PREFACE

The International Workshop on "Water on Agricultural Practice", held in Rio de Janeiro, Brazil on September 16-20, 2019 involved 30 participants from 14 different countries that made the event very broad in participation and expertise. Their findings on water-related issues dealing with sustainable agricultural practices covering erosion control and monitoring, use of reclaimed wastewater for irrigation, and environmental services and education are set in chapters grouped around these 3 themes.

This proceedings document is an outcome of the EXCEED SWINDON Project termed "International Network on Sustainable Water Management in Developing Countries". This initiative is a venture for capacity building through higher education and joint research based on a network of 35 partners from Latin America, Middle East, South East Asia, and Sub-Saharan Africa, coordinated by the Technical University of Braunschweig. This project is carried out within the framework of the DAAD Program "Excellence Centers for Exchange and Development".

Professor Dr. Ali Müfit Bahadir reviewed all papers submitted to the workshop in terms of their scientific content and also made the final publishing review. As the issue co-editor of this proceedings book, I cordially acknowledge his invaluable contribution while publishing this book.

I believe that the wide range of global interests on sustainable agricultural practices combining with the issue of this proceedings book should contribute to attaining the Millennium Goals set by the United Nations.

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EROSION CONTROL IN AGRICULTURAL PRODUCTION SYSTEMS IN BRAZIL

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Abstract

With the increase in demand for agricultural and forestry products, the pressure on soil and water resources intensifies, leading to extreme food, nutritional and socioeconomic insecurity in the world. This paper aims to present the political and technological strategies to control erosion in agricultural production systems in Brazil presented during the Workshop - *Water on Agriculture: Training the Trainers*. Erosion has been causing economic damage and degradation in different regions of the country, mainly over sandy soils and areas used since the first agricultural cycles in the 16th century. The largest land use is occupied by pasture with different levels of degradation. Radical changes in soil management and throughout the production system are required to control erosion and to prevent soil and water degradation. The continental expression of Brazil, housing six biomes with different types of vegetation, relief, soils and climate, in addition to the contrasting socio-economic and cultural aspects, requires that the construction of a national policy for sustainable soil and water development should include adaptations considering territoriality and regional specificities. It is necessary as well to develop information on the potentialities and limitations of soil for agricultural production. A strategy to start solving these problems is being initiated trough the National Soil Mapping Program (PRONASOLOS) with detailed information on the country's soils over the next three decades at the most appropriate scales in order to plan agricultural production in a sustainable manner and to prevent water and soil degradation. Zero tillage systems and agroecological production systems can also be considered as examples for erosion control. To further reduce soil and water losses due to erosion in Brazil, it is necessary to expand the use of more sustainable agricultural production systems considering the different limitations and potentialities of the soil and the socioeconomic and cultural conditions of the country.

1 Introduction

The conversion of natural areas into productive areas has made it possible to increase the supply of food, fiber, energy and other raw materials for the development of humanity. However, many lands that generate wealth through livestock are currently degraded or in the process of degradation. It is estimated that some 33% of land in the world show some kind of degradation [1]. In Brazil these areas occupy approximately between 16.5% [2] and 22% [3] of the territory with varying levels of degradation.

Water erosion accelerated by inadequate land use and management is already considered one of the most serious environmental problems nowadays, as it causes the removal of the richest layer of the soil with the consequent loss of nutrients, and creates pollution and siltation of water resources, floods and a sharp drop in agricultural productivity [4, 5].

In a scenario of growing world population and increasing demand for agricultural and forestry products, pressure on soil and water resources intensifies further and could lead to a world of extreme instability as well as socioeconomic, food and nutrition insecurity [1]. This issue worsens during water crises either due to lack of water during drought periods or excess water during the rainy season, causing severe losses to the productive sector [6-8]. Lack of application of conservationist practices causes a reduction in soil infiltration and water storage. Consequently, in periods of less precipitation there is less water availability in degraded areas compared with well-managed ones. This results in decreased tolerance of crops to periods of water stress due to less soil water retention. In situations of excessive rainfall, degraded soil exposed to erosion agents produces more sediment, causing greater siltation of water resources [6]. This situation leads to an increase in the occurrence of floods and reduces reservoir life, increasing costs for hydroelectric power generation and water treatment for urban water supply [7].

With climate change, the problems caused by the degradation of soil and water resources can become worse. Increasingly frequent extreme events such as high-intensity storms worsen erosion processes, and rising temperatures generate higher water consumption for agricultural production, impacting negatively a wide range of crops which creates risks to food security [9]. Erosion has been causing economic damage and degradation in different regions of the country mainly over sandy soils and areas used since the first agricultural cycles in the 16th century (Figure 1).

In the semi-arid climate region of northeastern Brazil, erosion contributes to the expansion of desertification (Figure 2). This paper aims to present the political and technological strategies to control erosion in agricultural production systems in Brazil presented during the Workshop – *"Water on Agriculture: Training the Trainers"*.

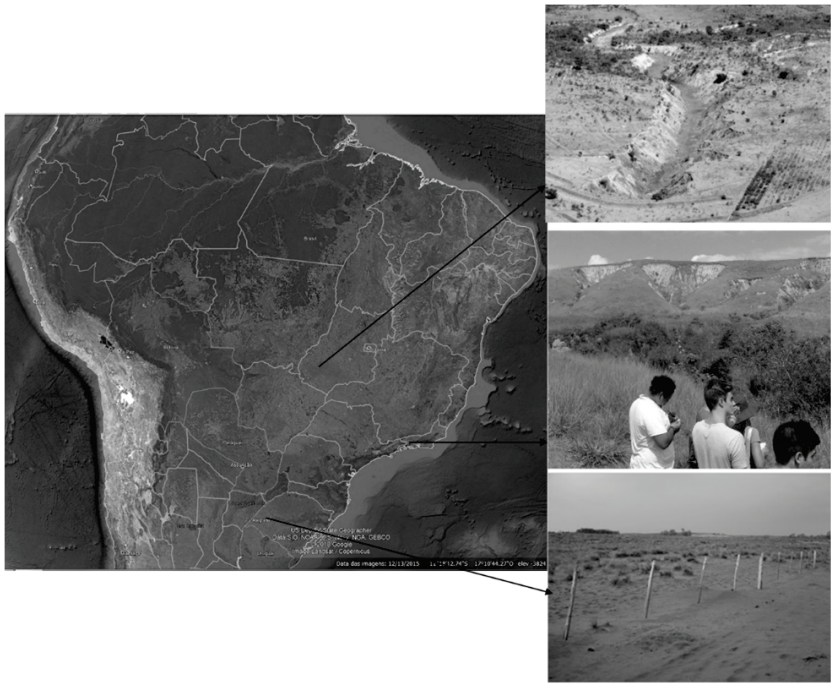

Figure 1: Degraded areas due to agricultural exploitation using inappropriate practices with laminar erosion and gullies in different regions of Brazil.

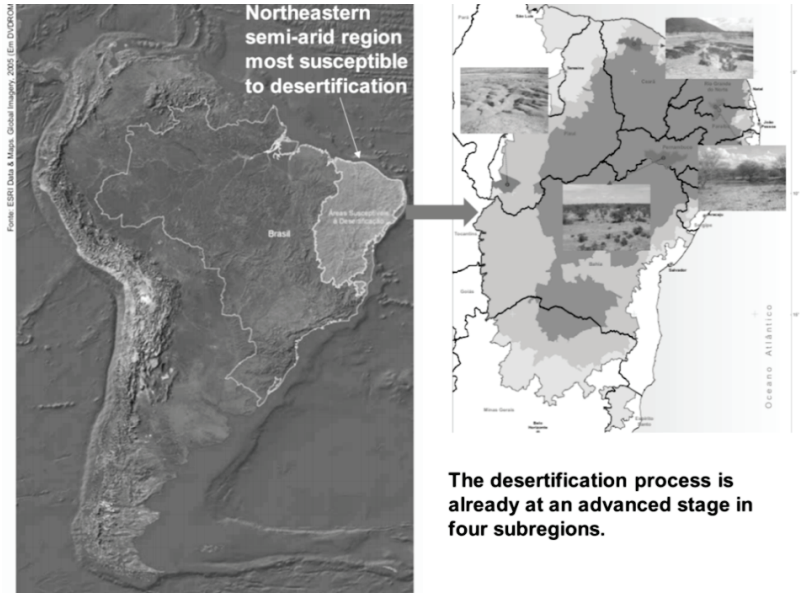

Figure 2: The northeastern region of Brazil with semi-arid climate is the most susceptible one to desertification in the country [10].

2 Land Cover Use in Brazil

In Brazil, 61% of the territory is protected by law (Figure 3). The largest land use is occupied by pasture with different levels of degradation. Although they occupy only 5% of the land, annual crops cause large erosion losses when conventional planting is used [11].

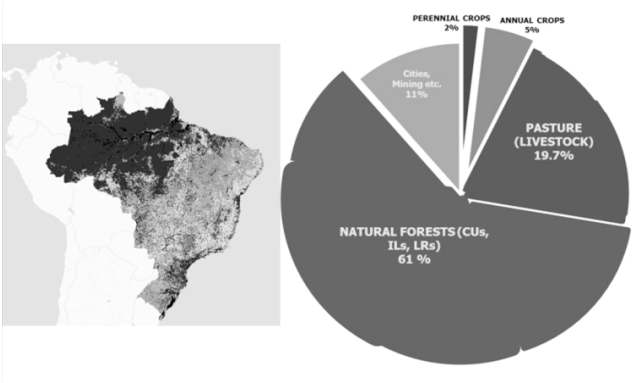

Figure 3: Land cover in Brazil

3 Economic Losses from Erosion under different Land Uses in Brazil

According to Polidoro et al., 2016 [12], considering the different land uses in Brazil, it is estimated that the financial losses caused by erosion amount to over US$ 6.3 billion/yr. Areas with annual crop planting without soil conservation practices and intensive tillage are the most problematic ones due to erosion (Figure 4).

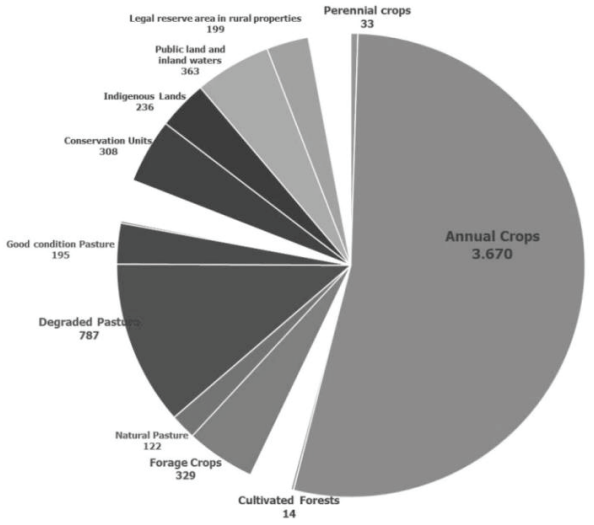

Figure 4: Economic losses from erosion under different land uses in Brazil (billion/yr)

4 The Green Revolution and the Consequences on Soil Erosion

During the 1970s' green revolution, the models of agriculture in Brazil were not efficient to control soil erosion, mainly due to the intensive use of mechanization (Figure 5). With the advance of erosion it was necessary to make changes in the production system. Initially only terracing was performed as a strategy to prevent erosion. However, this technology was not enough to significantly reduce the damages caused by erosion. Radical changes in soil management and throughout the production system are required to control erosion and prevent soil and water degradation.

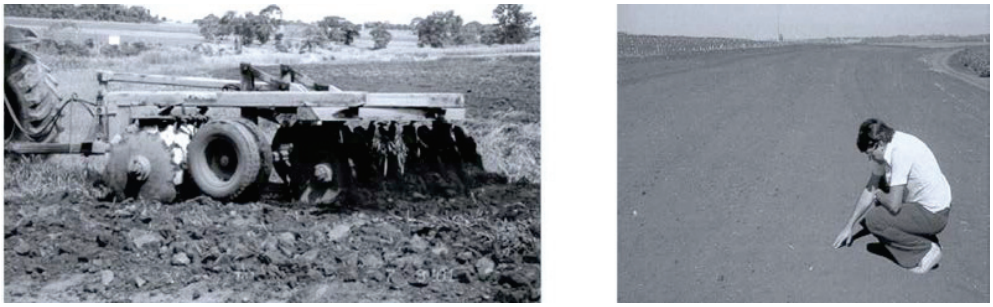

Figure 5: Unstructured soil due to intense tillage through plowing and harrowing

5 Controlling Erosion in Brazil

5.1 Laws and Policies related soil and water conservation

In Brazil, people are becoming increasingly aware of the importance of environmental preservation and the restoration of rivers, steep slopes and other permanent preservation areas provided for in the environmental legislation. However, the importance of properly managing soil and water for agricultural production and their consequences beyond gates of rural properties still have not reached all the regions of the country. In the socioeconomic dimension, the problem of erosion and loss of fertile soils has a strong influence on the reduction of job offer and income in rural areas [13]. The devaluation of rural property, the abandonment of previously productive land and the rural exodus with migration to large urban centers worsen the social problems related to urban agglomerations.

However, the country still has a major socioeconomic and environmental liability caused by soil degradation in areas of agricultural production, bequeathed by the various agro economic cycles and a lack of governance and planning in the countryside. To prevent this degradation with the advance of agriculture in the country, the National Soil Conservation Plan was created in 1975. Later in 1987, it was replaced by the National Program of Watershed. Currently, only a few states participate in this program or develop independent programs. The absence of a national soil and water conservation policy has been shown in Brazil's Soil Governance Audit Report [2] as one of the main risks to sustainable management of these resources. Although there are legal instruments governing the theme, such as Law 6.225/1975, which calls for discrimination by MAPA in regions for the mandatory implementation of soil protection and erosion control plans, and Law

6.938/1981, which establishes the rationalization of subsoil, water, restoration of degraded areas as one of the Principles of National Environmental Policy, protection of areas threatened with degradation and grants special incentives to producers, who adopt conservation practices, there is still a considerable risk for the country as soil and water resource degradation advances [2]. On the other hand, new initiatives point to efforts to reverse this situation through policies such as the National Policy on Agricultural Land Use, Management and Conservation bill and the recent Decree No. 9,414 of June 19, 2018 establishing the National Soil Survey and Interpretation Program of Brazil (PRONASOLOS). It will make it possible to detail the information of soils in the country at scales more compatible with the planning for sustainable use of soil and water resources.

Considering the large underused areas with varying levels of degradation that currently exist in Brazil, the possibility of their reintegration into the high yield chain is an opportunity to increase national agricultural production on a sustainable basis without the need to expand agricultural frontier by converting new areas of natural vegetation.

5.2 Strategic Guidelines for formulating integrated soil and water conservation policies

The continental expression of Brazil, housing six biomes with different types of vegetation, relief, soils and climate, in addition to the contrasting socio-economic and cultural aspects, require that the construction of a national policy for sustainable soil and water development should include adaptations considering territoriality and regional specificities. Through the survey and systematization of information on the existing institutional, legal and technological structure on soil and water governance in the country, training of multiplier agents of the five Brazilian regions, strengthening interpersonal networks and management tools based on participatory approaches and an update of the National Soil and Water Conservation Plan is being proposed. Discussion processes and propositions will be promoted involving actors from the governmental, productive sector and civil society organizations with influence on soil and water governance for sustainable agricultural production and the provision of other ecosystem services. To update the National Soil and Water Conservation Plan, six Strategic Guidelines are proposed:

(1) Legislation - Compliance with the bill: National policy for soil and water conservation in rural areas for watersheds, states and municipalities. It proposes: (a) strategies for the approval of the bill (PL); (b) mechanisms for adaptation and implementation of the PL, as necessary, at the Country, State and Municipal levels; (c) the development of monitoring instruments and systems to ensure the use, management and conservation of soil and water in different regions of the country; (d) alert mechanisms, fines and integration with the Rural Extension to correct the deficiencies detected; and (e) the creation of a fund to receive fines and other financial contributions from other sources of financing for the use of funds in the priority Work Plans defined by the management committee of the Plan.

(2) Prevention - Prevention of agricultural land degradation aimed at new areas with high environmental vulnerability and to curb and promote the replacement of degrading practices It proposes: (a) mechanisms to improve the use of existing information to formulate public policies that

promote the use of new areas only in accordance with their agricultural suitability, indications of agro ecological zoning and adoption of soil and water conservation practices; (b) strategies to prevent the exploitation of areas of high environmental vulnerability; (c) incentive mechanisms for conservation farmers; (d) strategies to prevent erosion and soil and water degradation processes; (e) the management of multiple demands for land and water use, emphasizing the use of techniques and procedures aimed at sustainability; and (f) strategies to curb the use of degrading practices.

(3) Conservation - Conservation of arable land: to promote greater productivity and sustainability of agroecosystems. It proposes: (a) strategies to conserve soil and water quality and promote the development of more sustainable agricultural production systems in areas with good productivity; (b) mechanisms for valorization and traceability of agricultural products that use good agricultural practices; (c) strategies to ensure for current and future generations the qualitative and quantitative availability of soil and water; and (d) improvement of soil and water conservation actions that promote the integrity of aquatic ecosystems as well as the functions of forests and areas with natural vegetation and conservation units to improve and maintain the water regime.

(4) Recovery - Recovery of degraded lands aimed at restoring areas of ecological interest and/or reinserting them into sustainable agricultural production. It proposes: (a) strategies for the development of tools for the characterization and mapping of lands with different levels of degradation; (b) mechanisms for the application of the most appropriate technologies for the different levels of degradation, environmental conditions and production systems of the country; (c) a strategy for the development and implementation of low-cost practices for erosion control and recovery of degraded areas; and (d) the provision and payment of environmental / ecosystem services to the recovery areas, taking into account the benefits for agricultural production and the environment in general.

(5) Monitoring - Monitoring, evaluation and adaptation of the Plan's actions. It proposes: (a) mechanisms and protocols for the diagnosis of the current situation of land degradation in the different biomes of Brazil; (b) creation of tools to predict the situation of land degradation without the intervention of the NAP - Soil and water, with the aim of establishing scenarios to take preventive measures to avoid the worsening of critical situations, such as the growth of areas in desertification, salinization and ravine; (c) a strategy to create a support database, through which technicians, producers or citizens themselves can feed the database from local and georeferenced observations; (d) mechanisms for the establishment of a management information system based on indicators and statistics related to the goals of the Plan; and (e) strategies and mechanisms to adjust and to redirect the Plan's actions as well as an estimate of the socioeconomic and environmental benefits delivered to Brazilian society.

(6) Integration - Integration of teaching, research and extension actions for soil and water conservation and the recovery of degraded areas. It proposes: (a) the insertion of the topics involved in the issue (soil and water) in the primary schools' program with appropriate regional

adaptations; (b) mechanisms to standardize the concepts related to the use, management and conservation of soil and water in rural and urban areas for the various higher education courses with adherence to the subject, such as: agricultural engineering, forestry engineering, environmental engineering, zoo technics, hydrology, geography, biology, among others; (c) the alignment of the research demands identified in the subject under discussion, with the R&D projects of the research institutes and the definition of priority topics for the development of undergraduate thesis and master's and doctorate dissertations; and (d) strategies to raise awareness of the importance of natural land and water resources at all levels and for all public, urban and rural.

Given the complexity of the proposed plan, it will be necessary to establish joint strategies to ensure the participatory building processes are efficient. In this sense, adjustments will be made to the proposed methodological strategy, the available financial resources and the priorities indicated by the team, as well as outlined efforts to obtain complementary resources.

The set of intended actions of the present proposal is in alignment with the Voluntary Guidelines for Sustainable Soil Management [6] and the Sustainable Development Goals (SDGs) established by the UN, especially the SDGs 1, 2, 3, 6, 7, 8, 11, 12, 13, 14, 15, 16, and 17. It is also expected to contribute to the improvement of other public policies, such as the National Action Plan to Combat Desertification and Mitigation of Drought Effects, National Water Resources Plan, Low Carbon Agriculture Plan and National Agroecology and Organic Production and Rural Credit Programs.

Through the expansion of legal provisions that enable greater incentives for innovation to address the problem of degradation, it is expected that an increase in the adoption of conservation technologies with regional adaptations to stimulate development of new technologies will occur, thus contributing to reverse the degradation scenario, enabling more sustainability of production systems and resilience to climate change.

5.3 National Soil Mapping Program (PRONASOLOS / BRAZIL)

Brazil has been developing its Soil Classification System for over 50 years [15]. It was necessary to develop information on the potentialities and limitations of soil for agricultural production. A National Soil Mapping Program (PRONASOLOS / BRAZIL) is being initiated. The objective is to detail information on the country's soils over the next three decades at the most appropriate scales in order to plan agricultural production in a sustainable manner and to prevent water and soil degradation. In Figure 6, one can see the soil map of the same area at different scales. The more detailed the map scale (the more soil types appear) allows the area to be divided into more homogeneous management zones, increasing the efficiency of inputs and ensuring greater production and protection of the soil.

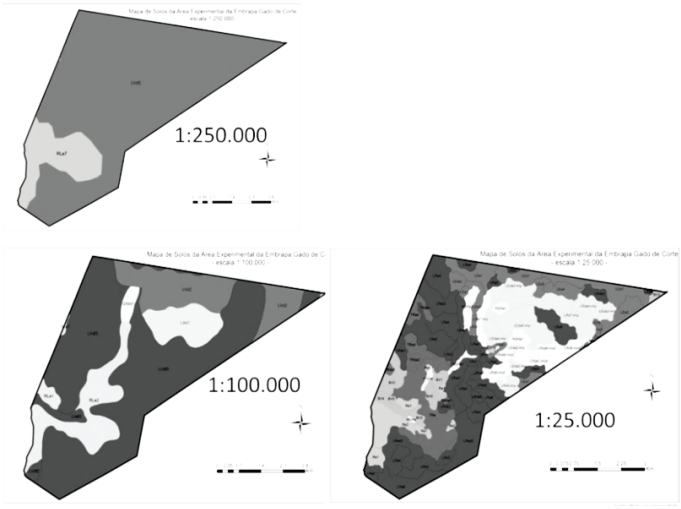

Figure 6: Soil map of the same area at different scales (Source Embrapa Soils)

5.4 Land Use Planning in Watersheds and Farms

By mapping the soils in more detailed scales in different regions of the country already prioritized by PRONASOLOS, it will be possible to carry out more appropriate land use planning. This information, along with the level of soil degradation through different technologies such as proximal sensors, satellite and drone image interpretation, makes it possible to monitor changes in soil quality in real time and to prevent soil degradation. By interpreting this information, land use planning can be carried out in watersheds and rural properties, including:

- Division of the area into management zones according to relief, soil type, degradation level, use and crop yield;
- Indication of crops and cover crops according to agricultural and climatic suitability of the area;
- Recommendation of soil and water management and soil conservation practices.

The division of the rural landscape into management zones enables a more efficient management of the soil, the use of inputs, labor and equipment, and the development of more sustainable production systems for large and small farmers. This makes it possible to use the soil with the most appropriate management system for the different positions of the rural landscape, either in Precision Agriculture or Agroecological Systems.

5.5 Zero Tillage System and Integrated Crop-Livestock-Forest

Among the existing production systems in Brazil, the no-till system is one of the most important for erosion control. This system began to involve not only the lack of tillage, but also crop rotation, permanent soil cover and traffic control [13]. This system is evolving in Brazil. It already occupies more than 50% of the area with annual crop production over 30 million ha.