# A THEORETICAL ASSESSMENT OF THE ENVIRONMENTAL CHANGE FROM FLOODPLAIN RICE FIELDS TO IRRIGATED PERIMETERS: A CASE STUDY IN THE SAN FRANCISCO SERGIPANO LOW VALLEY IN THE NORTHEAST REGION OF BRAZIL

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ABSTRACT

Four decades after the construction of the Sobradinho Dam, the consequences associated with the modification of the course of the San Francisco River can be verified through the environmental impacts on the use of the land: the cultivation of rice through flooding has changed to cultivation in "Irrigated Perimeters" in the San Francisco Sergipano Low Valley. Currently, the shortage of agricultural technicians, water distribution in the crops along with the increase in rat plagues, and fish farming in the irrigated perimeters are some of the consequences that have brought about economic losses for the farmers, in addition to the potential loss of traditional rice cultivation in the valley. This article is a case study which compares the characteristics between traditional and current models in the use of land and production systems, the advantages and disadvantages of the Irrigated Perimeters and the restoration strategies for this area. A tendency to return to traditional agricultural work both with and without the help of technology was discovered in this study. Future prospects for sustainable development depend on government action taken with respect to the San Francisco River.

*Keywords: Betume, environmental change, floodplain, San Francisco Sergipano Low Valley, Propriá, Sobradinho.*

## 1 INTRODUCTION

The North-East of Brazil ("NEB") is a region that has a semi-arid climate where water is a limited resource and is characterized by an irregular occurrence of precipitation in both spatial and temporal scale. For a long time, the San Francisco Sergipano Low Valley ("SFSLV") was fed by the San Francisco ("SF") tributary river. The SFSLV is the result of the SF River movement: its waters erode the outer banks widening its relief, producing a fertile valley, the San Francisco Valley ("SFV"). For centuries, the SFV was irrigated by the fluvial seasonal SF River flooding, as a natural characteristic of the area of land adjacent to a stream or river which was flooded, marking the freshwater floodplain. The meanderings of the SF River over time and the general topography in this area in the NEB region, this interaction river-valley determined the shape of the numerous floodplain ecosystems. The SFV is one of the sub-regions within NEB, based on the SF River which according to Souza et al. [1] is subdivided into four stretches: High, Middle, Sub-Middle and Low San Francisco (location of the SFSLV). For a long time, this region has been seen as an example of the natural interaction between river and floodplain systems [2]. As a result of this natural process over centuries, an agroecosystem with its traditional landscape and land use were formed in the SFSLV. In the NEB region, the SF River has played an important role in popular culture, as part of its history, economy and social aspects in relation to water, land use and the coexistence of communities in the valley. The environmental changes in the SFSLV took place after the construction of the hydroelectric Sobradinho Dam, causing a change in the course of the SF River. As a consequence, the natural floodplain areas with traditional rice cultivation were changed to Irrigated

WIT Transactions on Ecology and The Environment, Vol 226, © 2017 WIT Press
www.witpress.com, ISSN 1746-448X (on-line)
doi:10.2495/SDP170231

Perimeters [3]–[8]. The Sobradinho Hydroelectric Project is located in the SF River in the state of Bahia, approximately 40 km upstream. With a river basin area of 498 969 $km^2$, and its potential to generate power locally, the Sobradinho reservoir can also regulate the annual flow of the downstream hydroelectric projects of Itaparica, Moxoto, Paulo Afonso and Xingo. Aside from the above-mentioned, it also supplies water for irrigation, navigation, flood protection and agricultural projects which are supplied with 25 $m^3/s$ for irrigation water [1]. In spite of its important role, Barros [8] reports that the Sobradinho Dam changed the overall balance of the ecosystem in the Low San Francisco and the human activity in relation to the use of SF River. "The traditional irrigation system reflects tangible and intangible assets that endow the rural landscape with personality and identity and represent a valuable cultural heritage" [9]. The wetlands perform many important functions on different ecological levels and are considered to be one of the most productive and valuable ecosystems and also the most endangered one [10]. This study makes a theoretical assessment on the environmental changes in the SFSLV. It compares the use of the land and the production system models before and after the environmental changes, the advantages and disadvantages of Irrigated Perimeters and points out the strategies for restoration in these areas. This article is a case study in comparing the characteristics between traditional and current models in the use of land and production systems in the SFSLV.

## 2 MATERIAL AND METHODS

The study took place in the Irrigated Perimeter Betume (IPB) 10º26'8"S and 36º32'23"W (Neópolis) and Irrigated Perimeter of Propriá (IPP) in Propriá 10º12'49"S and 36º50'28"W [11], that is part of the SFSL Valley, state of Sergipe 9º31'54" and 11º34'12"S and 36º24'27" and 38º11'20"W, NEB, Brazil [12]. Both floodplains were cultivated through traditional rice cultivation by the SF River flooding before the environmental changes in the SFSLV. Propriá is included within the semi-arid tropical zone and Neópolis within the sub-humid zone [13], [14]. The research is based on a bibliographic review, direct observation and the use of individual interviews with key open questions, applied to the discriminatory sampling of key informants who were selected based on the topic and aim of the research [15]. The individual interviews with open questions which were asked to key informants represented by: 2 farmers (rice growers) from IPB; the IPB group with 01 Agronomist, 01 agricultural technicians and the Administrator of the IPB; and 01 Agronomist/farmer (rice grower) and 01 agricultural technicians in the IPP and the Regional Administrator of the Irrigated Perimeters (CODEVASF/Sergipe/Brazil) in the SFSLV. The farmers´ key informants in the IPB and IPP were interviewed about the purpose of study with respect to the SFSLV floodplains *versus* Irrigated Perimeters and about differences in the use of the land and production system before and after the environmental changes. The field study and bibliographic review identified the advantages and disadvantages of the irrigated perimeters, and finally the IPB group, the agricultural technician in the IPP and the Regional Administrator of the Irrigated Perimeters were interviewed regarding a restoration strategy for these areas. The interviews were conducted on an individual level and registered in audio and audio-visual records, later registered in writing, on Dec. 2015.

## 3 RESULTS AND DISCUSSION

This study looked at: the use of the land and production systems in the SFSLV, the advantages and disadvantages of the Irrigated Perimeters in the SFSLV and restoration strategies for these areas.

### 3.1 Use of the land and production systems in the SFSLV

#### 3.1.1 Advantages and disadvantages of the irrigated perimeters in the SFSLV

Advantages: a) Improvement in the quality of life for those who live in floodplain areas; b) Rice growers themselves become the owners of cultivated land in the floodplain; c) Implementation of basic sanitation in this region; d) Increase in rice productivity in these areas; e) Introduction of fish farming as a new means of production and commercialization.

Disadvantages: a) Breakdown in the ecological river-floodplain relationship with environmental impacts on these areas; b) Loss of popular cultural traditions connected to SF River; c) Loss of traditional culture of conservation and preservation of river's ecosystem; d) New generations move to the city, leaving behind traditional means of production linked to the land; e) Commercialization of rice is governed by free market; f) Risk of rice growers replacing rice cultivation for fish farming; g) Lack of specific legislation and monitoring with respect to administrative procedures in sustainable land use and irrigation in the SFSLV floodplains.

Table 1: A comparison of the use of the land and production systems in the SFSLV before and after the environmental changes.

| Traditional System (Floodplain) | Irrigated System (Irrigated Perimeters) |
|---|---|
| SF flooding was the principal natural resource (fluvial energy) and regulator of the floodplain agro ecosystem | Water storage in the Sobradinho Dam generates hydraulic energy and regulates the volume of flow of SF River |
| Water collection/distribution through natural flooding from SF River (river-floodplain) | Water collection/distribution regulated by irrigation and drainage systems |
| Organic soil fertilization ("colha") | Use of chemical products for soil fertilization |
| Natural cycle system production based on the flooding in the SF River with fishing, rice fields and ranching | Predominance of rice cultivation |
| Territorial organization made up of open field, flooded area, humid and dry soil and pastures | Territorial organization made up of plots of land from 3,4 to 9 |
| Supplementary work for rice grower families: traditional fishing, ranching and family farming | Supplementary work for rice grower families: small scale fish farming and ranching without the use of technology |
| Basic maintenance of agroecosystem through natural river cycle and cattle | Basic maintenance of agroecosystem using agricultural machinery |
| Variations in rodent fauna in the semi-arid area were regulated by the flooding of SF river, without economic losses to rice growers | Variations in rodent fauna in the Irrigated Perimeters were regulated by rice growers thus bringing economic losses |
| The SF cycle served as a natural barrier against rodent plagues in the rice fields | Use of pesticides against rodent plagues controlled by rice growers |
| Workforce by family, "meeiros" (a mode of remuneration used in the SFSLV), "renting" and leasing of land | Workforce by family and wage labor |
| Market system with a middleman | Untrammeled free market system with monopolization of rice business in the region |
| Fishing – directly linked to flooding soil conditions | Introduction of fish farming for business purposes |

Table based on key study questions, field observation and a bibliographic review.

### 3.2 Strategy for restoration in these areas

a) Development of renewable technology by replacing hydraulic energy with solar and wind energy; b) Maintenance of the flow volume of SF River; c) Recovery of autochthonous species in fauna and flora; d) Reincorporation of organic materials in soil; e) Use of sub-soiling to reduce soil compaction; f) Cost minimization; g) Maximization of productivity; h) Elimination of a middleman and processing of rice in irrigated perimeters; i) Investment in ecotourism and environmental education; j) Legislation and regulation to promote sustainable irrigation practices; l) Willingness of politicians to put sustainable development projects into practice.

The Irrigated Perimeters were introduced in the SFSLV as a result of the change to the course of the SF River. The interaction between the SF River and its floodplains ecosystem play a key role with respect to ecology, human activities, economy and cultural history in the Low San Francisco. In [3]–[8], [16]–[19] the environmental changes in the Low San Francisco (sub region of NEB) were directly linked to the building of reservoirs by using dams, especially in the case of the Sobradinho Dam which altered the course of the SF River. Consequently, these changes have brought permanent and negative environmental effects to this region. Moreover, the fluvial processes, which were the SF River´s natural driving force in this agroecosystem, no longer exists. Irrigation and drainage systems replaced the natural spread of water through flooding in the floodplains. Fonseca [17] reports this change included modern techniques such as building ditches, irrigation canals, bridges, water pump structures, control stations, roads and other elements which have backed up the new production system. In this context, the water management of the fluvial ecosystem as the basis of cultural, social and traditional agricultural systems was changed, breaking the natural cycle of flooding in the floodplain ecosystems. As a result, the traditional production system (fishing, rice fields and ranching) dependent on the SF River and its territorial organization were changed. The natural organic soil fertilization is known by rice growers as “colha” and [20] “colha” – a natural deposit of 2 to 3 cm of organic material, carried into floodplains by the SF River, together with cattle and ovine manure – was substituted by chemical products. In [21], the environmental conditions in the SFSLV are a result of incorrect government decisions which changed the natural cycle of the production system involving flooding in the SF River. The predominance of intensive cultivation and its territorial organization in flooded rice-field floodplains was changed to land divided into plots. Supplementary economic activities (fishing, ranching and small-scale farming) for rice growers in the traditional flooded system were changed to “family fish farming” and ranching without the help of technology. Fishing as a natural and cultural activity in this area was substituted by fish farming. The constant losses stemming from difficulties in obtaining water and rat plagues have driven some rice growers to substitute the cultivation plots for fish farming as their main economic activity. For example, in the Propria Irrigated Perimeter [22] reports that there was a serious risk that some rice growers may leave the irrigation rice cultivation behind for fish farming. In Neto et al. [23] and in [24] report the fish farming first appeared in the SFSLV in the 1980s as an alternative to complement and substitute the traditional activities such as fishing and small-scale farming in the floodplains. In [25] Fish farming is very much on the rise in Brazil and in [26], the production of some fish species is of important commercial value due to its demand in both the U.S. and European markets. Currently in the SFSLV, fish production is an extra source of income for families and given the importance of small-scale fishing in the region, policies along with rural and technological development programs are necessary for the sustainable development of this activity in the SFSL region [23]. The family labor force

continues to be very important in the SFSLV. The “meeiros” and “renting” were substituted by land owners with their own family labor force and work without contracts according to the need in these plots. Rice growers suffer great economic losses due to the fact that they are unable to process their rice in an uncontrolled free market system, monopolized by the middleman [22]. Another serious problem in this region is the irregular rodent outbreaks which occur in an irregular temporal scale, but in the same spatial scale. From 1978 to 2015 serious outbreaks of rodent plagues appeared in 1978, 1982–83, 88, 1993, 1998–99, 2005, 2009–10 and 2015 in the irrigated perimeters [2], [18], [27]–[28]. In these areas, the natural river cycle took care of basic maintenance which is currently controlled with agricultural machinery. With respect to the traditional production system before environmental changes occurred and Góis et al. [24] report the relations of production were unfavorable to “meeiros” and both big and small-scale rice growers. The agricultural practices were very primitive, the rice grower lacked basic health services (especially concerning malaria and schistosomiasis), running water, basic education, technical assistance and the land was unevenly distributed (most land owned by just a few people).

Currently, the Irrigated Perimeters in the SFSLV are responsible for 5–8 thousand direct and indirect jobs in the region with 1500 families benefitting from the Irrigated Perimeters project. Productivity has increased in the last three years, and Sergipe is in 3rd place among rice- producing provinces in the NEB [29]–[30]. However, the environmental impact and critical points can be seen in these areas concerning erosive processes, problems with obtaining water in the Irrigated Perimeters, the free market system, the increase of soil salinity in the perimeters and in the SF River water, all of which are harmful to people’s health. In [31]–[34] changes in the river´s volume of flow, restriction of leisure zones in order not to lose agricultural areas, loss of fauna and flora, a compromised sustainability situation and a development model that doesn´t take the conservation and preservation of natural resources in this region into account. Therefore, this model doesn´t contribute to improving the population´s quality of life. Floodplains are part of the drainage system of rivers in Junk et al. [35], and one of the most threatened ecosystems types [36], and such as the wetlands which, in [37] reports, play a significant role in agricultural landscape and in rural development. The floodplain areas in the SFSLV need governmental policy and action for its conservation and sustainable use. In [38], although the concept of sustainability has become popular and widely used since the Brundtland Report, it remains vague and elusive with regard to its empirical implementation. Mendes [39] reports, the objective of sustainable development is to ensure protection of human life in all aspects. In [21], the environmental impact in the SFSLV was a consequence of incorrect governmental decisions and in [16] without previous environmental evaluation in these areas. Since the beginning of time, human history has shown a dependence on floodplain ecosystems in relation to human life, as the concept of sustainable development indicates. In the SFSLV, since the first human settlements in XVI in this region, human life has been connected to the SF River [40]. Through sustainable policies and strategies involving restoration and prevention, the government administration can improve environmental conditions in these floodplain areas which are currently suffering negative environmental impacts. Decisions regarding future projects in the SF River could determine the future of the area and its people.

In conclusion, this study has shown that the differences identified between floodplains (rice fields) and Irrigated Perimeters in relation to land use and its production system in the SFSL Valley were: the natural water-soil cycle and the condition of the soil (flooding soil, flooded rice-field and dry soil), soil fertilization method, production cycle, territorial organization, supplementary work to contribute to household incomes, work division, basic

services and the commercialization system of rice. The rodent fauna was strongly influenced by changes. The Irrigated Perimeters have improved the quality of life of the population. However, there isn´t a positive balance between Irrigated Perimeters and sustainable development in the SFSLV region. Traditional fishing was substituted by fish farming with some rice growers abandoning rice cultivation. The strategies proposed in this article could decrease the environmental impact in this area and also help government with respect to decisions concerning sustainable development.

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