Soil is one of the most indispensable resources that we can find on our planet and is often overlooked and taken for granted. Soil is a fundamental resource that distributes major elements that are essential to all forms of life. Everything that lives in the biosphere requires elements from the earth’s crust; soil transports them through plants. The countries in which the Amazon rainforest resides have seen higher rates of erosion in recent years due to agriculture, mining, and forest fires. The agriculture in the Amazon has been rising over the years improving the economy of the country but devastating the environment. The agriculture industry in Brazil occupies about 25% of all its land mass and is growing every day. Artisanal and small-scale mining (AGSM) companies are also a major contributor to the environmental destruction of the Amazon rainforest. Before these companies can drill out the cores that contain gold, they must first clear-cut vast tracts of the tropical forest and are responsible for major deforestation that is having extreme effects on the soil. AGSM companies also add toxic mercury levels in the environment, poisoning the land. Another factor in deforestation has been linked directly to the amount of forest fires in the Amazon. Accidental forest fires are an increasing problem; the forest no longer is as humid as it used to be due to deforestation. Human activities such as secondary vegetation slash-and-burn and the use of fire to clear out pastures is spreading to the neighboring native landscape which in turn has become degraded and more prone to burning. In an act to help restore and conserve the tropical forest the United Nations has added a major initiative to the climate treaty. The introduction of Reducing Emissions from Deforestation and Degradation (REDD) is the first step the world is taking towards the growing global concern of deforestation not only in the Amazon but across the world.

Even though soil is naturally found in the environment it regenerates at a very slow rate; because of this slow rate soil is classified as a non-renewable resource. Even though soil is only a very small fraction of the natural material that is found on earth, it is still essential to life. If there is not enough healthy soil, the environment will degrade. Plants are the first step in how any animal including humans get the proper nutrients for survival. If the soil quality is low, vegetation is not able to absorb the nutrients that it requires to grow. This results in loss of the natural resources that plants rely on for energy. Soil depletion is an issue that if not stopped can cause destruction to vegetation leaving humans with no place to grow crops, no food for farmed animals to graze, and
will create an end to the logging industry. Without these necessary resource’s humanity will be unable to survive.

Composition of soil

Soil is on average composed of four different main components: air (25%), water (25%), organic material (5%), and mineral material (45%) (Fedrick K. Lutgens, 2016). Material that has been eroded away is the source that develops into soil and is called the parent material. There are two main types of parent material. It can be the underlying bedrock, or a layer of unconsolidated deposits like sand or silt. If soil is formed from the bedrock it is classified as residual soil, and if formed from unconsolidated sediment its classified as transported soil.

Scientists create soil profiles that consist of the soil composition, texture, structure, and color. These characteristics are found as we go into the earth and look at the soil from a side view. After a long period of time, five sections of soil are formed called horizons, see Figure 1 for details. From the surface downward, they are designated as O, A, E, B, and C (‘Essentials of Geology’, 13th Edition-Pearson (2016) page 173). The O horizon is composed of largely composted material and plant material, and also serves as the habitat of many different forms of microscopic life. The second horizon is the A horizon, composed of mainly mineral matter. The combination of these two zones construct what is known as topsoil. Moving down a layer we find the E horizon; this does not contain much organic material and usually light-colored. The process of eluviation takes place in this horizon wherein water moves through the layer, dissolving inorganic soil components (this process of dissolving material is called leaching). Then as the water flows it takes the components with it into the deeper soil zones. The B horizon or the subsoil is the location where all the decompose material from E horizon accumulates and enhances the water retention of the soil. The last layer, the C horizon, is usually in the form of bedrock and is the parent material for the soil sample. It is important to remember not all soil samples will have all five of the horizons because a soil profile is related to the ecosystem around it making it differ between locations.
Oxisol is the primary type of soil that can be found throughout the floor of the Amazon rainforest. This type of soil is high in oxides including aluminum oxides and hydroxides; it also contains a high concentration of iron. The color is always red or yellowish. Residing in moist climates oxisol soil forms as stated in ‘Oxisols, S.W. Buol, H. Eswaran, April 28, 2008’ from the weathering of situ rock or other basic rock, but mainly come from the polycyclic sediments that have undergone weathering prior to deposition. The growth of new vegetation in the Amazon is not easy with the presence of the oxisols because of the low bulk density, high permeability, friable consistence, and the low water holding capacity. Farmers in the Amazon have had difficulties due to these soil characteristics. The low bulk density and low rates of water retention are the main issues for the farming industry. Without the soil able to keep packed together or hold in moisture, there is a weak foundation for vegetation to grow.
Soil erosion

The life cycle of soil always ends with the natural process of soil erosion. Renewing material in the environment is a constant process that allows the circle of life to continue. Soil erosion is one of the major factors in the recycling process of material found in different ecosystems. Once that parent rock is broken down into soil the two main erosional forces are wind and water. As rain falls and wind blows soil particles become dislodged and carried away. In past years soil erosion was not a problem and nature maintained the balance between soil creation and erosion. Human activity is fueling soil erosion rates; as a result erosion rates are becoming dangerously high in many areas. When more of the surface of the earth was protected by vegetation, erosion rates were lower and nature was able to balance the forces that cause spiked erosion rates. Human activity is not something the earth is able to counter; recent human activity increases soil erosion to a level that has caused global concerns. Humans cause problems such as “decreased soil fertility, increased landslide activity, reservoir sedimentation, contaminant diffusion, rocky desertification, and ecosystem disturbances, all of which significantly impact human development” (Chengguang, et. al.). Rates of soil erosion reach a point that is considered harmful when the environment is unable to keep up with the new demand for soil. We can see these impacts happening throughout the different habitats all over the world, especially the Amazon basin. The Amazon’s balance has been disrupted for many years and is perhaps beyond the point of no return.

Soil erosion in the Amazon

The countries in which the Amazon rainforest resides (Brazil, Bolivia, Peru, Ecuador, Columbia, Venezuela, Guyana, Suriname and French Guiana) have seen higher rates of erosion in recent years. “The rate of water erosion in Brazil has been estimated to be between 600 and 800 million hectares yr⁻¹.” (The Expansion of Brazilian agriculture: Soil erosion scenarios) As Brazil and other countries are beginning to adopt Westernization in their agricultural processes, the rates of soil erosion are going up as the demand for the land is increasing. The country is exporting goods which supports the economy but this is having negative consequences on the forest floor.
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Soil erosion is a way that scientists can look at the damages that humans are doing on the environment. The erosion rate through the forest is linked with disturbances human activity have created. We can study the differences between the erosion rates of areas that have been disturbed and ones that have been left alone. The areas that have had no outside environmental input show signs of erosion but in the long term we can see the effects are balanced by soil production. Tree roots and the top layer of nutrient rich soil has the ability to withstand natural soil erosion rates. When the areas that humans have inhabited are studied, it is shown throughout the forest the rates of net soil erosion are drastically higher than untouched land. The addition of humans into the natural ecosystem leads to irreversible and destructive soil erosion. This might turn into good thing when it comes to the saving and preservation of the rainforest. “Here we address the role of soil erosion in a positive feedback mechanism that may persistently alter the functioning of disturbed tropical forests.” (Flores). Soil erosion and the erosion channels that have been created can be positive for the rainforest by creating paths for water to pass through the ground without harming any more of the landscape.

Agriculture and soil erosion.

The agriculture in the Amazon has been rising over the years, improving the economy of the country at the cost of the environment. The agriculture industry in Brazil, for example, occupies about 25% of all its land mass and is growing every day. We are seeing that the soil used to grow crops and graze animals is being eroded due to the effects farming has on the environment. Cattle and other animals that graze degrade the soil until it is almost rendered useless. These parts of the land cannot hold the soil together and cannot stop erosion from happening. We can see that in old and new pastures the soil has created erosion channels that carry the soil away to rivers and streams. These erosion channels are harming more than areas that it is going on it. See Figure 3 for an example of erosion channels in agricultural land.
The channels create a major concern downstream due to the runoff of the animals remains and waste. The chemicals farmers use on their crops now have a newly formed highway to pristine water ways. This makes the levels of natural elements that were once in the soil to rise in waterways and puts harmful chemicals into the water that will affect all types of life. Fertilizer will cause eutrophication, toxins will end up in drinking supply for animals. This can cause animals and plants to become sick and even die if the chemicals and element levels in the water get too high.

The demand for the different countries to produce more and more resources cause the farmers to grab more space grow more crops and have enough land for pastures to hold the animals; this land is not available not unless we continue to invade into the native vegetation. This is forcing the farmers to find different ways for their animals to graze. One way is by having them graze in the forest instead of pastures and use the already nutrient depleted land to grow crops. Moving domesticated animals into the wild with the knowledge of what already happens in the pastures to the soil will cause more effects throughout more ecosystems in the tropical forest as well. As the
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animal’s graze and travel throughout the rainforest, they alter the way the soil reacts to the environment. Nature is able to adapt and react to many challenges and put itself back to equilibrium but when humans add different species to the habitats the ecosystem nature is unable to save itself. Instead, we are seeing that the addition of the animals is spiking the rate of soil erosion and soil compaction that will lead to irreversible affects if humans do not act now. Organic material in the areas that farm animals have been introduced have been decreasing. In one study (Antoneli, V, et. al.) the places in the forest in which native animals’ fed from has a high organic soil content (6.3 g k⁻¹) and a bulk density of only (1.29 g cm⁻³). Locations with domesticated farm animals have much lower amount of nutrients in the soil (4.8 g k⁻¹) and a higher bulk density of (1.34 g cm⁻³). Agricultural feeding grounds throughout the forest has been studied and proven to have up to three times the amount of soil loss then areas were only the native species feed.

The expansion of agriculture is on the rise and this means more land must be seized. If farmers are unable to expand their land into the surrounding forest, the farmers will be unable to keep up with demand and lose their livelihoods. The threat of going out of business leads to farmland encroaching on and the destruction of the native land and vegetation. Landowners must be able to see the destruction of the neighboring ecosystems and develop ways where both the industry and the environment will be able to survive. Education is key!

Effects on the rainforest if the farming increases its land grab of the native ecosystem will be drastic and irreversible. This can lead to major global effects if too much of the forest floor continues to be damaged and the soil is no longer able to contain enough elements the results will be a major loss of biodiversity and even entire section of the forest gone forever. Agriculture is not the only way humans have damaged the ecosystem, mining is a major factor in deforestation as well.

ASGM and soil erosion

Artisanal and small-scale mining (ASGM) are companies that are ruining the soil and resources found in the Amazon rainforest. These companies excavate ores out of the ground and rivers and check for gold and other precious materials. Once the ores have been excavated it is then broken
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and examined for gold particles. It then is transported and put into mills where the gold extraction begins. Mercury is added to the broken ore; the mercury binds the gold particles together so they can be retrieved easily. The mixture of the gold and mercury forms amalgam and then is burned to make sure nothing but gold is left. After being burned off the mercury is then left in tailings piles and gets into the ecosystem mainly through soil erosion.

Before these companies are able to drill out the cores that contain gold they must first clear cut many acres of the tropical forest. ASGM companies are responsible for major deforestation that is going on throughout the Amazon and thus is having extreme effects on the soil. When the gold is extracted in one section the mining operations move into another area leaving behind nothing but contaminated soil that is ripe for soil erosion. The results of this clear cutting by the mining companies have been obvious. Without the roots of the trees nothing is stopping the forest floor from eroding away until it is so depleted it becomes useless. “The model estimated that observed decreases in forest cover increased soil mobilization by a factor of two in the Colorado River watershed during the 18 year period and by 4-fold in the Puquiri subwatershed (the area of most concentrated ASGM activity)” (Diringer).

An additional issue is the added mercury levels in the environment. “The ASGM industry emits an estimated annual average of 1,000 metric tons of inorganic mercury, about one-third of which is thought to go into the air while the rest winds up in piles of mining waste ("tailings"), soils, and waterways.” (Diringer). A massive amount of the mercury has been introduced into the environment and two thirds of the material is left absorbed in the soil. Due to the weakened soil and erosion rates going up it is very easy now for the mercury to get into the delicate ecosystems in the Amazon rain forest. If the erosion rates continue to rise and there is no stopping to the clear cutting, we will unfortunately see that the levels of mercury rocket to twenty to twenty-five percent higher than the recorded levels in 2014. The mercury is flowing from the terrestrial landscapes into the aquatic environments that are essential for the heath and future of the rain forest. Volcanic activity in the Amazon leaves the soil with already high levels of mercury and adding more will lead to irreversible effects. The mercury rich tailings piles along with soil erosion causes major effects downstream. This poisonous element is now in every different ecosystem and affects all
animals from the fish swimming in the water, the animals drinking the water, and the plants that rely on these waterways to stay alive.

Deforestation and soil erosion

Deforestation in the Amazon is a growing global concern; the tropical forest is losing millions of acres are each year. “Deforestation already reached almost 20% of the original forest area of the Brazilian Amazon alone”; if these rates stay the same it can alter global climate (Zemp). See Figure 4 to see how evapotranspiration, precipitation, and forest resilience declines with increasing deforestation in various environments.

The rainforest and the climates all around the world rely on the water cycle in the Amazon rain forest, and with the decreased number of trees the water cycle has been disrupted. In the areas that are downwind from places that have been clear cut and altered by humans, “We find rainfall reductions by up to 20%” (Zemp). Without the trees the process of evapotranspiration is reduced because the atmosphere is unable to absorb as much water leaving the surrounding areas will less rain fall. With the rainforest no longer being able to produce the same amount of moisture the forest ecosystem might go from a moist environment into a much drier one.
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Deforestation is the main factor that is influencing the growing rates of erosion in the Amazon rainforest. The climate of the forest is extremely humid and having constant rainfall, already makes the ecosystem extremely prone to soil erosion. Natural has ways to defend ecosystems from the damages events like monsoons can bring. The tree cover acts as a barrier to the soil below protecting it from the elements with the thick vegetation that grows. The roots contain the soil and prevent erosion. The large trees that soil relies on are being removed and this is causing not only harmful effects within the immediate area but across the world. Soil eroding away from the deforested areas leads to soil erosion in other places. The downstream ecosystems are built to withstand the erosion but with such volume of water flowing it is causing increased erosion rates of even untouched parts of the Amazon. As the erosion increases the surrounding vegetation has begun to deplete. The soil is being flushed away due to the spiked erosion rates and depletes the plats of the nutrients their roots would normally be able to absorb. With depleted fertility in the ground the plants are unable to process the nutrients that are required for their survival. The animals that rely on the plants as their source of food are greatly affected. Animals migrate to other areas, and with the added number of animals in that new area, drastic change occurs throughout the entire forest. Not all animals will be able to relocate and entire species will go extinct. Hundreds of plants that are only located in certain locations will become extinct as well. The soil erosion linked to the deforestation thus leads to the loss of biodiversity.

Soil erosion and forest fires

Human actions along with climate change are the factors that have increased the occurrence of forest fires in the Amazon. Over a period of 33 years (1984-2016) the area of the Amazon rainforest that has been destroyed by fires reached 525,130 hectares of land. (Silva). This study was based in the Brazilian state of Acre. Acre recorded most forest fires in the Eastern part of the state where agriculture and settlement projects are at their highest.

Drought in the Amazon is one of the biggest contributors to forest fires throughout the rainforest. In 2015 the Amazon went into drought that caused the largest ever ratio of active fire counts to deforestation. Climate change in the ecosystem of the Amazon rain forest has been the driving
factor for drought; global warming is associated with human fossil fuel burning since the 1800s. Accidental forest fires are increasing because the forest no longer is as humid as it used to be. Human activities such as vegetation slash-and-burn and the use of fire to clear out pastures has spread to the neighboring native landscape which has become degraded and more prone to burning. The drought events that have occurred in 2005, 2010, and 2015 serve as evidence of the shift of precipitation in the tropical forest.

Figure 5: Spatial patterns of water deficit and active fire incidence in the Brazilian Amazon. Pixel-based annual anomalies (σ) of the Maximum Cumulative Water Deficit (MCWD) for 2005 (a), 2010 (b) and 2015 (c) and the histograms showing the pixel counts for each category in the MCWD map for 2005 (d), 2010 (e) and 2015 (f). Similarly, we show maps of active fire anomalies for 2005 (g), 2010 (h) and 2015 (i) and their respective histograms (j), (k), (l). Red and blue bars indicate respectively positive and negative anomalies for fires and the opposite for the MCWD. All units are standard deviation values calculated as the departure of annual values from the 2003–2015 annual averages, excluding drought years (2005, 2010 and 2015) (Aragão).
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Figure 5 demonstrates the active forest fires and the patterns of water deficiency. The depletion of the forest has caused major climate change to the region and is creating drought in areas that would usually remain unharmed from the dry seasons. “by calculating the number of active fires per square kilometre deforested, we found that from 2003 to 2015 an increased number of fires were detected per km² of area deforested” (Aragão). This shows that the areas that humans have modified by deforestation are increasingly burning during the dry seasons in the Amazon. Climate changes in recent years degraded parts of the forest, humidity has been decreasing and the forests become more susceptible to forest fires. Characteristics of human modified forests include greater openings in the forest roof, larger stocks of dead material, drier microclimate, and lower wood density. These are all factors in making the forest more flammable.

To have a sustainable ecosystem in the Amazon nutrient full soil is required. But with forest fires comes the mass depletion of the essential resources that are required for the forest floor to prevent the erosion of the soil. The article ‘Assessment of Post-fire Soil Erosion Risk in Fire-Affected Watersheds Using Remote Sensing and GIS’,2013, found that after a forest fire in tropical forests, such as in the Amazon, the area effected by a forest fire will be 90% prone to elevated rates of soil erosion compared to only 55% before the fire took place. Forest fires in the Amazon have been a result of human’s harmful treatment of the environment, and are having long-lasting effects on the soil health. Without the cover from the vegetation above and no roots left to act as an anchor for the soil, erosion rates will continue to rise unless humans take action. What actions have humans taken to remedy the effects of deforestation?

Reducing Emissions from Deforestation and Degradation

The Amazon rainforest become one of the biggest global environmental concerns. The depletion of the vegetation in the rain forest have been caused by humans altering the climate across the world.

To help restore and conserve our beautiful tropical forests the United Nations has added an important section to the climate treaty in 2008. The introduction of Reducing Emissions from Deforestation and Degradation (REDD) is the first step the world is taking in response to the growing global concern of deforestation globally. REDD is a partnership between the UN Food
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and Agriculture Organization (FAO), the United Nations Development Program (UNDP) and the United Nations Environmental Program (UNEP) that puts into place part of the Paris Agreement and Sustainable Development Agenda.

REDD focus on the restoration, and protection of water shields. See Figure 6 for a diagram of the intervention plan.

Figure 6: Summary of potential ecological cobenefits of the five principle interventions that tropical nations could make to reduce carbon emissions from deforestation and forest degradation. (From Global Change Biology: The potential ecological costs and cobenefits of REDD: a critical review and case study from the Amazon region; 2009)

The authors of this section have based their models on water shields in their best efforts to have the proper output of water, energy, and minerals the ecosystems need to live. The long-term fate of our world’s ecosystem is relying on the world to create change in the forest. REDD has the
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ability to postpone forest dieback due to the input of the water shields and the cessation of soil erosion. Countries that agree to bind themselves to REDD will receive compensation for reducing the depletion of their natural resources from the UN. Due to REDD the globe’s forests will see lowered carbon emissions, more tree plantations, lowered deforestation, slower rate of forest fires, and even the ability to reverse the dying of surrounding native vegetation.

In conclusion soil is one of the most important resources that is found in nature and with the addition of humans the rain forest is losing the foundation of life. Humans affect rainforests through agricultural activities and mining activities. Recently humans have opened their eyes to the damages to the environment and programs such as REDD have been established to “turn back the clock” on the environmental devastation that has occurred. It is up to all of us to make daily decisions to reduce our carbon footprint and make our daily life Green!

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