ENVIRONMENTAL CHANGE AND A QUALITATIVE APPROACH TO THE PRODUCTION SYSTEM IN "IRRIGATED PERIMETERS": CURRENT MODEL IN THE LOWER SAN FRANCISCO SERGIPANO, NORTHEASTERN BRAZIL

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ABSTRACT

Until the 70s, the fertile Low San Francisco (LSF) Valley had several floodplain areas designed for rice-growing. For centuries, the San Francisco (SF) river floods allowed the riverbank population to develop their traditional systems for "rizicultura" (rice-growing), fishing and livestock farming. The building of the Sobradinho Dam changed the SF's river bed, causing serious environmental changes in the floodplain's ecosystem, its landscaping model, its use of the land in the valley's production system, going from a natural flood-dependant rice-growing agroecosystem to drainage and watering one. This study examines the impact farmers face with the current rice-growing model in the Lower San Francisco Sergipano (LSFS) and looks into how to minimize its effects as well as restoration strategies for these areas. The study was carried out at the LSFS's "Irrigated Perimeters", in Betume and Propriá (a sub-region within LSF Valley), Northeastern Brazil (NEB) with key informants (farmers and Agricultural technicians). The results showed the impact on environmental, technical, social, economic and political levels. The study seeks to contribute with a reflection on the issues the key informants encounter with the current rice-growing model in these areas, which are a direct result of the change in the use of the land. It also hopes to generate discussions at governmental, scientific and social levels, where more complete environmental studies can be contemplated, focusing on the impacts of these actions on the LSF valley in the future.

Keywords: aquaculture, Betume, "Irrigated Perimeters", "Propriá", "rizicultura", "ratadas", San Francisco, Sergipe.

1 INTRODUCTION

For centuries, the fertile land of the Low San Francisco (LSF) Valley in Northeastern Brazil (NEB) kept itself irrigated by the San Francisco (SF) river floods. Rice-growing, the "rizicultura", on the SF's banks, has been a cultural and economic practice in the region since its native inhabitants, the Indians, to the Europeans settlers, who used African slave labour. The region of the humid valleys of the LSF consisted of 13 municipalities, with 578 areas dedicated to rice-growing. These areas depended directly on the favourable physical conditions of the fluvial lakes, the floodplains or "várzeas" in Portuguese, taking advantage of the ebb and flow of the SF river on its banks. The process occurred by decreasing the influx of water in the floodplains, keeping a sufficient amount of flooded area for the rice growing. The process took place from the perimeter to the center or downstream [1]. Environmental policies, aiming to optimize the use of hydro power potential for energy generation, have been responsible for the significant changes in the natural LSF environment [2]. The Sobradinho Dam, built in the 70s, its construction starting in 1973 and in full service in 1979 [2]–[4], flooded an area of 4.214 km^2, moved a population contingent of 60,000 people according to official data, submerged several cities, and made the peripheral areas unstable due to the environmental changes as a result of its construction [2], [3], [5]. Wanting to solve energy, social and economic issues caused by the climatic variability on a temporal

WIT Transactions on Ecology and the Environment, Vol 217, © 2019 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/SDP180141

and spatial scale (periodic droughts) and the need for electric power in the North and Northeastern Brazil (NEB), the 70's national government decided to build the Sobradinho hydroelectric dam [2], [3], [6]. Due to the change in the volume of the SF river, the building of the Sobradinho Dam caused a major environmental impact in the floodplain. Consequently, to keep the "rizicultura" system in place (used by the peripheral population in these areas), an "Irrigated Perimeter Project" was implemented for rice-growing, a system based on drainage and watering. The "Irrigated Perimeters" of the LSF substituted the natural floods of the river, changing its ecosystem, its landscape, the use of the land and the rice-growing production system. Martins et al. [7] report that the dams built along the SF river in the LSF sub region condition the volume of flow in the region of the SF river, and Barros [8] reports the Sobradinho Dam has changed the entire balance of the LSF's floodplains, thus extremely affecting human activities, linked to the river´s cycles. Environmental effects such as the modification of the river´s regime, the solid particles in suspension [9], erosive processes in its right bank in the Lower San Francisco Sergipano's (LSFS) section [10], the acceleration of marginal erosion, altering the landscape towards the "Irrigated Perimeters", endangerment of agricultural areas, restriction of idle areas resulting in loss of agricultural areas [11] are common in these locations. The environmental impact on wildlife, loss of harvests due to rodent outbreaks, water distribution shortages in the "Irrigated Perimeters" and technical assistance scarcity are some of the issues faced by the farmers in the LSFS. The floodplains are known to be one of the most productive and valuable ecosystems but also one of the most threatened environmental resources [12], given that the rice fields are the habitat for native species and other animals [13]. Almost 40 years after the changes in those areas, the "rizicultores" (rice growers) still encounter problems. As in other areas cultivated where rice is grown, Reig and Estruch [14] report the balance between sustainable development and agricultural technology is the major challenge to be measured. In the "Irrigated Perimeters" of the LSFS, besides the challenge of sustainable development, which nowadays is imperative for the floodplains ecosystems, the current rice-growing situation in the Valley leads to discussions regarding the pros and cons between the conventional and technological production systems in these areas.

The sustainable concept established by the Brundtland Report remains confusing and imprecise and the main methodological aspects discussed in the literature related to agriculture is as if the agricultural technology is universally better than the conventional one and, on the other hand, the search for studies on a global model of sustainable indicators [14]. The qualitative methodology through key informants can be very useful when identifying field issues. The observation and interaction with the community allow farmers to specifically pinpoint their everyday reality in the field. This study attempts to analyze the impact the farmers face under the current rice-growing model in the LSFS, looks into how to minimize its effects as well as restoration strategies for these areas.

2 METHODS

The area of study is located in the Irrigated Perimeter Betume (IPB) and Irrigated Perimeter of Propriá (IPP), which make up the LSFS, state of Sergipe (9º 31`54`` and 11º 34`12`` S and 36º 24`27`` and 38º 11`20`` W (GR)), NEB [15]. This study has a qualitative approach and researches the impact conditions, as well as the minimizing and restoration strategies of these areas. In order to collect information for data analysis, the research is based on direct observation and the use of individual interviews (face to face) with subjective questions, applied to discriminatory sampling [16], [17], represented by specific key informants: farmers and agricultural technicians of the LSFS "Irrigated Perimeters". The discriminatory sampling is associated to a codification process, maximizing opportunities to verify the

argumentation or the developed argument [17]. The 4 key informants were selected based on the topic and purpose of the study: 3 from IPB and 1 from IPP. Two key informants (Informant 1 and Informant 2) from IPB and Informant 3 from IPP focused on the issues faced by the farmers in the rice-growing fields nowadays, and the fourth key informant represented the IPB management staff, and put forth alternatives such as strategies for minimizing the current conditions in the perimeters and alternatives for restoring these areas. In the IPB, Informant 1 has as an important characteristic, the fact that he is the most senior farmer in the IPB, he is the farmers' representative and he has witnessed the great changes which have occurred in the LSFS to date. Informant 2, also from IPB, represents the new generation affected by the environmental changes in this perimeter. Informant 3 is an Agronomist and a farmer, representative of the IPP farmers and also belongs to the post-change generation in the LSFS. Informant 4 is an Agronomist and a technician of the "Irrigated Perimeters". The interview based on field observation was geared towards the topic of research, without any previous collaboration, or questions prepared in advance [16], [18], [19]. The interviews were done on an individual level – interviewer and interviewee, audio and video taped and then written down on Nov/Dec/2015. After providing documents which verified the academic nature of the research access to the field was granted by the representative of the perimeters and the key informants agreed to participate in the interviews. Using field observation as the main approach to the research, the interviews focused on two basic questions: "What are the difficulties faced by the farmers in the "Irrigated Perimeters" of the LSFS?" and "What alternatives or strategies could be implemented to minimize the impact and restore these areas?" For the data handling, the information was categorized in descriptive units, called substantial codes, going from a relational to finally a selective categorization, as is expressed in the results, focusing directly on the purpose of the study. This last categorization of codes was divided into types of impact and was based on the definition of environmental impact as reported by [20]. The results were discussed and, finally, a conclusion was reached for the final report. The qualitative model aims to understand human behaviour, where the subjects of the study are and where they interact [21]. The epistemological and technical differences between quantitative and qualitative research reside in the purpose and reality each method wants to approach [17]. In the case of the qualitative method, unlike the quantitative one, its focus is on a reality characterized by specific aspects of a historical process under construction [17] where the subjects are a real and permanent part of it. Direct observation followed by the use of an informant (a person of the group who is well-versed in the subject matter) is a common data collecting technique for assessment. In communities affected by disasters or changes, the direct observation technique and the use of key informants are very important for data collecting. Once the key informants´ answers were recorded, the final part of the selective categorization was completed, which is shown in the results, followed by a discussion and a conclusion.

3 RESULTS

After analyzing the data from the interviews done with the key informants from the IPB and IPP, categories of impact that caused damages for the farmers through the current rice-growing model in the LSFS were found. They are as follows:

3.1 Environmental and technical assistance impact

The three key informants from both "Irrigated Perimeters" highlighted the following as environmental issues resulting from the current "Irrigated Perimeters" model: a) Irregular rat plagues reaching the entire rice-growing region in the LSFS Valley; b) Precarious

environmental sanitation related to the maintenance of the surrounding areas of cultivated lots on both perimeters: ditch, irrigation channel and road cleaning and the presence of invasive native vegetation, etc.; c) Precarious environmental sanitation in some uncultivated lots due to the lack of specific criteria for the planting farming calendar; d) Diminishing of the SF river flow, with the threat of jeopardizing water collection for the "Irrigated Perimeters".

With respect to technical assistance, according to the key informants in the IPB and the IPP, the following were considered common characteristics of the "Irrigated Perimeters": a) Lack of modernization in the irrigation system, old structures and elements of support in the "Irrigated Perimeters" in bad conditions; b) Shortage of technical assistance in the field, a reduced number of technicians; c) Precarious water collection for rice-growing.

3.1.1 Social Impact in the IPP

According to the IPP key informant, the impact situation in his social circle is currently happening due to:

a) Withdrawal of IPP farmers from the traditional rice-growing culture;
b) Increase in "psicultura" (aquaculture) in the perimeter area, involving a threat of substitution of rice-growing for livestock farming with the purpose of selling beef and dairy products, even though they lack the technology;
c) Although there weren't any incidents, rat plagues expose rice growers and all the riverside population to public health problems;
d) Lack of technology in the substitution of rice-growing for "psicultura" and livestock farming in the region.

3.1.2 Economic and political impact

The results showed the following: a) Loss of harvests due to poor water collection; b) Loss of harvests due to rat plagues; c) Lack of bank insurance coverage against loss of harvests due to rat plagues and poor water collection; d) Low rice prices due to the free market; e) Absence of an external market, monopoly of the internal market; f) Effects of the global economic crisis on the rice-growing cultivation in the LSFS; g) Politically, insufficient governmental and administrative investment in the "Irrigated Perimeters" and lack of organization among the "rizicultores".

3.2 Strategies for minimizing impact and restoring damp areas

In the IPB, the staff which manages the perimeter through key Informant 4 suggested alternatives which could be implemented in order to minimize the impact of the environmental changes and also promote restoration in the riverbanks. The following were proposed: a) Gradual substitution of the main energy source (SF River) for alternative sources; b) Decrease of the "língua salgada" (salty tongue) and of the processes of degradation of the marginal areas of the river; c) Recovery and maintenance of the riparian vegetation according to specific legislation; d) Introduction of a subject related to the history and conservation of the SF River and its marginal areas into the basic school curriculum; e) Maintenance of the river flow and its tributaries; f) Creation of natural reservoirs of native species of the riparian vegetation and aquatic fauna; g) Maintenance of the water table in potential agricultural areas from middle-upper third to steep areas; h) Economic use of the land in the floodplain areas, decreasing the use of pesticides; i) Cultural practices of land maintenance in its physiochemical aspects in order to provide sustainable quality and quantity; g) Urgent regulation for quantity and quality of SF water supply in order to stop

contamination processes and control the salinization of potable water; l) Treatment of water used for irrigation in order to return it to the river; m) Rationalizing the use of the water for irrigation; n) Continued technical assistance in the various production systems used in the perimeters, and a boost for other activities, focusing in particular on ecologic tourism as a means of increasing income.

4 DISCUSSION AND CONCLUSION

The first environmental impact encountered by farmers in the LSFS, once the "Irrigated Perimeters" became operational, was related to the local fauna. For four decades, over the same area, at irregular time periods, rat plagues appeared. Rodent outbreaks are a natural disturbance in the LSFS semiarid valley [22], influenced by the NEB periodic droughts and the "El Niño" Southern Oscillation event [23], [24]. Rat infestations or "ratadas" are characteristic of the entire semiarid South American continent [25], [26]. The environmental changes in the SF river bed, characterized by the absence of floods in the floodplains, generated the conditions for the proliferation of the infestations in a cyclical manner over time in the rice-growing fields. Consequently, the farmers became accustomed to dealing with the appearance of rodent outbreaks, which occurred for the first time in 1978, and again in 1982–83–88; 1993–98–99; 2005–09–10 [24] and in the current decade, at the end of 2014 into 2015. In the damp areas with the cultivation of "secano" rice (dry land), in Brejo Grande, an area out of the scope of this study but a part of the LSFS Valley, in May of 2015, the outbreak was responsible for 80% of the losses in rice production, also reaching the coconut palm cultivation [27], [28].

With regard to the maintenance, the field observation data indicated that the "Irrigated Perimeters" showed signs of precarious environmental sanitation in the adjunct areas to the cultivated lots. Although there are projects aimed at recycling organic matter on land, in practice, the field observation results showed there was inefficient sanitation in the surrounding lot areas, with ditches and highways taken over by native vegetation. With respect to the lots, according to the key informants, there are differences of opinion among the farmers concerning the agricultural calendar. Those who plant according to the calendar are affected by the ones who do not (Informants 1 and 2, IPB, 2015). As a result, uncultivated lots facilitate the presence of invasive vegetation and rat infestations. During the rat infestation cycles, crops are seriously affected, and the precarious environmental sanitation of the perimeters also contributes greatly.

Concerning the decrease in the SF river flow, this fluvial element and its tributaries feed all of the LSF Valley, a sub-region of Northeastern Brazil. In November 2015, the national television broadcasters, through an official announcement, reported that the decrease of the SF river flow, as a consequence of the well-known NEB periodic drought, reached the most critical point of its history, threatening to paralyze the Sobradinho Dam. It went from its storage capacity of 34 trillion cubic meters of water, down to 3% of its volume capacity, and only 2 of its 6 turbines were working. With a prognosis of reaching 0%, and the possibility of stopping the energy generation [29], this situation is a serious threat to the riverside population, navigation and the irrigated areas. The regularization of the river flow in the LSF through the building of the Sobradinho Dam, although it has minimized the big floods downstream, the presence of the dam has negatively affected traditional activities of the riverside population like fishing, navigation, and agriculture [7]. The Low San Francisco (LSF) has been severely affected by incorrect governmental decisions, related to the sub-basins in the upstream are of the SF River. Studies carried out in 1940 and 1957 already showed possible negative effects in the LSF as a result of the construction of hydroelectric power plants for energy generation [30]. Also, as a result of the activities in the perimeters,

in relation to the water contamination in the IPB, the chlorpyrifos, tetraconazole and tebuconazole, although found in low levels in the Betume River, in comparison to the acceptable daily intake standards (IDA) of ANVISA (Agência Nacional de Vigilância Sanitária) and Environmental Protection Agency (EPA), the chlorpyrifos and tebuconazole, according to the European Union, showed high levels in months of 2013 and 2014 [31]. In the IPP water evaluation, in some areas of the perimeter, the presence of organophosphorus compounds and total compounds were noticed as well as high levels of electrical conductivity due to high salinity, and in specific areas within some lots, out of established classification pH values were found [32]. Concerning technical problems, considered "technical assistance impact" in this study, technical support for the farmers is scarce [33], [34]. The key informants in both perimeters were of the same opinion given that only two technicians are available for the entire the rice-growing cultivated area. The shortage of staff to monitor the problems in the field is added to the fact that the old structure of the perimeters, which has been held together with repairs for almost 40 years, has had no replacements in the irrigated structure or had the drainage and watering system modernized in that area. As a result, the inadequate water collection leads to a loss of harvests and serious economic losses for the farmers. The loss of the harvest due to the problems caused by the old hydraulic system, with some structures running on half their capacity, is common for farmers in both perimeters. Many times, farmers delay harvesting due to lack of machinery. In the IPP there is an increase in the number of farmers who withdraw from the rice-growing cultivation, due to the losses caused by this practice in the "Irrigated Perimeters". According to the data collected by the IPP key informant, 20% of the farmers in that perimeter withdrew from rice-growing. Unlike the IPB, the IPP was not initially designed for fish farming. However, this activity has been growing and substituting traditional rice-growing in the Irrigated Perimeter of Propriá. Family fish farming and livestock farming (beef and dairy products) have both been increasing in the IPP, substituting rice growing. The IPP key informant reveals that the process also lacks the technology needed and farmers try to replace the technology as best they can within their means. Barros [8] reports, the agroecological conditions of the damp valley were favourable for fishing in the flooded areas, which for six months a year supplemented the family income. Family fish farming was brought into the LSFS in 1980 as a replacement or supplement to the traditional practice of fishing, after the environ mental changes in the LSF Valley, caused by the building of the Sobradinho Dam, and as a consequence of the implementation of the "Irrigated Perimeters" by Codevasf [35]. In the LSF, the "psicultura" (fish farming) is classified as family fish farming and reaches 28 municipalities of the San Francisco basin in the State of Sergipe. The young fish are supplied by Codevasf, through the Center. About 2000 families are estimated to be practicing family fish farming in the LSFS. The fish obtained is usually consumed by the families and the surplus is sold to intermediaries or final consumers. Besides, the semi-intensive commercial "psicultura" is assisted by technicians from Codevasf, Emdagro and Federal Government organizations. In family fish farming, which substitutes the traditional fishing in the floodplains, the "psicultores" (fish farmers) face several issues such as fish farming in rain water reservoirs, the presence of predators due to lack of asepsis and the use of homemade feed to fatten the fish [35]. In Propriá the "psicultura" has been the most important activity surpassing rice-cultivation, but it also encounters problems with distribution. Nevertheless, unlike rice farming, it is possible to make a profit, since the cost of fish farming is cheaper, even though there is a risk of being subjected to water shortages, producing a loss of harvests. The farmers who opt for family fish farming lack the technical knowledge to run the system on their own. As far as livestock in the IPP, between 15% and 20% of the lots are already being used for beef and dairy cattle. According to the key informant (Informant 3): "…there

is no technology, it occurs naturally, with the pasture practically native, and when one plants, the pasture is extensively made in a dry area, fertilizers are used, and they search for a better handling to obtain a greater production. Many people are breeding beef cattle and others dairy cattle, however, without technical assistance or investments" [36].

Although there are neither records nor evidence of diseases among the population related to the rat infestations, because of its cycle, the presence of small rodents, sometimes for 2 consecutive years, like 82–83, 98–99, 2009, 2010 [24], is a risk for this population. The extermination of these rats is done by the farmers during hunts, where they use dogs, sticks, knives, and are in direct contact with those animals. Farmers pay for each hunted rat, since rat poison is as ineffective as in other places. In economic terms, in the years when rodent outbreaks have occurred, the losses in the field are common for the majority of the farmers. The insurance farmers take out against harvest losses do not take rodent outbreaks into account given that banks consider them to be predictable. Through Informant 1 from the IPB, in his lifetime as a "rizicultor" in the LSFS Valley, *with the appearance of the "Irrigated Perimeters", the farmer starts to need insurance against losses; however, the banks have never, ever covered the losses generated by the rodent outbreaks* [37]. The losses related to the precarious irrigated structure, like losses due to the insufficient water collection, or floods in the perimeter are usually dealt with by the farmers by going to court, but the process is too slow and sometimes the cases are dismissed. Economic problems involving bank loans also make rice production expensive causing a significant number of farmers to withdraw from rice cultivation, substituting it with "psicultura" (fish farming) and livestock farming in the "Irrigated Perimeters". The low price of rice in relation to other provinces also puts the viability of the "rizicultura" in the IPP at risk. The absence of tools of organization among the farmers allowing the establishment of market prices and the inexistence of the commercialization of the product out of the province, impose low prices in the free market, allowing a monopolistic system to thrive. The world economic crisis has also put the rice trade in the LSFS in a predicament. Given that the Federal Government was responsible for the environmental changes in the LSFS, it is incumbent upon them to come up with a policy of modernization of the "Irrigated Perimeters" which in practice, according to the informants, is not enough.

Despite the critical situations and difficulties faced by the "rizicultores" in these areas which are classified as an impact situation on different levels, in 2015 the State of Sergipe came in third place in rice production in the NEB, for the harvest of 2014. In January 2016, the IPB broke the record of national productivity with the harvest of 2015 among the "Irrigated Perimeters" of the LSFS. The national productivity average is 5.4, according to the Conab [38]. Rice-growing in the main "Irrigated Perimeters" of the LSFS which make up the areas of the big floodplains: IPP (Propriá), IPB (Betume) and Cotinguiba/Pindoba, produces a gross income of 20 million reais a year (5.3999,800.00 euros), with approximately 5 thousand jobs in the region.

Recently, a joint action was agreed upon with the University of Auburn where exchanges in expertise in the areas of fishing management, aquatic ecology, environment, water resource management and protection of endangered species [39].

Even though it is possible to point out advantages in relation to productivity in the "Irrigated Perimeters" of the LSFS Valley, this study concludes that, after almost 40 years of implementing changes in the use of the land in the LSFS Valley, the results for the rice producing riverside population can be summed up in problems on different levels which involve different kinds of impact. The alternatives put forth by the key informants are essential strategies which can establish a more sustainable future scenario involving minimizing impact and restoring these areas.

ACKNOWLEDGEMENTS

We acknowledge the cooperation provided by the Regional Administration (Irrigated Perimeter Betume (IPB) (Aracaju/Neópolis/Betume) and Irrigated Perimeter of Propriá (IPP) (Propriá) and the rice growers represented by the key informants.

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