic issues – Policy and institutional coherence	
	17.13 – Enhance global macroeconomic stability, including through policy coordination and policy coherence	

	17.14 – Enhance policy coherence for sustainable development	
	17.15 – Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development	
	Systemic issues – Multi-stakeholder partnerships	
	17.16 – Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries	
	17.17 – Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships	
	Systemic issues – Data, monitoring and accountability	
	17.18 – By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts	
	17.19 – By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries	

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