Chapter 5

Prevention of advancing degradation and recovery of degraded lands

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Introduction

This chapter presents an overview on the main technological contributions of Embrapa and partners to halt land degradation, accelerated erosive processes, desertification, sanding, salinization, and to restore degraded lands, as established in target 15.3 (United Nations, 2018): 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.

Understanding the causes of land degradation, its consequences for the environment and agricultural production, and technological alternatives to halt its advance and recover already degraded lands are some of the biggest challenges to a sustainable life on Earth. In the world, around 33% of lands present some type of degradation (Status..., 2015). In Brazil, around 22% of the national territory is considered to be degraded; agricultural exploitation with the use of inappropriate practices is the main cause (Bai et al., 2008).

In general, accelerated erosion aggravates degradation of these lands, and, in an arid and/or semi-arid climate, it promotes desertification, mainly in the Northeast Semi-arid Area of Brazil, in Tocantins' *Cerrado*, and in the North of Mato Grosso and Minas Gerais. In *Pampa Gaúcho*, the sanding process is advancing in some cities.

Different kinds of erosion with varying intensities are still degrading lands in several regions of Brazil. Besides compromising the potential of agricultural production and the resilience of different ecosystems, erosion also causes the silting and contamination of water resources, thus creating rural exodus, floods, decreased capacity of hydroelectric power generation, increased costs for water treatment and loss of land and aquatic biodiversity. Thus, water erosion, which can be sufficiently sped-up by inappropriate land use and management, shall be considered as one of the most extreme environmental problems of humanity (Feng et al., 2010; Andrade; Chaves, 2012).

Currently, most lands under agricultural use in Brazil (around 173 million hectares) grow pasture. Only 10% of these areas adopt less impacting pastoral systems, such as fallow period, rotations, and integrated crop-livestock-forest (ICLF). Degraded pasture recovery is part of the voluntary commitments of Brazil in the 2009 *United Nations Climate Change Conference* in Copenhagen (*COP15*). These commitments were ratified in the National Policy on Climate Change, in which the Plano Setorial de Mitigação e de Adaptação às Mudanças Climáticas para a Consolidação de uma Economia de Baixa Emissão de Carbono na Agricultura (Sector Plan of Mitigation and Adaptation to Climate Changes for the Consolidation of a Low Carbon Emission Economy in Agriculture) (ABC Plan) was established to agriculture. Among its targets is the recovery of 15 million hectares of degraded pastures by 2020.

This scenario makes the recovery of degraded pastures for sustainable agricultural production one of the greatest opportunities to increase national agricultural production with no need for converting more natural vegetation areas to the advancing agricultural frontier. In addition, besides generating income, these degraded lands, when properly recovered, will also provide ecosystem services, such as erosion control, regulation of groundwater recharge, increase of carbon stock on soil, and, consequently, mitigation of the effects of greenhouse gas emissions (GGEs).

Halting degradation and land desertification

Absence of planning for land use, indiscriminate deforestation — even in permanent preservation areas (PPAs) that are highly environmentally important and/or susceptible to degradation —, agricultural exploitation in lands with restricted suitability or no suitability and/or high environmental vulnerability, monoculture, plowing and harrowing towards the slope, use of fires, lack and/or excess of fertilizer and corrective applications, and overgrazing are the main causes of degraded lands and/or desertification.

Among the strategies to avoid advancing land degradation and desertification, Embrapa provides the understanding of agricultural production potentials and limitations. The Company offers technologies to characterize and analyze potentials and limitations of lands for agricultural production in different geographic scales, among which the following stand out: the Manual de Métodos de Análise do Solo (Handbook of Methods of Soil Analysis), the Sistema Brasileiro de Classificação dos Solos (Brazilian System of Soil Classification), the Sistema de Avaliação da Aptidão Agrícola das Terras (Evaluation System for Agricultural Land

Suitability), the Sistema Brasileiro de Classificação de Terras Para Irrigação (Brazilian System of Land Classification for Irrigation), the Zoneamento Agrícola de Risco Climático (Agricultural Zoning of Climate Risks), the Zoneamento Agroecológico (Agro-ecologic Zoning), the Planejamento Conservacionista da Propriedade Agrícola (Conservacionist Planning for Agricultural Property) presented in *Dia de Campo* TV Show and which aims at its environmental and productive adequacy, the Integração Participativa de Conhecimentos sobre Indicadores de Qualidade do Solo (Participative Integration of Knowledge on Soil Quality Indicators), among others (Ramalho Filho; Beek, 1995; Claessen, 1997; Barrios et al., 2011; Santos et al., 2013). Currently, the elaboration of a National Program of Brazil's Soils is ongoing, which intends to continue large-scale searching and interpreting of soils so as to allow more efficient planning for suitable land use.

Besides increasing the efficiency of methodologies for data analysis, storage, and interpretation for purposes of land use planning, this information should be more frequently used both for designing public policies and for providing ecosystem services and/or increasing agricultural production. Thus, mechanisms that encourage substituting degrading practices for more sustainable practices (such as the ones on agro-ecological basis), which aim at redesigning degraded landscapes to jointly create diversified production systems to improve income generation for the farmer and environmental services for all society, have been more effective not only to avoid advancing degradation, but also to produce higher quality agricultural products (Figure 1).

The *Manual para o Pagamento por Serviços Ambientais Hídricos* (*Handbook for Payment for Hydric Environmental Services*), which Embrapa recently released, approaches this theme (Fidalgo et al., 2017). Furthermore, some initiatives for training environmental education agents in themes such as soil and water management practices and conservation and recovery of degraded lands are ongoing and some new are scheduled. Studies to improve the prediction of extreme climate risks so as to contribute to increased efficiency of drought, slide, and flood prevention initiatives and to allow a better mapping of areas of higher environmental vulnerability in Brazil are ongoing.

In addition to technologies offered by Embrapa for land use characterization and planning (to avoid using lands which are highly susceptible to degradation, and to predict extreme climate scenarios), several others conservationist technologies have been developed for different ecosystems. Among them, the following can be mentioned:

Photos: Aluísio Andrade

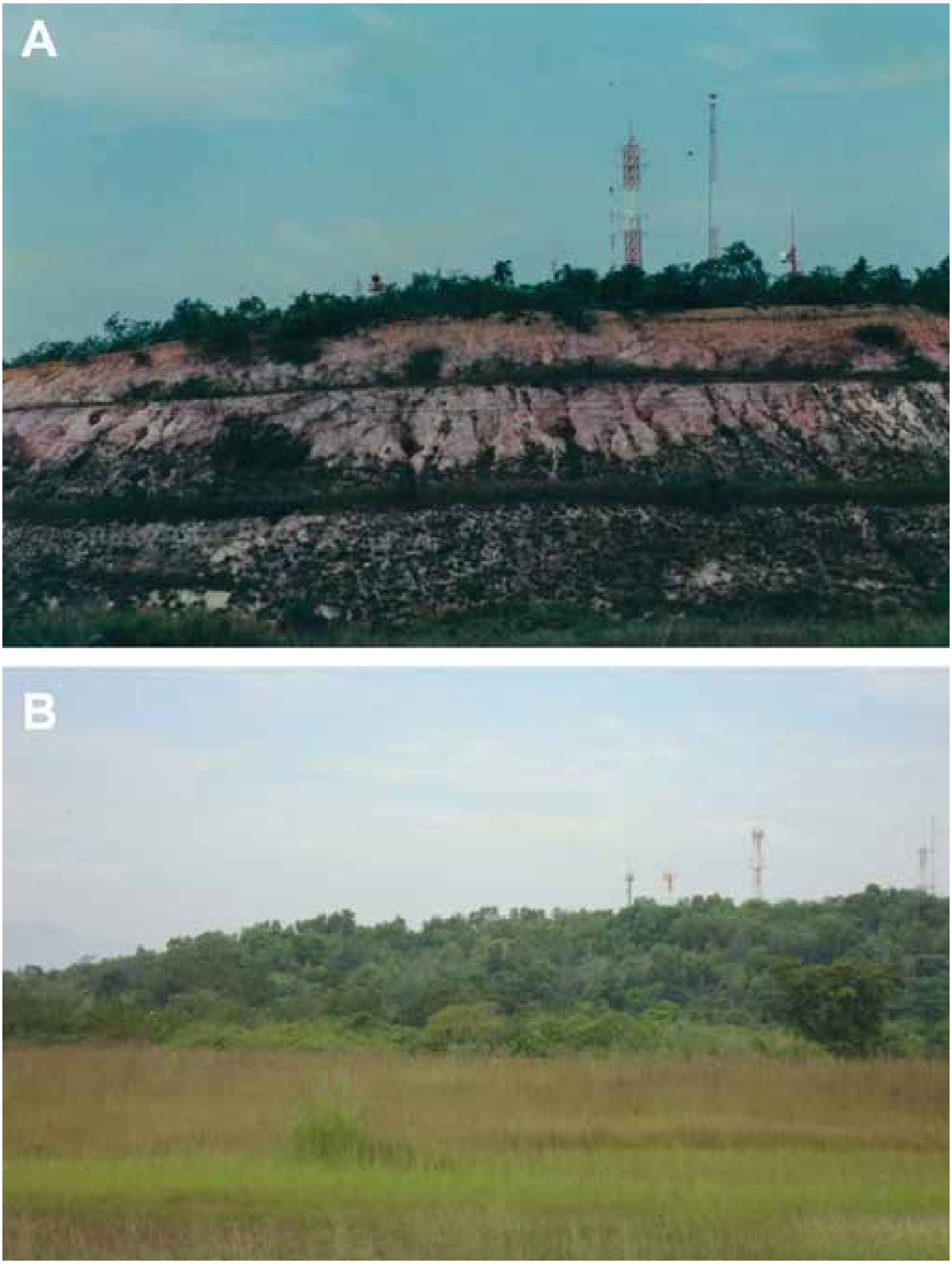

Figure 1. Degradation due to the removal of land for civil construction industry in 2003 (A) and ongoing recovery after mechanical and vegetation practices in 2005 (B).

Source: Andrade et al. (2005).

- Collection, selection, improvement, and storage of native genetic resources.
- Management and recovery of Permanent Protection Areas (PPAs).
- Diagnosis of degradation and/or conservation of management zones in areas with potential for agricultural production.
- Use of no-tillage system, with rotation, intercropping and/or succession of crops and/or livestock in agroforestry arrangements.
- Use of residues.
- Surface stormwater drainage to promote control of erosion, increase water retention (through the construction of small dams), increase water table level (through underground dams), divert upstream waters from gullies (through terraces and catchment areas) or downgrade water level through alternative drainage systems in areas under flooding.

Many activities to train environmental education agents, guide post-graduate students, and collaborate in implementing, managing, and monitoring degraded lands recovery plans and programs on soil and water management and conservation have been performed, thus allowing Embrapa to be present in the main actions to avoid advancing degradation in all regions of Brazil.

In short, good agricultural practices using lands based on their limits and potentialities and maintaining or improving soil chemical, physical, and biological properties can avoid land degradation. This enables higher soil aggregation, avoids its compression, increases water storage, and the availability of essential nutrients to plant growth, and also increases possibilities of employment and income generation. It all favors sustainability of these new agrosystems, making it possible to transform what causes degradation into an agent for sustainable rural development. In this aspect, as emphasized above, scenarios of land degradation have regularly received Embrapa contributions to revert them.

Recovery of degraded lands

To evaluate the level of land degradation, Embrapa has developed and offered methodologies for analyzing and interpreting orbital images, such as Projeto Geodegrade, which mapped areas of *Cerrado* degraded pastures and soil, water, and biodiversity quality indicators. When jointly analyzed, these data allow increasing the efficiency of recovery actions to be implemented.

According to these methodologies, technologies are adopted in two main steps. The first consists of dividing the areas in plots (management zones), as homogeneously as possible, in accordance with the characteristics of the terrain, such as topography, vegetation cover, current use, crop productivity or support capacity (if any) and exploitation history, applied conservationist practices, type and frequency of erosive processes, and soil type. If there are no soil maps in suitable scale to the farm size, the following should be observed: surface and subsurface horizon color, texture, structure and thickness, and the effective depth of roots.

The second step consists of the detailed diagnosis of the state of conservation and/or soil degradation in each management zone aiming to characterize and measure ongoing erosive processes and the presence of residues (rests of crops, correctives and/or fertilizers, animal detritus, pesticide packages, plastic bags, etc.). In this step, recommendations are to evaluate the rate of water infiltration in soil and the occurrence of compressed layers, to collect soil samples to evaluate grain size and fertility (routine analysis with inclusion of carbon) and to describe the natural vegetation cover and/or the current use and existing management practices. After diagnosis is accomplished, a set of mechanical, edaphic, and vegetation practices for recovering soil productive capacity have been developed for different environmental conditions and production systems.

Mechanical practices aim at ordering and dissipating the energy of surface runoff waters, and promoting water infiltration and sediment retention. Among them, are terracing (Figure 2), retention basins, level cultivation, drains, and subsoiling of compressed areas by overgrazing and/or excess of machine traffic. Edaphic practices refer to fertility management with a suitable application of organic and mineral fertilizers, correctives, and soil conditioners to promote increased water availability for vegetation in periods of water stress. Vegetation practices correspond to plant selection and management (rotation, intercropping or succession) for purposes of production, soil protection, biological nitrogen fixation, organic matter supply, nutrient cycling, biological decompaction, and soil structuring.

This set of practices promotes soil structure preservation and/or improvement, water and organic matter infiltration increase, nutrient cycling, and maintenance of soil coverage (live or dead) (Figure 3), which increases its resistance against erosion. No-tillage systems, agroforestry systems, integrated crop-livestock system (ICL), and ICLF are good examples of systems that contribute to soil conservation and recovery. For this same purpose, technologies for monitoring and planning


Photo: Joseani Mesquita Antunes

Figure 2. Terraces built to avoid surface drainage in wheat crop (*Triticum* sp.).


Photo: Claudio Lucas Capeche

Figure 3. Cropping of maize (*Zea* sp.) on mulch in Technological Showcase of Embrapa Maize and Sorghum.

are been developed and provided, such as Plano ABC (through Projeto GeoABC), which incorporate analysis of orbital images, and soil and water quality indicators.

Even mined areas have been re-vegetated through herbaceous legume, shrubs, and tree species seedlings inoculated with nitrogen fixing bacteria and mycorrhizal fungi. This technology has been efficient to recover highly degraded areas (as gullies, hills, and cutting slopes, and landfill and areas contaminated with oil) and to supply nitrogen-rich organic matter for intercropping and/or agroforestry systems. Besides efficient plants, technologies for identifying characteristics and properties of degraded soils and subsequently recommending practices enabling to rebuild its fertility at large have been developed with improvements in its physical, chemical, and biological properties.

For degraded lands with recovery potential for purposes of agricultural production, there is a set of technologies that can contribute to reinsert them in the sustainable agricultural production. Among them, are technologies to identify variable soil properties through proximal sensors, drones for air inspections in order to better separate management zones, and agroecologically-based technologies, such as the use of biological pesticides, management of green manure, and selection and arrangement of crops and creations in agroforestry systems.

Final considerations

Considering the territorial extension and the variability of environmental and socioeconomic conditions and agricultural production systems of the different regions of Brazil, Embrapa has a great challenge: to contribute to increasing the generation, transfer, and innovation of technologies which enable to reach this target. There are technologies available to be applied and there is technical and operational capacity to promote the joint construction, with different players of society, of a broad and permanent national program on prevention of land degradation, soil and water management, land conservation and degraded land recovery.

In conservationist systems, the following beneficial practices are adopted, among others: reduced or even no soil preparation, leveled crop, fertilizer and corrective applications in accordance with crop needs and interpretations of soil analysis, intercropping, succession and/or rotation and permanent soil cover (with the use of vegetation cover), residue recycling, implementation of living fences, terraces, drains, and catchment basins (as appropriate), selection of vegetal species, varieties, and cultivars adapted to the different local environmental conditions, integrated management of pests, diseases and weeds, production diversification, and suitable destination of useless residues.

In order to offer more efficient technologies and develop new solutions to degraded land recovery, Embrapa efforts shall be mainly towards:

- Selecting and evaluating useful and low-cost indicators to detect different levels of land degradation through images and in field.
- Developing technologies of land recovery under varied levels of degradation.
- Evaluating the necessary investments and identifying opportunities for receiving financial incentives for recovering land under several levels of degradation aiming at sustainable agricultural production and provision of environmental services.
- Generating consistent data on the economic and environmental benefits that may come from transforming degraded lands into productive lands.
- Training technicians and farmers to increase the use of good agricultural practices, to contribute more effectively to reach target 15.3, to contribute to several other SDGs and their respective targets, specially: no poverty, zero hunger, sustainable agriculture, good health and well-being, decent work and economic growth, climate action, peace, justice and strong institutions, and partnerships for the goals.

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