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Adaptative success and perceptions on the hydrological disturbances by riverine populations in Brazilian semi-arid streams

Sucesso adaptativo e percepções das perturbações hidrológicas por populações ribeirinhas em rios do semiárido brasileiro

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Abstract

Brazilian semi-arid streams are characterized by extreme hydrological events, with short periods of flooding and long periods of no surface water flow. Human populations living in the surroundings of these systems must be adapted to such hydrological disturbances. This paper evaluates the perceptions of riverine human populations in the Brazilian semi-arid, in relation to the hydrological disturbances, adaptations of such populations to withstand drought while maintaining social structure, and their utilization of the watershed during times of flooding. Data presented was collected from three riverine human populations that live near intermittent streams in the semi-arid region of Brazil. These populations rely mostly on the intermittent water supply from these systems and on the production from small-scaled agriculture and livestock. The surveyed populations maintain the stability of their social structures and organizations by producing an identification process through representations of hydrological disturbances (floods and drought). The resistance and resilience to these events basically involve strategies to avoid social ruptures, through the practice of subsistence agriculture, and the search for opportunities (e.g. adequate sites) to build weirs, wells and "cacimbas" (water holes). A simple yet well-structured scheme to utilize the watershed was found to be important during wet periods. The history of human adaptation to the Brazilian semi-arid depends on the configurations that both ecosystem and the social system take at each hydrological cycle. These aspects should be taken into account by decision-makers, and should be included in development-oriented policies adopted for the region. Any attempt to manage the semi-arid ecosystems should include the utilization of hydrological disturbances as part of the human element and its dimensions.

Key words: riverine populations, survival strategies, flood, drought, stability, intermittent stream, semi-arid.

Resumo

Os rios do semiárido brasileiro são caracterizados por extremos hidrológicos, com curtos períodos de inundação e longos períodos de ausência de água. Populações humanas vivendo próximas a esses sistemas devem estar adaptadas a tais perturbações hidroló-

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gicas. Este trabalho avalia a percepção de populações ribeirinhas no semiárido brasileiro, considerando as perturbações hidrológicas, suas adaptações para resistir à seca enquanto mantêm a estrutura social e o uso da água durante os períodos de inundação. Este estudo foi realizado em três populações que vivem próximas a rios intermitentes na região semiárida do Brasil. Essas populações dependem principalmente da água de rios intermitentes para a agricultura em pequena escala e para a pecuária. As populações estudadas mantêm a estabilidade de suas estruturas e organizações sociais por meio das representações das perturbações hidrológicas (inundação e seca). A resistência e a resiliência a esses eventos envolvem basicamente estratégias para evitar rupturas sociais através da prática de agricultura de subsistência e pela procura de oportunidades (locais adequados) para construir açudes, poços e cacimbas. Um esquema simples e bem estruturado de utilização de água é também importante durante períodos de inundação. O histórico da adaptação humana no semiárido brasileiro resulta da conformação do ecossistema e do sistema social a cada ciclo hidrológico. Estes aspectos devem ser levados em conta por tomadores de decisões e devem ser considerados nas políticas que orientam o desenvolvimento dessa região. As ações de manejo nos ecossistemas do semiárido devem incluir a utilização das perturbações hidrológicas como parte do elemento humano e suas dimensões.

Palavras-chave: populações ribeirinhas, estratégias de sobrevivência, inundação, seca, estabilidade, rio intermitente, semiárido.

Introduction

Wetlands are important ecosystems since they show high productivity and biological diversity. They are a key component of freshwater habitats, providing flood control, carbon storage, water purification, energy, and goods, such as fish, shellfish, timber, fiber, transport, and crop production (Taylor *et al*., 1995; World Resources, 2000-2001). Almost half of the world's wetlands disappeared in the last century due to agricultural and urban development (Shine and Klemm, 1999). In Europe, the situation is critical with the loss of almost two-thirds of wetlands by the beginning of the 20th century (Santamaría and Klaassen, 2002). The diminishment of these ecosystems compromises the sustainability of many regions of the planet, mainly those located in semi-arid zones.

The values attributed to wetlands in humid regions are also applicable to wetlands in dry lands, with the difference that many of these values are often enhanced given the arid nature of the surrounding environment (Williams, 1999; Maltchik and Medeiros, 2006). Regarding riverine populations, dry land wetlands may be important economically (e.g. as a source of water and fish), aesthetically and culturally (Reed, 1965). Dry lands occupy about one-third of the world's land surface area (Thomas, 1989) and are home to one-third of the human population (Graf, 1988). People living in dry lands are highly dependent on the aquatic ecosystem. However, the arid and semi-arid zones of the world receive only two percent of the world's runoff (World Resources, 2000-2001).

In Brazil, about 11% of the national territory is classified as semi-arid land (some 925,000 km^2). This region is inhabited by more than 23 million people (Ab'Saber, 1994-1995; MMA, 2004). The Brazilian semi-arid region is characterized by scarce and irregularly distributed rainfall, with 1-11 months of dry periods. The main climatic difference between the Brazilian semi-arid region and other semi-arid lands is the low annual thermal amplitude. This particular climatic rhythm results from its geographical location, near the Equator, and determines the ephemeral nature of the rivers and streams (see Maltchik and Medeiros, 2006). In this sense, these wetland ecosystems exert an important role on the survival strategies of human populations of this region. Over most of the Northeast Region of Brazil the average annual rainfall ranges between 500 and 750 mm (37% of the Northeast Region), but a small proportion receives less than 250 mm (<250 mm = 0.3%, 250-500 mm = 11%, and 750-1000 mm = 20% of the Northeast Region of Brazil). However, annual averages are poor climatic parameters in an area where local rainfall may vary from close to zero to as much as ten times the long-term average, and deviation from the normal rainfall may be higher than 55%. Therefore, the main characteristic of the rainfall in the region is its erratic nature, varying greatly both spatially and temporally. Such variability determines the start and the duration of the wet season (Sampaio, 1995).

Associated to the environmental context, human populations in the Brazilian semi-arid show a traditionalistic history in the structure of social relations and means of production. This leads to a strong demand for natural resources, mostly water and natural vegetation, as well as pressure on soil for production. The stress on natural resources associated with such organization of socio-environmental relations is progressively being aggravated. This leads not only to loss of resources, due to transformation and ultimately suppression of the natural ecosystems, but also destabilizes local and regional

bases for production. These factors associated with a lack of appropriate management strategies, poor planning, and scarce and inadequate investment policies from the government reflect negatively on every social aspect, leading to impoverishment, illiteracy, rupture of family bonds, crime and emigration. This scenario enhances the environmental stress and the results are loss of biological integrity in natural systems and bankruptcy of the social structure and social organizations (Vasconcelos Sobrinho, 2002).

The main goal of resident human populations is survival (Ghosh Maulik, 1996); for this reason they must conform to the surrounding environmental conditions to enable their existence. Social systems are integrated with ecological systems (Duncan, 1961) and the former are endowed with survival strategies that parallel those found in the living organisms (Holling and Goldber, 1971). Many human populations around the world have learned to extract goods from marginal systems without further degradation (Diegues, 1992). Recently, scientists have begun to demonstrate how local peoples can teach new models for sustainable natural resource use and management (Chaibva, 1996). Their ancient traditions, developed through millennia of experience, observation, and experimentation, have relevance in providing options for the future of the Planet (Posey, 1990). This social perspective includes the way people perceive, use, allocate, transfer, and manage their natural resources (Morin-Labatut and Akhtar, 1992).

Within this framework and based on studies related to human ecology (Begossi, 1993; Arruda, 1997), social systems are important units holding strategies that ensure the stability of social structures and organization. Furthermore, mainstream ecological research often neglects the importance of many human aspects in relation to the environment, failing to consider appropriately such aspects in the understanding of interactions between human populations and the environment (Arruda, 1997). This is particularly important in semi-arid lands, where the streams and rivers are essential to human survival (Swinton, 1988; Krannich *et al*., 1995). In the Brazilian semi-arid region, flooding and drought affect the way of life of the riverine populations and their persistence is related to the survival strategies adopted in association with the different hydrological phases of streams and rivers (Barbosa and Maltchik, 1998).

This work evaluates the perceptions of riverine human populations in the Brazilian semi-arid regarding the hydrological disturbances and the dynamics of the intermittent streams. It also assesses the adaptations of such populations to withstand drought while maintaining their social structure and their utilization of the watershed during times of flooding.

Methods

Study area and design

This study was carried out in the Taperoá River basin (7,924 km^2), which is located in the driest region of the Brazilian semi-arid (Figure 1). During the study period the resident population of Taperoá River basin was 112,242 inhabitants (MMA, 2004), with 46,918 habitants in the cities and urban districts and 65,324 habitants in the rural areas.

Mean air temperature and total rainfall in the study area, between February 1996 and September 1997, were 27.3^{o}C ±1.6^{o}C and 721.7 mm, respectively. In this region of the country rainfall is irregularly distributed, which determines the intermittency of the watercourses. The natural vegetation in the drainage basin known as "Caatinga" is characterized by an arboreal to shrubby deciduous open forest composed mostly of xerophytic species (Ab'Saber, 1994-1995). In some areas, the marginal stream vegetation has been modified by the planting of the leguminosae "algaroba" tree (*Prosopis juliflora* (SW.) DC).

Riverine populations are usually established along intermittent streams that flow only after unpredictable rains, yet water is frequently available in the dry river beds as temporary and semi-permanent pools or sub-surface water during the dry phase. This pattern is interrupted by flooding after torrential rain during the summer-autumn season (in the southern hemisphere). Approximately 25 riverine populations were identified throughout the catchment basin of the Taperoá River. Of these, three populations were selected at two tributaries and in the main river in order to assess human populations at different levels of river hierarchy (Figure 1). A total of nine residencies were surveyed. They were represented by 17 families distributed in the margins of the three intermittent rivers studied. The population of Alagamar (7^{o}28'08"S, 36^{o}31'17"W) is placed in the margins of the Avelós stream, an ephemeral second-order stream, with 7 km of extension and 42 km^2 of drainage area. The population is placed near an upwelling reach along the main channel that forms a perennial pool of approximately 3,600 m^2 (280 m x 13 m). The population of Várzea Nova (7^{o}25'46"S, 36^{o}34'51"W) is placed in the margins of the Serra Branca stream, an ephemeral fourth-order stream, with 23.5 km of extension and 432 km^2 of drainage area. The population of Jurema (7^{o}23'14"S, 36^{o}33'24"W) is placed in the margins of the Taperoá River, a temporary sixth-order river, with 133 km of extension and 7,924 km^2 of drainage area. In this area, a semi-permanent pool in the river bed with approximately 350 m^2 existed during the period when this study was performed. The surveyed populations survived mostly from small scale agriculture and cattle and goat breeding for subsistence. Handcraft manufactory of bricks and the re-use of goods and assets are also important activities.

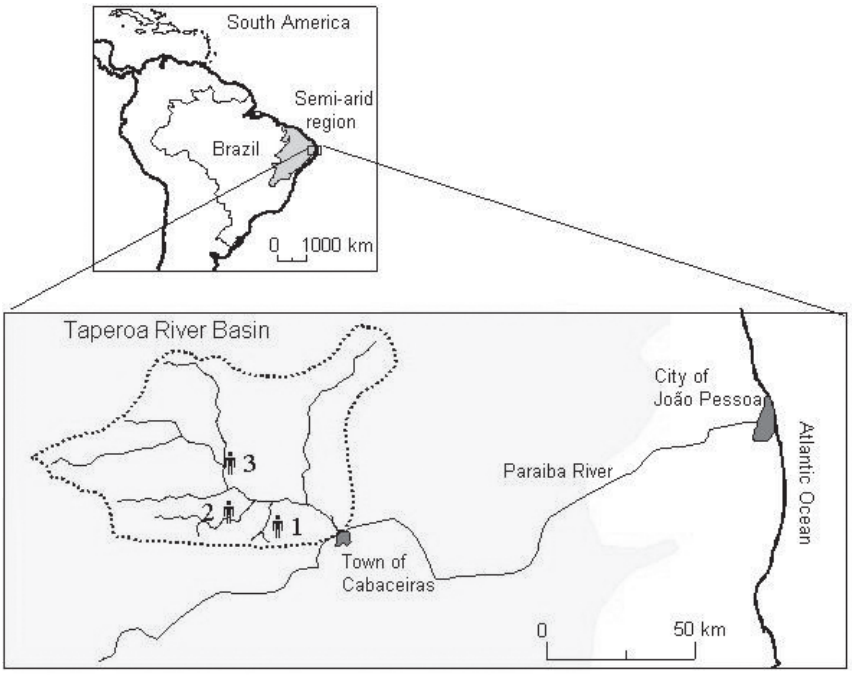

Figure 1. Brazilian semi-arid region and location of the riverine populations studied in the catchment basin of the Taperoá River. Populations: 1, Jurema (Taperoá River), 2, Várzea-Nova (Serra Branca Stream) and 3, Alagamar (Avelos Stream).

The interviewing process

Perceptions and adaptations of human populations in response to drought and flooding were evaluated through open-ended interviews. These were recorded (with their approval) and used for comparison of their speeches, and for analysis on how the social subjects elaborate and re-elaborate their practices and productive spaces in reaction to the processes occurring in the river. Individuals interviewed consisted of men and women between 17 and 76 years old. The families interviewed occupied areas between two and five hectares, generally inherited from relatives. Individuals were native from the area and have long had their lives linked to the riparian zone.

At first, the daily activities related to agriculture and subsistence cattle breeding were questioned. After that, they were motivated to reveal their attitudes regarding the hydrological disturbances, as well as their behaviors, beliefs and feelings. This procedure was useful to encourage them to speak freely. The interview was based on thematic information for the description of the behavioral situations that focused on familiar organization of riverine populations and their interactions with the ecosystem. Interviews were performed in accordance with the different hydrological phases of the streams (rewetting, wet, drying, and dry) for two years (1996 and 1997). Frequency of interviews was once a week during the rewetting and wet phases. During the drying and dry phases interviews were performed fortnightly.

Results and discussion

Resilience and resistance of riverine populations in the Brazilian semi-arid

Resilience strategies to drought by Brazilian semi-arid populations are revealed during times of flooding. Following the period of total lack of surface water flow in the streams, flooding represents temporary abundance of water, which produces supplement of protein for riverine populations as it repopulates pools and small reservoirs with fish (see Medeiros and Maltchik, 2001). However, flooding is also perceived as a hydrological disturbance by families of the riverine populations, as they build their houses close to the rivers but at higher ground on the watershed by understanding that it is a safer place:

> *He built a new house closer to the river. He was uneasy about the flood though (young man talking about his father).*

As revealed by the above statement, riverine populations are also aware that flooding magnitude varies in long-term time intervals, so they can move further or closer to the river at different times. Moreover, the distance established in the location of the houses frees the riparian zone, which is in turn used for the practice of subsistence agriculture. The studied riverine populations also recognize that flooding is related to the quality and quantity of the newly available water:

> *If the winter lasts one to three months, the stream will flow for three to four months* (family member from the Jurema population. Note that "winter" means rainy season).

> *When plenty of water passes through the river, we know it is good water* (family member from the Jurema population).

The water is stored in different ways in different compartments of the watershed, e.g. wells and waterholes in the riverbed, and small reservoirs ("barreiros") excavated in the run-off area or built on small tributaries (small weirs). This determines the water available for each type of consumption, such as drinking water, cattle water, irrigation water etc. Additionally, the humid alluvial soil is used for

agricultural purposes. With this scheme riverine populations establish the adequate physical limits for the proper exploitation of water and enhance the utilization of the watershed. Individuals understand that flooding brings humidity and nutrients needed for the complete development of the plants and animals and therefore developed efficient ways of compartmentalizing the water and using it.

The resilience of the riverine populations is therefore expressed as the reassurance of their dignity and hope (during the flooding season), which had been threatened by the shortage of water during drought. The resilience of the studied riverine populations also involves the opportunity for men and women to get involved in the exploitation of the riparian zone, through the humidity found in the river troughs and adjacent areas. This humidity is used to re-grow their crops such as cultivated corn, beans (*Vigna sinensis* Endl. and *Phaseolus vulgaris* Linn.), sweet potatoes (*Convolvulus batatas* Linn.), watermelons (*Citrullus vulgaris* Scharad.), and, sometimes, grass (*Panicum maximum* Jacq.). Resilience also manifests itself as the reallocation of labor from producing supplementary food for livestock to the utilization of the rainwater barred in small dams and weirs.

With the end of the wet season and the inevitable recession of flood waters, vulnerability increases, and the reduction phase (drying phase) progresses up to the point of facing a total lack of surface water flow (dry phase), posing at each moment a series of different challenges to the riverine populations. The riverine populations studied perceive drought as a hydrological phenomenon, and developed strategies to resist this disturbance according to the availability of hydrologic resources at different fragments of the watershed. The presence of pools along the main stream channel is then associated with the notion of ownership, and in many instances, dividing fences are placed perpendicularly to the dry watercourse, on the properties borders. However, a strong sense of cooperation in the utilization of water can be observed in the riverine populations' social structure. Also, once the river bed is dry, livestock can cross properties borders, therefore fencing the dry bed of the river is a necessity to prevent loss of livestock. When facing a total lack of surface water, the decision to search for sub-surface or hyporheic water and to construct wells and "cacimbas" (water holes) is made during family gatherings. In these gatherings, decisions are made on when and how to protect the water from animals through enclosures made out of twigs, so that the water can be used for domestic purposes, depending on its palatability:

> *The choice of a place to dig a well is made based on the presence of an evergreen tree* (member of the Alagamar settlement).

In a strategy adopted to increase availability of water during drought, riverine populations become involved in constructing new weirs and/or repairing old ones for the storage of rainwater next winter. Individuals belonging to the families who live along the riparian area are accustomed to drought, and place it in their economic planning and lives (Swinton, 1988). In this way, they develop strategies to respond to that event, basically through domestic effort to (i) minimize the risk of failure in the production of their means of subsistence and to (ii) limit their losses, in face of the drought's magnitude and representations (Binswanger *et al*., 1979; Swinton, 1988).

Given the unpredictability of the drought's magnitude, economic restrictions during the end of this phase can lead to the possibility of loss of productive resources and assets. The riverine populations develop, at each hydrological cycle, strategies to avoid such losses and to guarantee the recovery of lost goods. They are almost always on the verge of social ruptures which can happen, for instance, through the loss of workers due to migration to urban areas or through the loss of agricultural land. This indicates that the social system can be destabilized, or even disappear (see Holling, 1973).

The means for production of riverine populations in the Brazilian semi-arid region are scarce. They usually own little cleared land, and therefore fields for cultivation of plants more resistant to droughts, such as foraging cactus (*Cactus ficus-indicus* Linn.), are small. Other drought resistant trees such as "algaroba" (*Prosopis algarobilla*) are not abundant in some areas. Furthermore, given the low scale of production, there are not enough resources to pay for pasture rental. Under the aggravating effects of the droughts, these small and medium-scale producers search for Cactaceae such as "mandacaru" (*Cereus jamacaru*) and "xique-xique" (*Pilosocereus gounnellei*), which are used to feed the cattle after their spines have been burned. In extreme cases, as a consequence of extended dry periods and the lack of means to feed the livestock, small-scale producers are compelled to sell part of the animals, always at prices below market value.

Restrictions regarding availability of water and of energy obtained from food are so interconnected that their adaptive responses cannot be considered separately (Lee, 1969). In this context, the agriculture practiced by the riverine populations functions as a dry season pasture, and its existence should be understood as a function of its relationships to the hydrological extremes and to cattle rearing. The soil of the riparian area once occupied by the crops has its fertility tied to the periodic floods. With the decrease in soil fertility during drought, riverine populations alternate to the use of animals for traction (additional labor) and production of manure to increment cultures of foraging cacti. Also, by-products of the remaining cultures are sun-dried and used to feed the livestock.

The strategies used to face drought in the Brazilian semi-arid show similarities to those used in Saelian Africa and India (Swinton, 1988; Ghosh Maulik, 1996). They include strategies which have been culturally transmitted through generations and that enable the riverine populations to succeed during a period of regular drought, through preservation of the productive goods, including family-based labor.

In the Brazilian semi-arid, in situations where drought is more extended, resistance strategies such as sale of livestock, temporary migration, non-agricultural activities and work, and loans of supplementary food for livestock are commonly used. However, when those human populations face a prolonged drought (tending to be an event of great magnitude), their capacity to respond to this environmental pressure can be exceeded and the existing social organizations and structures may rupture (Winterhalder, 1980; Krannich *et al*., 1995). In the Brazilian semi-arid this is related to the impossibility to recover production assets. These aspects show that human social systems in this area are vulnerable to large-scale environmental changes, especially those associated with unpredictability, such as flooding and drought. They also show that adaptive processes, including the bio-cultural one, have their own limitations; neither can they withstand all degrees of disturbances in a linear manner, nor withstand all types of disturbances (Winterhalder, 1980).

The identity-building process in face of hydrological disturbances

The social adaptation of the Brazilian semi-arid riverine populations and their socio-spatial-cultural aspects suggest a flexible social process in which the representation of those hydrological disturbances influence choices and decisions that will guarantee the maintenance of the internal connections of the human social systems and of their natural aquatic ecosystems.

Maintenance of configuration and structure of riverine populations' relationships depends on (i) organizational decisions which lead to efficiency regarding site selection for crops, water storage, etc.; and (ii) the detection of the appropriate time to search for water and to exploit this resource at each hydrological cycle. In both cases temporality is a relevant fact for planning a sequence of actions. This means that meetings, discussions and agreements regarding the significant elements, which represent the nature of the social goal, should precede the decisions.

Members of the riverine populations face hydrological disturbances, understanding that these events represent natural phenomena, typical of the aquatic ecosystems to which they are tied to. At each cycle, some of them learn by experience or apply the experiences which have been culturally transmitted and stem from aspects of nature such as wind direction, flowery and fructification of trees, arrangement and position of clouds and stars, as well as from cues provided by birds or insects (Araújo *et al*., 2005; Oliveira, 2006). On the other hand, during the dry phase the individuals manage to take advantage of remaining pools on the main stream channel, understanding that following a large-scale flooding there will be brackish water in the wells they have built in order to utilize the sub-surface water. Furthermore, individuals recognize the riparian zone as an ideal place for agricultural purposes due to its humidity and suitability for agriculture based on rapid cycles.

In this way, semi-arid ecosystems appear as historical entities and their history is important to the present configuration of riverine populations, in the same way that it is important to the human social systems. Through this, the Brazilian semi-arid riverine societies and culture can be understood as the historical product of their adaptations to the hydrological disturbances. Similarly to a natural ecosystem, the social identity of riverine populations in this part of the country is continuously in a transitional state, with several stable states among its elements (see Winterhalder, 1980). In this way, the stability of the identity and of the ecosystems is crossed by history and contains information on the human social systems resistance and resilience. Any initiative dealing with development-oriented models and programs directed at the Brazilian semi-arid region should take into account the hydrological disturbances, as phenomena inherent to the semi-arid natural aquatic ecosystems, and the human society centered around them. This society constructs a process of identification based on intergroup relationships that influence the representation of floods and droughts, and maintain the stability of their social structures and organizations. Therefore, any attempt to manage the semi-arid ecosystems should include the utilization of hydrologic disturbances as part of the human element and its dimensions.

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