Sediments and Suspended Solids in the Amazon River Basin

Christian Porreca

Richard Stockton University

March 14, 2017

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The Amazon River is the major waterway flowing in South America. Starting in the Andean mountains on the eastern shore of South America, the Amazon picks up water from five countries, including Peru, Brazil, Venezuela, Ecuador, and Bolivia. It stretches 6,400 km, or 4,000 miles, and has over 200 tributaries. The height of the Andes Mountains and flow of the westerlies allows for a natural ringing of water from the atmosphere, effectively keeping most of the water in the basin of the Amazon. As well, the Andes Mountains rose in the past, which has caused the Amazon River to run east. At first the river ran west, but as the Andes Mountains in the west rose, the river has started to flow back towards the east.

Along with all of its tributaries, the Amazon is the second longest river in the world, behind the Nile. At any given time, however, there is more water flowing through the Amazon than there is in any other river at any given time, making it the largest river in the world. The width is what makes it such a massive river, as there is an average discharge of water at the mouth of the river of approximately 175,000 m^3 per second (The Amazon). Sediments discharge at a rate of $1.2*10^9$ in this area as well, 2% of which is bedload, 85-95% is suspended silt and clay, which can travel f. The mouth of the river is located on the northeastern coast of Brazil, and it allows nearly $1/5^{th}$ to $1/6^{th}$ of the total discharge into the oceans of all of the world's rivers combined (The Amazon). This is nearly ten times that of the Mississippi river. The river is located in the Amazon Rainforest, and the rivers basin area covers around 7,000,000 km^2. During the rainy season, approximately 135,000 square miles of land is submerged, however, in the dry season, only 42,000 square miles of land is submerged by the river. Also, during the rainy season, the river can be 31 miles across, while during the dry season the river may only be 6.8 miles across. This shows the drastic changes that can be seen on a seasonal basis in the Amazon River basin, as well as just how powerful the river really is. On the Rio Negro, you

could be looking at the river from one bank and the other bank could be 19 km away, while the river bed is 300 feet deep!

The Amazon River basin acts as a water vapor sink. Water in the atmosphere is collected in clouds, and eventually condenses, causing it to rain. The rain is then dropped down onto the river basin, and during the day, the water is heat back up and turned into vapor again. This vapor is being collected constantly, as water is trapped in the forest and heat up directly from the trees, or it is evaporated off the ground, or the surface of the water. The water evaporated goes back up into the clouds to be precipitated again. Approximately 1/3rd of the water that comes down as rain is discharged into the ocean (The Amazon). Most of the water is caught up in the forest and re-evaporated before it makes it into the ground. On average, the water cycle in the Amazon drops 75 inches of water annually. This clearly allows for a high biodiversity of trees and other plant life. There are around 40,000 plant species in the Amazon basin. The geographic isolation here, as well as constant disturbances, has allowed for one of the most biodiverse areas in the world. Such a diverse area in terms of plant matter, has allowed for the water in the amazon to eventually flow with nutrients contained in those plants.

The amazon is the black-water capital of the world. Black-water rivers are known by the name because of their darker color, and low visibility. Black-water Rivers derive entirely from soils of lowland forests, which are rich in leaves and other decaying organic matter. They collect tannins, and acidity from nutrient rich soils and become colored by the plant materials in the same way you would brew a tea. There is a low pH associated with them. Because of the tannins, and acidity, black-water Rivers generally have less bugs, including mosquitoes and flies, as well as other organisms thriving off of the river. The Rio Negro is a black-water river. When these rivers flow over land, they actually deposit nutrients into the soil, and act that way mostly

during the rainy season, when the most amount of ground is covered. Black-water rivers are surrounded by black-water forests, which have a low tree species diversity. This is because of the acidity in the water. Less tree species in these forests mean that there are less bugs, like forest dwelling mosquitoes, that can live here, but it also allows means that tree species are at a greater risk of being found and cut down since there are so many of the same species. Deforestation here may cause underlying sediments to be exposed, and during flood seasons, eventually washed away completely.

The Amazon also has White-water Rivers. White-water rivers contain heavy sediments washed in from the Rainforest Rivers in the mountains and generally are faster flowing than black-water rivers. Tributaries that flow with heavy storm water has slowly eroded through the forest floor, allowing underlying sediments to slowly make their way into the water-ways. Sediment loads in tributaries cause the rivers to run with a slightly neutral pH. White-water tropical rivers are generally in the form of large rivers in lowland tropical forests (Butler). Tropical rainforests generally have flat or little elevation, causing the large rivers to flow slowly through the area. In the area of the Amazon, near the Peruvian river port of Iquitos, the river descends at a rate of only 1.8 inches per mile (Butler). This area is nearly 2,300 miles from the mouth of the Amazon River in the Atlantic Ocean (Butler). This shows just how much water is being dropped in the Amazon River basin, and just how much eroding power the rain waters will have, as there is nowhere for the water to go but into large, cutting channels.

The mouth of the Amazon River empties into the Atlantic Ocean, taking with it sediments for deposition. The width is what makes it such a massive river, as there is an average discharge of water at the mouth of the river of approximately 175,000 m^3 per second (The Amazon). Sediments discharge at a rate of $1.2*10^9$ in this area as well, 2% of which is bedload,

and 85-95% is suspended silt and clay. As a result of such depositions, the continental shelf off the eastern coast of Brazil has collected a sediment cone about 680 km long and with a width of 11,000 meters (The Amazon). These sediments are mostly being carried downriver from the Andes Mountains, which contains large amounts of sedimentary rock, the Guiana shield in the North, and the Brazilian Shield in the south (The Amazon). This flow of water eventually makes it to the Solimoes region, where most sediments are put into the Amazon River. Where the Solimoes river reaches the Rio Negro, is where most sediment loads are put into the Amazon River. Sedimentation is the process of settling or being deposited as a sediment. The deposition of these sediments can be due to gravity, centrifugal acceleration, where the sediment is acted on by centrifugal force, or electromagnetism, where electricity and magnetism act together as one phenomenon of attraction of molecules or particles. Heavy flows of water suspend such solids until they are dislodged further down the river and eventually form huge sand banks. The water carries any remaining sediments to the mouth of the bay.

This is where sediments are dislodged from the flow of water as the water slows down when it enters the ocean, allowing these particles to fall out of solution, with the smaller sediments traveling farther out into the ocean, and the large sediments dropping quickly after the water reaches the ocean.

The sedimentation coefficient characterizes a particles behavior in sedimentation processes, and is the ratio of a particles sedimentation velocity to the acceleration that is applied to it. Big particles generally have a larger sedimentation coefficient and drop faster, and larger sized particles are usually dislodged in areas of construction, as leaching of the river-bed would generate turbidity characterized by mostly clays. This may be detrimental in areas where large particles have an effect on the community structure, forest ecology, and water source as a valuable commodity. Particles in the water are making it into forests and other new and different ecosystems, and we do not know the effects this will have yet.

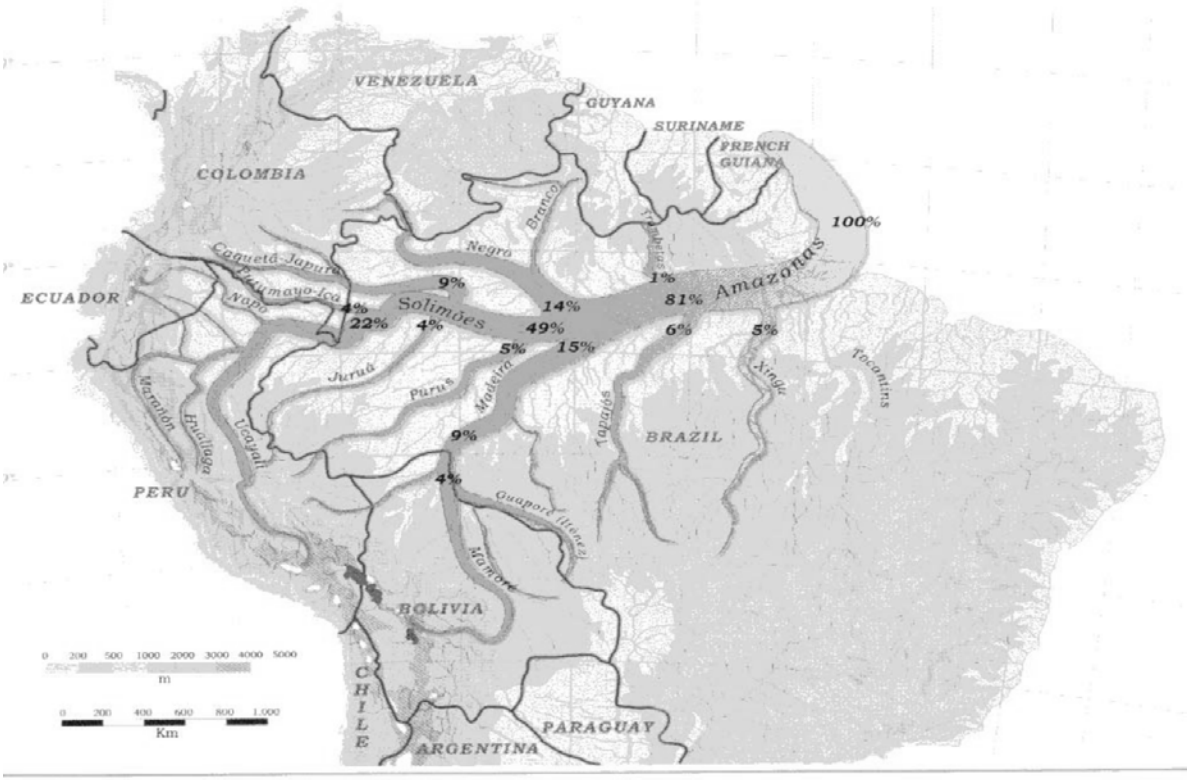
In a study done in New Zealand on the effects of sediment in streams, it was determined that the sediments could have varied effects on the ecosystem and the streams aesthetic value (Paddy). Streams have differing capacities to deal with sediments depending on fauna, gradient, and the nature of the stream. Aesthetic standards could outweigh ecological effects in many instances, as proposed by the study (Paddy). It was determined that low turbidity levels could decrease primary productivity by 3-13%. Turbidity is the cloudiness or haziness of a fluid that is caused by large numbers of individual particles that are generally invisible to the naked eye (Karsh). It is a good test of water quality, and can be compared to smoke in the air, or particles in the air. In lakes, rivers, and reservoirs, turbidity can have an effect on light reaching lower depths, which effects plant growth and primary productivity. It can also kill fish easily in slow moving water or non-moving water. The fish can get sediment trapped in their gills depending

on the type of species. In streams and large bodies of flowing water that are in rain prone areas, turbidity can be greatly affected by human activities (Karsh). Sedimentation increases have been seen due to construction in urban areas with high runoff, which carries high pollutant levels and sediment. Mining and agriculture also provide sediments and chemicals to the water, as mining is another form of land reclamation which releases sediments and also contributes high loads of chemicals. Agriculture uses slash and burn tactics to degrade the forest and expose underlying sediments across large areas. In the Amazon basin, where heavy rains and high storm runoff go over exposed land for agriculture, underlying sediments and any fertilizers used in farming processes are washed with the runoff water and make it into streams and eventually main channels. Drinking water is greatly affected by high turbidity, as the risk for gastro-intestinal diseases has been shown to increase in these areas. Viruses and bacteria cling to sediments and suspended solids in the water and eventually make it into source water reservoirs. High turbidity areas are also seen to have higher sedimentation rates in areas where there is more land reclamation. The top five hazards to biodiversity in Brazil, according to (Karsh), are agriculture, deforestation and logging, mining, ranching and grazing, and urbanization and development.

In the article about sedimentation in New Zealand, it was shown that in most places where there is heavy silt deposition, there is a change in community structure rather than a total loss of fauna. The sediments are deposited on a major food supply, epiphytes, which interferes with the feeding of benthos organisms (Paddy). Sediments deposited in areas where there is high microbial life is bad for the organisms that feed on these organisms. Aggregates of rock, or bottom gravel, is filled in by these sediments, and completely changes the community structure (Paddy). According to Ryder (1989) from the paper (Paddy A.), “reduced invertebrate abundance in response to fine sediment deposition can be explained by the actual reduction of

interstitial space". Suspended solids can impact fish, also, by decreasing the amount of species of fish that can live in the environment. Loss of fish species was seen in studies regarding suspended solids and species of fish. Species that are more sensitive to clogging of their gills will die in areas where the turbidity level exceeds their ability to filter such solids. The ability of turbidity to damage fresh-water ecosystems and their aesthetic value will have an effect on humans.

The Guiana shield is the name for the area in the north-eastern region of Brazil, where the average elevation of land is around 270 meters to 2000 meters where sheer cliffs have been eroded (Lujan). This area contains 7,000 meters of sediments beneath the surface. Tributaries to the Amazon here also carry an estimated average of 2,792 km^2 of water per year, or a fourth of South America's total volume of freshwater exported to the oceans (Lujan). This movement of water has created the topography of the area today, but also causes the flow of sediments, as the area sees a lot of rain. Tributaries to the Amazon River that are located in the Guiana shield form on the west to south-west slope of the Kanuku Mountains, and at an elevation of 400 – 1,000 meters (Hammond). The three largest systems in the Guiana shield are the Rio Negro, the Rio Orinoco, and the Rio Essequibo. The Rio Orinoco is a black-water river that derives from the Andes in Venezuela, and the Guiana shield. It is a thin, snaking river that provides mainly fresh water to the Atlantic Ocean. The Orinoco is also a deposition area for sediments washed from the Andes and the Caribbean Coastal ranges. The Rio Negro, also a black-water river, is the shields largest self-contained drainage area, with the drainage region surrounding the main-stem of the river having an area of 720,000 km^2 (Hammond).



The Rio Negro runs as a black-water river, until it mixes with the Solimoes river in the state of Amazonia. Here is where the confluence of the Iquitos river, which met with other tributaries to form the Solimoes River, lies. The Iquitos river comes from high in the Andes mountains and though it is hundreds of miles from the ocean, it has a river bed that is below sea level (The Amazon). The Iquitos River flows with pollution from the city Iquitos, which uses lead in gasoline refining, and does not have good trash cleanup. The Madeira drainage basin is another basin that provides a lot of sediments to the Amazon River. Dam projects are littered throughout the rivers located in the Madeira drainage basin. The effects of dams are being looked at today, as there are ecological and economic problems associated with them.

Dams in the Amazon are a problem when it comes to environmental hazards. Though they are a good means of generating electricity, hydro-electric dams have an environmental, and even an economic cost. They impact fisheries, as they dissolve oxygen, nutrients, and suspended

solids into the water. They also alter the temperature of the water. When a river runs down a mountain, or comes from a low to middle area of the water column to be impeded by a dam, the water stagnates and eventually heats up. This can have grave implications on fish, nutrients, and other organisms in the water. Increases in mercury are also the result of dams, as flooding of plants causes the decay of a material in the plants, which turns to a methylated form of mercury that is biomagnified and harmful. This is harmful to fish in many ways. The release of green-house gases happens as a result of dams, when flooding of forested areas and peatlands releases CO_2 and NH_4 into the water. Wetlands are sinks for CO_2 so if they are flooded by water, they are not useful in the aspect of collecting carbon from the atmosphere. Forests are sinks for these green-house gases, and tend to remain at equilibrium if undisturbed, but when they are flooded, they become strong net sources of green-house gases. Flooding caused by dams will also increase the suspended solid load, as the reservoir picks up particles that would otherwise be untouched by the water mass. Dams have negative implications on the environment around them, though they can generate electricity to power the lives of many people.

Keeping the fresh-water source of the Amazon clean and usable is a major task to tackle. The inability to see the current status of this natural resource as hazardous has put many lives at risk as well as killed almost half of the rivers fish species and changed the ecosystem for future fauna. One way to keep regulations here and ensure that they are implemented is through the use of limnology. Limnology is a modern, multi-disciplinary science that integrates the basic technologies of biology, chemistry, physics, and geology in order to study inland waters as complex ecosystems. The idea is that through limnology, you will get to understand the full range of human impacts on aquatic ecosystems, and devise cost effective means of ensuring freshwater ecosystems for generations to come (MacDonald). Limnologists determine ways to

optimize preservation of inland waters. Watershed management is implemented to maintain and improve the quality of surface water. Changes in quality of the water have been caused by land use changes, which alter the yields of chemical constituents and sediments to water bodies. Devising science based watershed plans is important. Wetland preservation looks at losses of wetlands that have occurred and developing policy to prevent further wetland loss. Wetlands provide habitat for important species, flood reduction, and filter of runoff before it enters lakes and rivers. Control of cultural eutrophication is important in areas of the Amazon basin where water is moving much slower. Eutrophication is the depletion of oxygen by excess nutrients in the water, like phosphorous. These nutrients come from all types of sources, but are mainly fertilizers found in agricultural practices in the Amazon River basin. The algal growths caused by these nutrients will cause problems if the water that it is occurring in is a source water (Baret). Maintaining that eutrophication is bad, it would be good to know that practices are being put into place to clean these waters up for drinking, as well as making them healthy and full of oxygen again so that many fish species will not die. Reservoir management will monitor the effects of dams (Baret). This is very important since Brazil is deciding that it would be very effective to use hydro-electric dams for power generation. This has caused minor setbacks in that the environmental effects were not fully realized. Checking the status of waters in dam reservoirs will put into perspective the effects that the dams have on the ecosystem and mainly the water found in the area. Evaluation of toxic pollutants will look at the anthropogenic effects on water quality, as well as assessment of damage from acid and air-born pollutants. Control of exotic species and prevention of species extinction will also be important. With the changing community structure in many rivers, exotic species will begin to make new homes. Maintaining the natural ecosystem will become that much more important, as species that cannot survive in

the new environment and with these new exotic neighbors will likely die off, changing the community structure even more.

Changing the construct of the Amazon River through erosion of underlying sediments is something that will have a resounding impact on the aesthetic value of water, as well as the organisms that live in the waters. Storm runoff in higher reaches of the basin collect sediments exposed by different land uses, be it mining, agriculture, urbanization, or other types of construction. This erosion takes nutrients out of the ground and physically makes land surfaces less sturdy. These sediments are also transported and deposited in different areas of the rivers. The deposition changes the volume of water bodies and actually fills in the underlying river bed. If a river bed is full of larger rock particles that give habitat to organisms, those spaces will eventually be filled in, and anything living off of that bedrock ecosystem, be it algae's, crustaceans, or fish, will be negatively affected. The sediments can range in size, and the smallest particles may contain viruses or bacteria, as well as pollutants and other chemicals. This makes sources of water that have a higher turbidity level than is accepted, to not be applicable for source water. If water that has high turbidity is used as source water, mainly drinking water, then humans will encounter problems. Gastro-intestinal diseases are found in areas where the turbidity of water is exceeding its allowed limit. Sediments flowing into these streams are only being found in higher concentrations due to land use changes, and that will greatly impact the future of these fresh-water resources to be used by humans, and will certainly have a negative effect on the ecosystems and organisms that utilize these fresh-waters.

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