The Impacts of Gullies in Zé Açú Micro-watershed, Brazilian Amazon

Jesuéte Brandão Pacheco¹*, Carlos Henke de Oliveira² and Carlos Hiroo Saito³

¹Department of Geography, University of Amazonas, Brazil.
²Development and Department of Ecology, University of Brasilia, Brazil.
³Department of Ecology, Center for Sustainable Development, University of Brasilia, Brazil.

Authors’ contributions
This work was carried out in collaboration between all authors. Author JBP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CHO and CHS have mentored the study. All authors read and approved the final manuscript.

ABSTRACT
The gullies represent the most complex and destructive way of soil degradation relative to linear erosion. In this context, the goal of this study is to address the impacts of gullies in the longitudinal profile of the Zé Açú Micro-watershed, at the Settlement Project (SP) Amazonian Village, Parintins municipality, Amazon State, Brazil and, as consequence of that, the impacts to the family farmers living there. Methodology: a) Cognitive Map; b) Geoprocessing; c) Field work from 2010 to 2012. Discussion of the results: Twelve gullies were mapped at the edge of the first order channels’ headwater in an area of extensive livestock. The upper stream is the more affected by the colmatation of tributary channels and the siltation of the mainstream. As consequence, in the river’s ebb tide (August to December) there is the scarcity of water (direct impact on domestic use, irrigation, transport, quantity of fishes; Indirect impact described as no potability because of the high charge of suspend sediments). These impacts affect 07 traditional farming communities (416
families). This problem leads to the vulnerability of local farmers and impacts can be seemed on their economy, social life and culture. Nevertheless, Zé Açu Micro-watershed is looking for its geomorphological reorganization, compatible with the new conditions that are imposed to it. The on-going changes, however, doesn’t permit recovering the same ecosystem, due the loss of soil, fauna and flora.

Keywords: Water scarcity; gully; fluvial stream; Amazon.

1. INTRODUCTION

The environmental equilibrium and disequilibrium (climatic factors and elements besides biotic and abiotic environments) are intrinsically related with the land use and occupation. Therefore, vulnerability and risk of the environmental changes and hazards depends on the genuses and composition of certain natural system and the relation with the land use and its occupation.

Thus, it is impossible to separate the set of physical conditions that interacts with on living organisms. This framework is an evident global concern about environmental issues. The vegetation, for instance, is important for the climatic equilibrium, and this last one is connected to the hydrologic cycle which is essential for the living beings and their environment, demonstrating the cyclic interdependence.

Regarding the Amazon studies, Aguiar [1,2] indicated the relationship between vegetation cover and weather: the absence of vegetation may cause reduction in the permanence time of water in the drainage basin, by favoring the accelerated flow and, thus resulting also in a decrease of water vapor in the atmosphere, by the reduction of humidity in the whole system. This argumentation corroborates the various studies [3-7], wherein it is said that precipitation arises from the combination of locally evaporated water (evapotranspiration) with humidity contributions originated at Atlantic Ocean.

Several human activities can destroy vegetation like: deforestation and burnings can produce impacts on water, as so as the inappropriate prepare of the soil and consequent soil compaction [8]. According to Mello and other [9], the effects of these impacts may change the superficial flow in the basin, including the shift of drainage from perennial to intermittent one.

Molion [7], explained that when the soil suffers vegetation suppression by shallow cuts, this allows variations in diurnal moisture fluctuation on the soil surface because of the increase on air temperature and humidity, generating a decrease in the rainfall. When the vegetation is removed, there is an environmental impact. The soil loss is directly occasioned by this, and the loss of material is also accelerated by hydric/pluvial erosion. In Brazil, the soil loss is around 2 to 2, 5 billions/ton/year [10]. Bertoni and Lombardi Neto when they studied a small area without green cover, the [11] y found data regarding the soil loss by pluvial erosion from 1.600 to 9.000 MJ.mm.ha⁻¹.h⁻¹.year⁻¹. Fearnside concluded that aggressive anthropic impacts cause the loss of environmental services: biodiversity maintenance, water and carbon cycling which can regulate the greenhouse effect [12].

Focusing in this issue, this work aims to address the impacts caused by gullies in watershed longitudinal profile at the Zé Açu Micro-watershed, and, as a consequence of this, there is scarcity of potable water to the local family farmers.

2. STUDY AREA, MATERIALS AND METHODS

2.1 Area of Study

The study was conducted in the Zé Açu Micro-watershed. This drainage basin has an area of 126,923 km², in which the main stream has an extension of 19,512 km, from southeast (upstream - 56°33′15,368′′W - 2°44′44,21′′S) to west (downstream-56°39′40,336′′W - 2°38′12,679′′S); and, from north (56°33′13,231′′W - 2°36′22,984′′S), northeast (56°32′3,993′′W - 2°38′54,774′′S), northwest (56°38′5,299′′W - 2°37′35,35′′S), until southwest-south-southeast (56°38′46,944′′W - 2°42′24,45′′S).

The Micro-watershed is situated in the domain of the Settlement Project (SP) Amazonian Village, in the municipality of Parintins, Amazon State, Brazil.
2.2 Methodology

The diagnosis was developed by a participatory approach. The local people involved were from the seven communities that constituted the Polo 07 (Bom Socorro, Nazaré, Paraisó, N. S. das Graças, Santa Fé, Boa Esperança, Toledo Pizza-Vista Alegre), specially the first ones with direct access to fluvial net of Zé Açu Micro-Watershed.

Therefore, the methodology applied used the following supports:

a) The cognitive maps: They were used to identify the problem-situations that affect direct and indirectly the Zé Açu Watershed and family farmers’ way of life. The choice of this technique (cognitive maps) is based on Cosgrove [13] and Nogueira [14], who argue in favor of stimulating people's perception to obtain the knowledge of a certain place, as a participatory diagnosis. Tuan [15] said that native people of a certain place has a complex perception of the environment because they are part of it, sharing local myths and values. A cognitive map belongs to the field of Phenomenological perception. In this case, the cognitive map allows credibility on data gathering, and integration researcher-local people.

b) The field work from 2010 to 2012: identification of fluvial channels with gullies, the clogging of first order channels and the longitudinal profile considering a process of sedimentation.

c) Geographic Information System (GIS): spatial data were gathered and stored in a geographical database, mainly the map of land use and occupation of the Zé Açu Micro-Watershed [16] and Satellites Images/Spectral waves TM/ LANDSAT-5 (orbit/point 228/062 and 229/062, August 2010 and 2011).

3. RESULTS AND DISCUSSION

The main findings of the performed diagnosis was the inadequate occupation and use of the land. This caused environmental impacts in the drainage basin such as the scarcity of water in the drought period, pluvial erosion, clogging and sedimentation.

Several factors can be related to the origin of the present problems: one of them, which can be considered as a central role, was the creation of the SP in 1988 as a land reform goal of the Brazilian’s Government. Until 1987, the occupations were spontaneous and at a very low rate, however, when the SP was coming the drainage basin surface was divided in parcels-which were donated to traditional farmers [17]. Some years ago, many of this plots were sold to the same people, causing land concentration with medium to large scale activities inside there. The Table 1 shows how the lands had been occupied, initiating in the settling of 1986 (before the creation of SP) and after two and half decades (in 2010).

The Table 1 shows how much the Zé Açu Micro-watershed is affected by the suppression of the vegetation, and its substitution by extensive livestock farming (bovine and buffalo). The environmental impacts mapped by the family farmers and confirmed by the filed true are held in the area of permanent preservation (headwaters and hillslopes of river channels), where cattle can be found (Fig. 1).

The development of livestock farming occurs on dystrophic yellow oxisoils. There, the relief is not plain, presenting elevations with several hills lopes because of the river basin design. The

<table>
<thead>
<tr>
<th>Land use categories</th>
<th>1986</th>
<th>1997</th>
<th>2005</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²) (%)</td>
<td>Area (km²) (%)</td>
<td>Area (km²) (%)</td>
<td>Area (km²) (%)</td>
<td>Area (km²) (%)</td>
</tr>
<tr>
<td>Family agriculture</td>
<td>27,991</td>
<td>22,05</td>
<td>36,52</td>
<td>28,77</td>
</tr>
<tr>
<td>Farmyard</td>
<td>1,759</td>
<td>1,39</td>
<td>0,67</td>
<td>0,53</td>
</tr>
<tr>
<td>Original forest</td>
<td>75,760</td>
<td>59,69</td>
<td>46,49</td>
<td>36,63</td>
</tr>
<tr>
<td>Hydrography</td>
<td>11,184</td>
<td>8,81</td>
<td>11,184</td>
<td>8,81</td>
</tr>
<tr>
<td>Pasture</td>
<td>10,230</td>
<td>8,06</td>
<td>32,06</td>
<td>25,26</td>
</tr>
<tr>
<td>Total</td>
<td>126,924</td>
<td>100</td>
<td>126,924</td>
<td>100</td>
</tr>
</tbody>
</table>
growth of this kind of activities is perceptible, from about 10 thousand km$^2$ of pasture and almost two thousand km$^2$ of farmyard in 1986, to more than 40 thousand km$^2$ destined for livestock farming (33,453 km$^2$ of pasture plus 9,292 km$^2$ of farmyard) in 2010.

The family agriculture is the second more developed activities in the interfluve area. They preferred plain topographies, distant form river and closer to roads and highways (Fig. 1), where the land preparing can be made with simple instruments such as machetes, hoes, ox-wagon, ax and some locally known artifacts as cambito [16].

The intense erosions gullies-like at Zé Açu Micro-watershed is due to deforestation: soils became exposed and susceptible to rainfall impacts, besides the bovine and buffalo trampling and soil compaction. The greatest gullies are located in twelve tributaries, distributed in three river channels. They affect directly their affluent and subaffluents (Fig. 2).

The clogging is located in the tributaries’ borders and also in the main stream channel between its upper and mid-course. The colmatation process was recognized in two first order tributaries at the upper river.

The elevated rates of sediment concentration (Csts) and charges of transported sediments (Qsts) are correlated to the presence of bovine livestock in the Permanent Preservation Areas (Áreas de Preservação Permanentes - APP) in river banks. The environmental impacts seemed more serious in the period of fluvial ebb, when the suspended sediments rate makes the water change its color and density on the river bed. These changes prejudice the ecosystem functions and environmental services [16].

![Fig. 1. Classes of land use, occupation, and tributaries rivers with gullies at Zé Açu micro watershed](Source: Org. Pacheco [16])
In those places where family agriculture is found don't present gullies. This result may due because even though there had been deforested, soil are not exposed, due to the traditional way of working (pieces of fallow, spontaneous gardens, use of simple tools). Another factor of less degradation regarding the cultivation of this productive system is its geographical location. Family agriculture is not practiced nearby the rivers; they do occur by the extension of the Boa Esperança and Santa Fé roads and highways to get facilities to leave the agricultural production by roads until the main stream, at the lower course of Zé Açu Micro-watershed.

4. CONCLUSIONS

i) In summary, the anthropic impacts on the fluvial environment of Zé Açu Micro-watershed can have two scopes: Regarding the vulnerability of the Zé Açu Micro-watershed focused on its fluvial environment: its upper streams concentrate most of the impacts: an increase on the edges of the river banks and the elevation of its bed, by cords of sand deposit. These changes are leading to the beginning of a process of “strangulation” between the upper course and the mid-course, which will develop a new fluvial metabolism. This new scenery represents the on-going hydric system adjustment with prejudice to local communities. Natural systems are dynamic, and they can evolve to new stable levels. Nevertheless, it should be recognized that the intensity of the anthropic interventions is promoting changes in the fluvial morphology and dynamics, with different types of losses (decrease of the aquatic fauna and its diversity, reduction of the Igapó Vegetation, diminution of water quotas, among others).

ii) Regarding the “fluviality” and the way of life: the 416 families are strongly impacted, because they are dependents of igarapés and rivers by the ecosystem services that supply them (navigation, communication, alimentation, recreation). In the periods that water becomes scarce in the river, at least 3 months of the fluvial ebb period, if the water quota/vertical section becomes
more and more lower the fluvial transportation becomes impossible, affecting their economy, culture, and social relationships. Even their health can be affected because of water’s lack of drinkability.

In this case, this study could show how nature and human process are interconnected, and some anthropic activities can give back prejudice to the humans themselves. When people are concerned to this cause-effect framework, they may realize the necessity of conducting actions and critical attitudes regarding their spaces as a place of living and also the importance of searching for the solutions by their own.

ACKNOWLEDGEMENTS

Contribution with the Stock Exchange of Doctoral Traineeship - Foundation of Support to the Inquiry of the State of the Amazon (FAPEAM).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES


2. As Alterações Climáticas em Manaus no Século XX. Dissertação (Mestrado). Departamento de Geografia, Instituto de Geociências, Universidade Federal do Rio de Janeiro; 1995 (Portuguese).


16. Pachêco JB. Uso e ocupação da terra e a sustentabilidade ambiental da dinâmica