

Summary of drivers, pressures and environmental impacts at the Contas river estuary, Bahia state, northeastern Brazil

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Physiographic settings

The Contas River watershed covers about 55,000 km², the biggest at Bahia State (Figure 1). The main canal extends for up to 700 km, from the headwaters, as high as 1,700 m asl at the *cerrado* (a savanna like biome), crossing at the middle course the *caatinga* biome, a semi arid environment and reaching the coast under tropical rain forest. The estuary at 14.3° S; 39° W, is characterized by a well defined canal at Itacaré City. This canal is limited by terraces extending from the end of fluvial stretch until the upper estuary and actually disappears a few hundred meters before the river mouth. This topographic setting results in very narrow flooded margins restricting mangrove occurrence and the formation of a broad coastal plain.

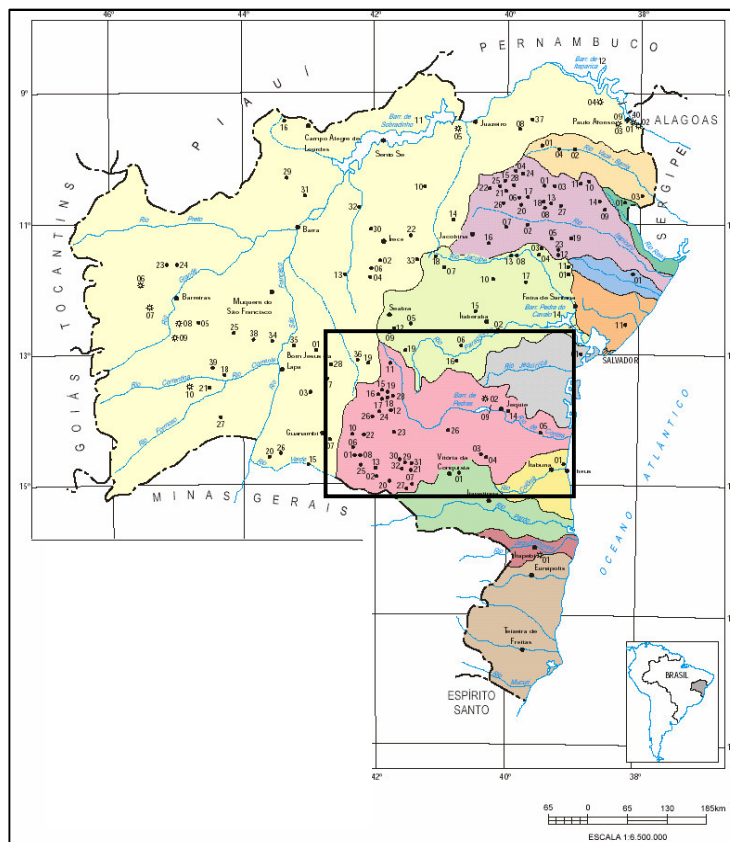


Figure 1: The Contas river watershed in the Bahia State (Brazil), modified from SEI (2008a).

Tidal regime is semi-diurnal, with 2.0 m maximum amplitude. Low discharge period induces a salt stratification at the lower estuary (PAULA *et al*, 2007), but salt intrusion reaches only five to six kilometers upriver (CAMPOS, 2001). These figures suggest low retention capacity of the Contas River estuary and dissolved and particulate loads are quite directly fluxed to adjacent marine areas. Average annual water discharge to the ocean (from 1970 to 2002) reaches about 1,200 m³.

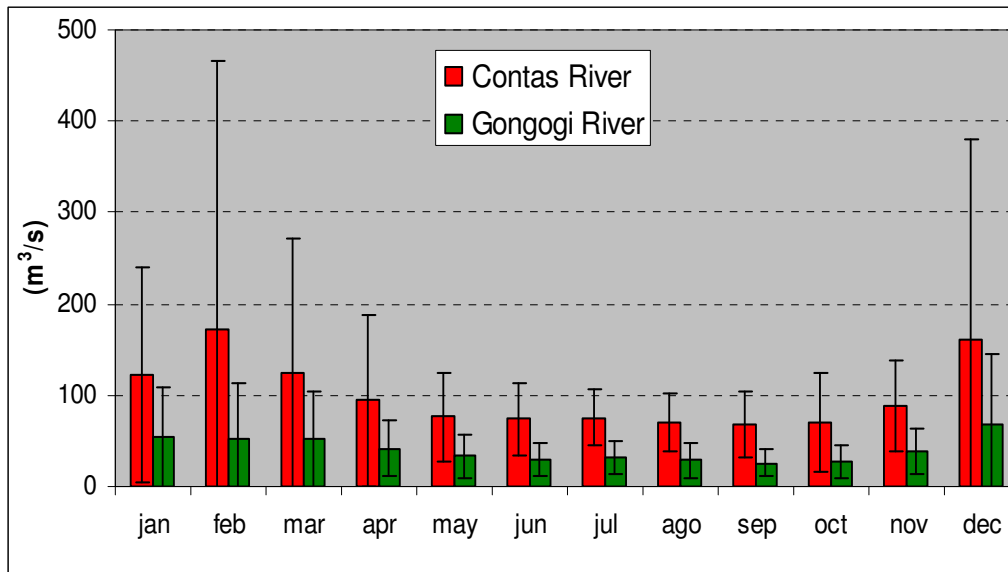


Figure 2: Monthly average discharge, from 1970 to 2002, of the Contas and Gongogi Rivers, based on ANA (2007).

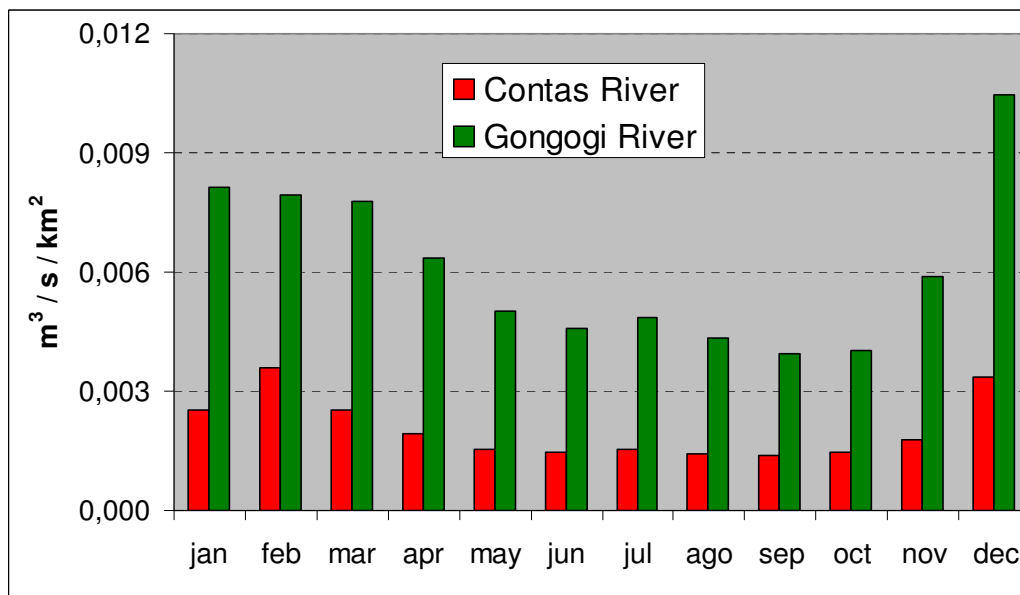


Figure 3: Monthly average specific discharge (m³/s/km²) of Contas and Gongogi Rivers from 1970 to 2002, based on ANA (2007).

In spite of the large basin area, 50% or more of the discharge to the Atlantic Ocean originates in the lower basin, here defined from the Funil hydroelectric power plant dam, the last significant topographic disruption at the river course. This area, representing about 15% of the total basin, presents a runoff three to four times greater than the Contas River as a whole. Only the Gongogi River sub-basin (6.600 km²), the biggest at the lower basin, yields an annual discharge of 460 m³.yr⁻¹, representing 30 to 40% of the monthly average of the total discharge (Figure 2). Thus, specific discharge is three-fold higher at the lower basin compared to the entire basin (Figure 3).

The geology at the lower basin is basically formed by granulites, intensely deformed pre-Cambrian rocks of acidic composition. The climate is tropical (Af on the Köppen system), with annual precipitation ranging from 1,200 inland up to 2,400 mm near the ocean, the wettest portion of the Contas River watershed (Figure 4). This favored the presence of an exuberant vegetation cover of tropical rain forest, a dense mat of streams and rivers, with low electrolytes concentration and TSS, 110 μS/cm and 5.0 mg.L⁻¹ respectively, measured at Taboquinhas during a low discharge period (PAULA *et al*, 2007).

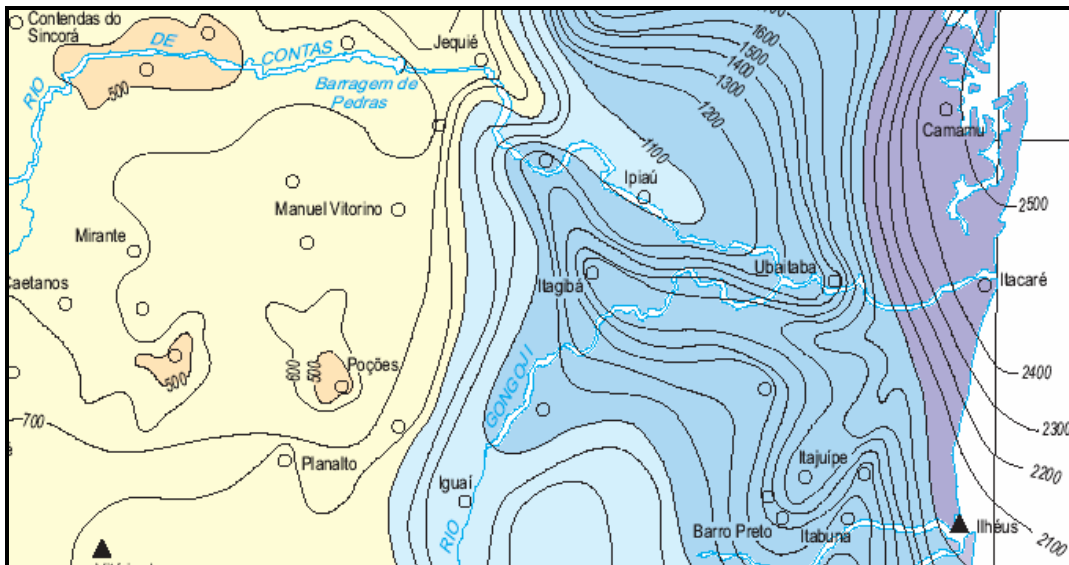


Figure 4: Annual precipitation values (mm) at the medium and low basin of Contas River, modified from SEI (2008b).

Although mining, irrigation, cattle and, to a lesser extent, urbanization, can be found over the entire watershed, at the lower basin the principal land use is cocoa crops, under the canopy of the rain forest, and cattle. Hence, these activities, coupled with damming, will be the major drivers of pressure to the estuarine and adjacent coastal areas.

Major drivers and pressures

Cocoa farms: Cultivation of cocoa trees under the shadow of the forest canopy, is a secular tradition of the south region of Bahia State. Since the late 1980's the decline of international cocoa prices, due to an increase of African countries production and local yields decrease from 400,000 tons in early 1980's to 150,000 tons in 2000 (BRIGHT, 2001), resultant of a widespread fungus disease, has imposed a strong economic pressure for a change on land use. Deforestation to pasture creation and palm heart and coffee plantations, were adopted by many farmers and approximately 250,000 ha (BRIGHT, 2001) of the whole region was slashed. However, for the lower basin of the Contas River this figure is much less extreme. Data from the Bahia State Agency of Social and Economic Studies, show less than 5% reduction, from 67,000 ha in 1990 to 65,000 ha in 2005, with different trends among the municipalities (Figure 5).

Even so minimal deforestation resulted in significant sediment load to water courses. Using the soil loss rate of 0.48 t/ha, for slopes <9%, obtained in a experiment of pasture land cover conducted at the Bahia cocoa district (INÁCIO *et al*, 2007), the final result is $2.4 \cdot 10^6$ tons from 1990 to 2005 for the lower Contas River watershed.

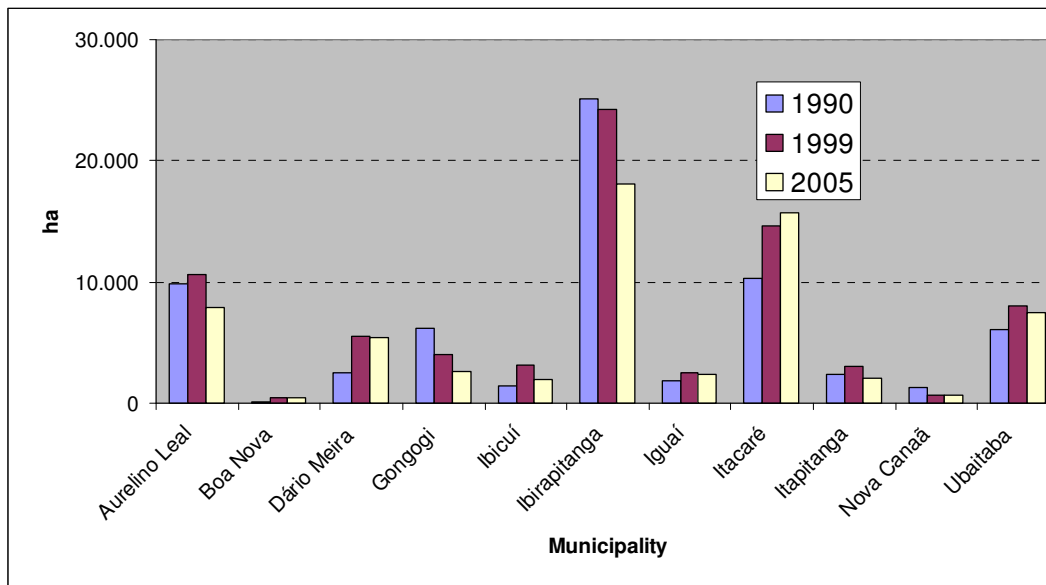


Figure 5: Cocoa crops area (ha) at the municipalities of low basin of Contas River (SEI, 2008c).

This is believed to be responsible for an observed siltation of water bodies and the estuarine portion of the basin, coupled by the reduction of

the flux pulses capacity, derived by the dam construction upriver (CAMPOS, 2001).

The hydrological behavior of the system is deeply altered when the forest cover is removed and infiltration and hence aquifer recharge is minimized. At the same time, superficial runoff is enhanced. The net result is an increase of both floods and droughts, which brings deleterious consequences to biological communities and to the human safety and activities as a general.

Deforestation also brings changes in the structure and biogeochemistry of the soil. Silva *et al.* (2007) working at Bahia State, found a sharp decrease in soil nutrients content from a sequence forest-pasture, with 59% less K and Mg, 65% less Ca and 73% of organic matter, as well as P reduction in pasture soils. These substances became available to be leached to streams, increasing nutrient loads and triggering, or at least collaborating to, the eutrophication of the receiving water bodies.

Regular management of cocoa crops includes the use of cupric oxide, which was more intense during the beginning of the fungi disease, although nowadays not all farm owners have economic conditions to follow this procedure, diminishing, at least temporarily, the Cu contamination of water courses. Recommended application of copper fungicides (50% formulation), is 3.0 g/plant, three to four times per year (OLIVEIRA & LUZ, 2005) with an average of 700 plants.ha⁻¹, the final Cu load range from 210 to 280 tons per year, as from 1990 when planted area reached 67,000 ha, and economical debts were not so high. This figure has been reduced from that time, but still the principle of *geochemical time bomb* (STIGLIANI *et al.*, 1991), could be applied. That practice was used during many years, even before the fungus disease, and many researches on that subject reported an increase in soil Cu content (LIMA, 1994; AKINNIFESI *et al.*, 2006). Considering the above cited soil loss figures, it is much probable that the extra load derived to the estuarine region of the Contas watershed is a significant source of Cu to the local biological communities and eventually to humans.

Cattle: Implementation of husbandry starts in 1920 extending to the fifties, with deforestation of original plant cover to establish artificial pastures. Cattle are concentrated at the Gongogi sub-basin, at the area where usually the cocoa crops do not present high productions. The activity is also the mostly common found at the recent deforested areas. The creation system is extensive, with low income and management practices, usually restricted to "slash and burning". Also the increase of TSS is the most important feature of that land use, but also results in an increase of nutrients load to the rivers (PAULA & LACERDA, 2008).

Urbanization: The region does not present noteworthy urban development, and about 191,000 inhabitants are distributed among 11 small cities, with variable urban concentration (Table 1). Although presenting low industrial and urban development, the municipalities at the studied area could be responsible for noticeable, compared to natural sources, emission factors of metals to the receiving water bodies, since the wastes are not treated before reaching the water courses. A preliminary study carried on at the lower Contas River, reveals that for Pb, Cd and Hg urban runoff, plus solid wastes disposal and wastewaters are their most important anthropogenic source to the local environment (PAULA & LACERDA, 2008). The fate of these substances for the region's estuarine and coastal waters are not well addressed, but have the potential to modify biological communities distribution and also to contaminate food webs and fishery resources.

Table 1: Inhabitants at municipalities of low basin of Contas River in 2007 and percent urbanization for 2000 (IBGE, 2008).

	Total 2007	Total 2000	Rural 2000	% Urbanization
Aurelino Leal	14.458	16.978	13.778	19
Boa Nova	16.007	20.593	4.588	78
Dário Meira	12.565	15.228	4.932	68
Gongogi	6.845	10.453	6.258	40
Ibicuí	15.777	15.116	10.443	31
Ibirapitanga	23.197	13.416	3.660	73
Iguaí	27.849	25.109	12.546	50
Itacaré	24.720	18.105	7.942	56
Itapitanga	10.106	10.373	7.077	32
Nova Canaã	18.829	15.367	5.974	61
Ubaitaba	20.478	23.861	18.580	22
TOTAL	190.831	184.599	95.778	48

Damming: Dam construction modifies the flux of water and sediments (CHARLES *et al.*, 2003) and associated substances (HUMBORG, *et al.*, 2000), downstream to the estuarine region. The Funil hydroelectric power plant operates since 1970, and the analysis of maximum discharge values at the fluviometric station downstream the plant (CAMPOS, 2001) showed a remarkable reduction after construction (Figure 6). Besides, the sediment trapping is very intense and nowadays nearly one third of the original depth at the dam wall is filled with trapped sediments, controlled by continuous dredging.

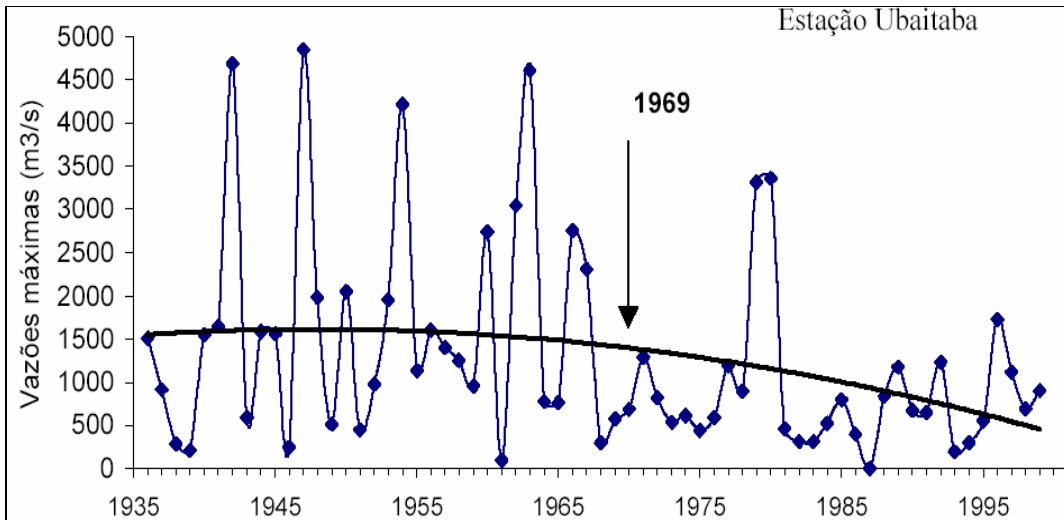


Figure 6: Maximum discharges at Ubaitaba fluvimetric station (CAMPOS 2001).

Figure 7 is a recent photograph of the Funil power plant, where one can see the dredge, in blue, but also the dense mat of macrophytes, due to the extreme eutrophication of the reservoir.



Figure 7: Photograph of the Funil Reservoir showing dredging operations and the intense growth of floating macrophytes.

Both reduced water and sediments supply, have promote changes at the estuarine dynamics, with reduction of substances from continental origin and increase supply of marine sand at the river mouth and also to the lower estuary (CAMPOS, 2001).

Table 2: Summary of Drivers, Pressures and Environmental Impacts at the Contas River Estuary, Bahia State, Northeastern Brazil. State change dimension: major, medium, minor, no impact or ? (Insufficient information).

Time scale: p = progressive, d = direct (spontaneous)

Driver	Pressures	State changes (qualitative index)	Impact on the coastal system	Time scale
Damming	Sediment trapping Altering nutrient balance Altering water balance Decrease of low transport capacity Increase tidal forces Increase erosion processes at river mouth.	Major	Reduction of fluvial sediment and nutrient loads Erosion at the river mouth Changes in biological communities due changes in nutrient availabilities. Siltation at the estuarine zone Water fluxes dependent on climate variability	d/p
Deforestation	Soil erosion Hydrological changes	Major	Altering sediment balance Siltation at the estuarine zone Increase of floods and droughts Increase nutrient and agrochemical loads	p
Agriculture	Soil erosion Pollutants emission	Medium	Eutrofication Enrichment of xenobiotics Changes in food webs and biological communities Possible contamination of fishery resources	p
Urbanization	Pollutants emission Altering nutrient fluxes Widespread of water related diseases	Medium	Eutrofication Enrichment of xenobiotics Changes in food webs and biological communities Possible contamination of fishery resources Epidemics to local population	p

Current changes and impacts

From the described scenarios damming, deforestation and urbanization should be considered the principal changes that induces impacts on the estuarine portion of the Contas River watershed. These impacts could be described as siltation, eutrophication and pollution at water bodies and related coastal waters. The biological community probably is already submitted to shifting from natural background functioning of the ecosystems due to food webs alterations. Economic activities, mostly fishery, are also probably starting to present a decline in production and hence bring a challenger to be overcome by local population.

Anticipated changes

The expected global rise of sea level can increase the residence time of estuarine waters and the development of larger sinks to sediments and associated contaminants in the estuary that will in turn intensify deleterious conditions to the local biota. Simultaneously, coastal water productivity, which relies mostly on the fluvial material export to the sea will probably suffer from the load reduction and also from the presence of metals and xenobiotics from land.

Eutrophication of estuarine waters can reach high levels, if the sanitation, sewage and garbage treatment, are not urgently addressed by the government.

For the local inhabitants and economic activities, one could expect a reduction of fishery resources and increasing level of toxic substances (e.g. Cu) in fish and shellfish. Also an increase in water related diseases and floods and droughts occurrence could be expected. This scenario for the human dimension will be determinant for the tourism exploration in the area, which starts to develop from 2000, being one of the major sources of revenue for the local population.

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