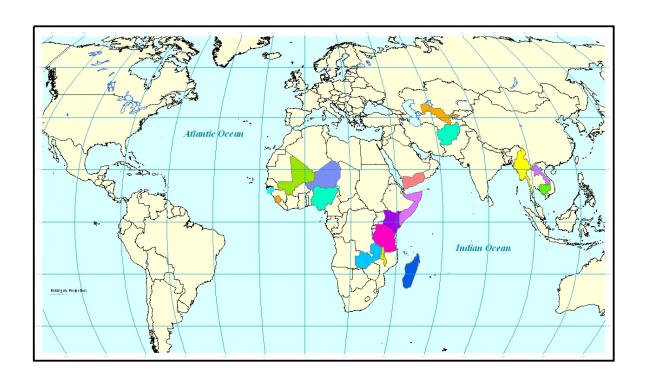
# Sedimentation Initiatives in Developing Countries Draft Report presented to UNESCO-ISI



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### Abstract

The International Sediment Initiative was set up by UNESCO in 2004 to address the sediment issues around the world. This report investigates sediment related issues in the world poorest countries. Although ranking varied from one source to the other, the poorest countries are located in Africa and Asia. The poorest countries of the world include: Afghanistan, Burkina Faso, Burma, Burundi, Cambodia, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Eritrea, Ethiopia, Guinea-Bissau, Kenya, Kiribati, Laos, Madagascar, Malawi, Mali, Nepal, Niger, Nigeria, Sierra Leone, Somalia, Tanzania, Togo, Uzbekistan, Yemen, and Zambia. General information and sediment initiatives about each country were obtained using the World Wide Web and summarized in this report.

This report provides a summary of major erosion and sediment impacts each country faces. The countries located in Asia are facing major issues related to land degradation, soil erosion, droughts, flooding and deforestation. The countries located in Africa are experiencing deforestation, land degradation, soil erosion, droughts and desertification. The differences are due to the regional issues each country faces. Overall these developing nations are experiencing land degradation, soil erosion, deforestation, and droughts are the leading cause of sedimentation and erosion within the poorest countries. The increased urbanization and agricultural expansion is continuing to affect the sediment continuity in these countries.

These countries primarily need food, potable water, improved roads, irrigation, disease protection and prevention. In most countries erosion and sediment are the least of their concern. However sedimentation is linked to many of their water problems. Improved sediment conditions could increase potable water, irrigation, reduce diseases and provide more food for the people.

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### 1 Introduction

The report focuses on identifying issues associated with erosion and sedimentation in the poorest countries of the world.

### 1.1. Purpose

The United Nations Educational, Scientific and Cultural Organization (UNESCO) was developed in 1945. UNESCO was set up as an international agency for advancing and promoting education, sciences, culture and communication at a global scale.

The International Hydrological Program of UNESCO set up a steering committee to address sedimentation and erosion issues around the world. The International Sediment Initiative (ISI) was established in September 2004, to assist with water resource management. The overall objectives of the committee are to:

- Increase the awareness of sedimentation and erosion issues:
- Improve and sustain the management of soil and sediment resources;
- Better advice policy development and implementation.

This report will list poor countries around the world that need assistance and identify problems associated with sediment and erosion within each country.

### 1.2. Objectives

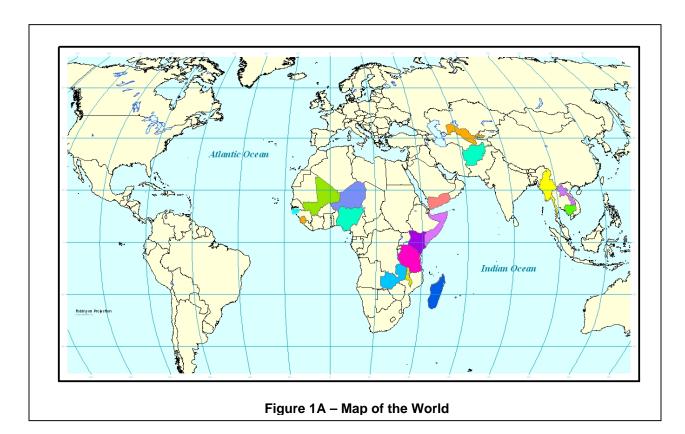
The objectives of this report are as follows:

- Identification of the poorest countries of the world.
- · Regional categorize countries.
- Provide a general summary about each country.
- Determine sediment initiatives for each country.

### 1.3. Methodology

Research was conducted using the World Wide Web to determine the poorest countries of the world. Data was collected and compiled from the following resources: US State Department, CIA World Factbook and the Ozone Hole Incorporated. The US State Department list was gathered by the Office of Electronic Information and Publications at the Bureau of Public Affairs. They determined the per capita income for all the countries in the world, and then the data was sorted to determine the poorest countries. The CIA World Factbook was developed with the aid from many different sources: National Science Foundation, Department of Commerce, Department of Labor, Central Intelligence Agency, Council of Managers of National Antarctic Programs, Department of Defense, US Department of State, Department of the Interior, Department of Transportation, Department of Defense and other public and private sources. This site contains a sorted list of the per capita gross domestic product for the world. Finally, the Ozone Hole Corporation used information from the CIA 2001 data to determine the poorest countries in the world. However, there was an inconsistency between the three data sites; hence a comparative analysis was deemed appropriate. Table 1A summarizes the data by region.

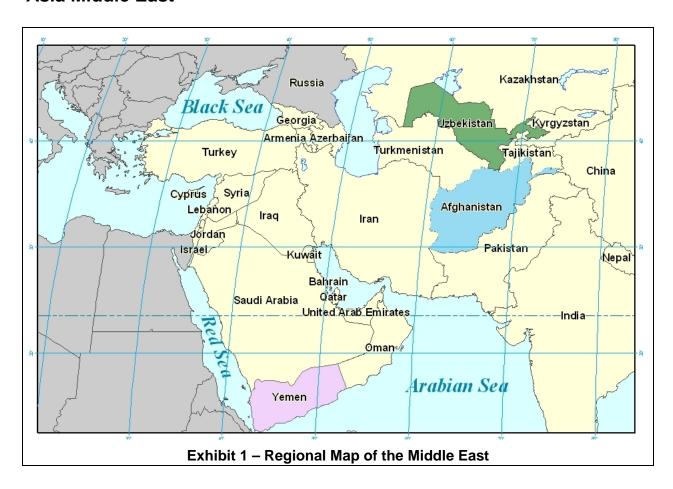
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Country	Source US State Department		Source The World Fact book CIA		Source http://www.solcomhouse. com/poverty.htm	
	Rank	Per Capita Income	Rank	Per Capita GDP	Rank	Per Capita GDP
·		Middle Ea	ast - Asia			
Afghanistan	6	\$165	11	\$800	16	\$813
Uzbekistan	24	\$300	51	\$1,800		
Yemen	36	\$508	17	\$800	12	\$727
		South	Asia			
Nepal	20	\$279	40	\$1,500		
		South E	ast Asia			
Burma	10	\$225	45	\$1,700		
Cambodia	21	\$282	59	\$2,000	6	\$671
Laos	25	\$320	53	\$1,900		
		East /	Africa			
Burundi	1	\$87	2	\$600	8	\$694
Eritrea	4	\$153	18	\$900	9	\$701
Ethiopia	2	\$92	13	\$800	2	\$519
Kenya	19	\$271	26	\$1,100		
Somalia	NA	NA	6	\$600	4	\$593
Tanzania	17	\$270	10	\$700	5	\$660
		Centra	l Africa			
Central African Republic	16	\$260	25	\$1,100		
Chad	12	\$237	42	\$1,600		
Republic of Congo*	42	\$700	8	\$800		
Democratic Republic of the Congo	3	\$99	12	\$700	7	\$687
		South	Africa			•
Comoros	43	\$720	7	\$700	10	\$709
Madagascar	13	\$240	15	\$800	13	\$742
Malawi	5	\$160	4	\$600		
Zambia	33	\$430	22	\$900	19	\$887
		West	Africa			•
Burkina Faso	23	\$300	30	\$1,200		
Guinea-Bissau	8	\$180	9	\$700	18	\$856
Mali	14	\$250	20	\$900	14	\$795
Niger	11	\$232	21	\$900		
Nigeria	22	\$290	23	\$1,000	20	\$896
Rwanda	15	NA	34	\$1,300	17	\$816
Sierra Leone	7	\$171	5	\$600	1	\$478
Togo	18	\$270.00	44	\$1,600		
		Pacific Isla	nds - Asia		•	•
East Timor*	35	\$497	1	\$400		
Kiribati	40	\$663	14	\$800	15	\$804
Tuvalu*	69	\$2,020	28	\$1,100	11	\$720
*Countries not researched	-	, , ,		,	1	



Thirty two countries are summarized in this list. However detailed summaries are only provided for twenty-eight of these countries. The countries analyzed were those ranked by the US State Department as being the top twenty five poorest countries in the world. This is because the data source was clearly identifiable. In addition, using the information from the CIA Factbook and Ozone Hole Incorporated were compared. Even thought the data sources are both from the CIA Factbook there are some inconsistencies. Thus if both sites stated that the country was on the top twenty five poorest country they were analyzed. In the end 28 countries were identifies and studied. Figure 1A highlights and identifies the location of the poorest countries in the world. The figure represents that these countries are located in Africa and Asia.

The CIA World Factbook (<a href="http://www.cia.gov/cia/publications/factbook/geos/xx.html">http://www.cia.gov/cia/publications/factbook/geos/xx.html</a>) was used to determine general information about each country. Then using the different search engines (Yahoo, Google and Dog pile) a summary of the sedimentation initiatives for each country was identified.

### **Asia Middle East**



### 2 Afghanistan



### 2.1. General Information

Afghanistan is a landlocked country located in Asia. Figure 2A depicts the location of the country relative to other Asian countries. The capital is Kabul, located at the base of the Hindu Kush. The climate of Afghanistan is arid to semiarid with cold winters (average temperature of -2.8 °C) and hot summers (average temperature of 24.4 °C). The average rainfall is approximately 330.2 millimeters. The country is approximately the size of Texas at 647,000 km². The highest point is Noeshak in the Hindu Kush at 7,485 meters and the lowest point is Amu Darya at 258 meters. The terrain is primarily mountainous, with some plains located to the north and southwest. The headwaters of the rivers are formed in the



Figure 2A - Map of Afghanistan

mountains in northeastern Afghanistan. Amu Darya, Morghab, Hilmand, and Harirud Rivers flow west into the inland seas, swamps, or salt flats found in the country. The Kabul River flows south from the Hindu Kush and joins the Indus River in Pakistan. There are a few small lakes scattered throughout the country: Lake Zarkol, Lake Shiveh and Lake Istadeh-ye Moqor (Saline Lake). The official languages of the country are Afghan Persian, Dari and Pashtu.

The country is rich in many different natural resources. However, the country is more dependent on their agricultural product: opium, wheat, fruits, nuts, wool, mutton, sheepskins, and lambskins. In the industrial sector the country produces textiles, soap, furniture, shoes, fertilizer, cement, and hand-woven carpets. In addition they extract natural gas, mine coal and copper.

The main postsecondary educational institution is the University of Afghanistan in Kabul.

#### 2.2. Sediment Initiatives

Over the past seven years the country has been experiencing severe droughts. Deforestation, overgrazing, clearing of vegetation, and the drought have caused the soil to degrade and erode. With the limited amount of water and the destructions of the forests desertification is occurring within the country.

In arid regions such as Afghanistan, irrigation is necessary to provide water to farmers. Thus irrigation canals are designed to transport flows to desired location. However due to sedimentation the irrigation canals are filling with sediment. The World Bank is sponsoring a project in Afghanistan that will cost approximately \$42 million. The project is entitled National Community Empowerment Program Project. Part of the project requires the removal of sediment and rehabilitates the canals that are used for irrigation. Figure 2B depicts the Char Dara irrigation ditch located in northeastern Afghanistan. The community is working together clearing the sediment from the ditch to allow the transport of flow to their farms.



Figure 2B – Farmers de-silting the Char Dara irrigation canal in northeastern Afghanistan.

Reservoirs are also an important source of water, but they too are filling with sediment. Repairs were made to the Dahla Gate in Kandahar, however due to the sedimentation the reservoir capacity is limited. In addition, Kajaki Dam located on the Helmand River is also filling with sediment. The sediment entering these facilities needs to be reduced to extend the lifespan of these facilities and provide a viable source of water. If nothing is done to improve these dams they will become ineffective.

The major environmental impacts associated with erosion and sediment within Afghanistan are: droughts, floods, land degradation and soil erosion, over grazing and inadequate potable water supply.

### 3 Uzbekistan



### 3.1. General Information

Uzbekistan was part of the former Soviet Union. It became an independent country after the breakup of the Soviet Union in 1991. Uzbekistan is a landlocked country located in southwestern Asia. Refer to Figure 3A, depicts a map of Uzbekistan and its location relative to other countries in the Middle East. The capital of Tashkent is located near Lake Ayddrjul along the border with Kazakhstan. The majority of the country is located in a mid-latitude desert with long hot summers (37.8°C) and mild winters, and the eastern portion of the country is semiarid grasslands. The country is approximately 450,000 km<sup>2</sup>, the size of California. The highest point is Adelunga Toghi at 4,301 meters and the lowest point is Sarigarnish Kuli in the Ustyurt Plateau at -12 meters. The countries terrain is mostly flat-to-rolling sandy desert with dunes. The main rivers are the Amu Darya and Syr Darva Rivers which flow into the Aral Sea locates in northern Uzbekistan. There are two major lakes the Ayddrkul and Sarykamsh. The



Figure 3A – Map of Uzbekistan

official language is Uzbek spoken by 75% of the population.

When it comes to employment and economy Uzbekistan does not only depend on agriculture. Approximately 40% of the labor force is involved in the agricultural sector producing cotton, vegetables, fruits, grain and livestock. Another 20% of the labor force is involved in the industrial sector producing textiles, food processing, machine building, metallurgy, gold, petroleum, natural gas, and chemicals. The remaining workers are involved in the service sector.

The main institution of postsecondary education is the National University of Uzbekistan. More information about the university can be obtained by visiting <a href="http://www.nuu.uz/">http://www.nuu.uz/</a>, however the information is written is Uzbek.

### 3.2. Sediment Initiatives

There is deforestation and degradation in the Aral Sea Basin. As a result of extensive irrigation the water level in the Aral Sea has drop significantly, which has caused the salinity level to increase and become toxic.

Over the past 40 years water has been diverted from the Amu Darya and Syr Darya Rivers for irrigation. As a result in the 1980's zero flow entered the sea, resulting in its shrinkage. Figure 3B depicts the changes to the sea over the past 40 years. Approximately 40 millions tons of sediment is blown yearly from the exposed bed, causing serious health effects. Due to the large

irrigation activities in the area, it is nearly impossible to restore the rivers to their original condition. However, there are opportunities to bring flow from rivers in Kazakhstan into Aral Sea. This will help improve the current conditions and help restore the Aral Sea.

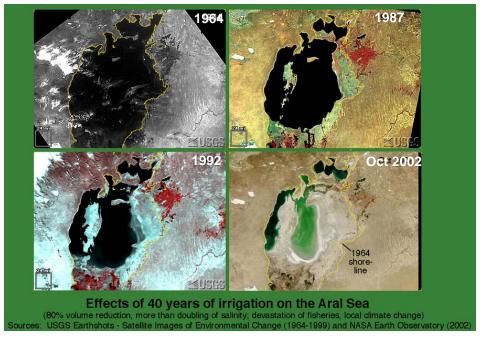


Figure 3B - Effects of irrigation on the Aral Sea

In addition the counties located in the Aral Sea Basin have written a Strategic Action Plan to address the situation, with the help from the World Bank. Part of the plan will address safety, improvement and sedimentation of the dams. This will help with irrigation and hopefully allow some flow to be returned into the Aral Sea.

Uzbekistan is an arid country, with sandy deserts as mentioned in the previous section. This results in lots of sediment in the limited water supply of the country. As the sediment deposits in the canal, they are becoming ineffective and the suspended sediment is eroding the pumps needed for irrigation. Thus in December of 2003 an environmental report was written to address the Amu Zang Irrigation Rehabilitation Project. Canals are used to provide water to the local farms. Sediment control facilities are necessary between Amu Darya River and the Amu Zang I pumping station to provide an effective waterway for irrigation due to the transport of over 100 million tons of sediment per year by the river. The plan includes the construction of sediment control at the inlets to these canals.

The major environmental impacts associated with erosion and sediment within Uzbekistan are: desertification, land degradation and soil erosion, and water quality.

# 4 Yemen

### 4.1. General Information

Yemen is located in the Middle East on the Arabian Peninsula. Figure 4A depicts the location of the country relative to other Asian countries. The capital of Sana is located in the mountainous area of Yemen. The country is primarily a desert. The desert to the east is hot, dry and harsh with temperatures as high as 42 °C. The climate changes in the coastal area to a hot and humid environment with an average temperature of 29 °C. In the mountains the temperatures are affected by the monsoonal rains and are cooler with an average temperature of 20 °C. The average annual rainfall is 600-1500 millimeters. The country is approximately twice the size of Wyoming at 527,970 km<sup>2</sup>. The highest point is Jabal an Nabi Shu'ayb at 3,760 meters and the lowest point is the Arabian Sea at 0 meters. The terrain varies from a narrow coastline plain into flat topped hills and mountains. At the central slopes there is upland desert plains that are connected to the interior desert of the Arabian peninsula. There are a few rivers in Yemen: Wadi



Figure 4A – Map of Yemen

Hadramawt, Wadi Mawr, Wadi Zabid, and Wadi Siham. However there are no significant lakes within the country. The official language of the country is Arabic.

When it comes to employment and economy 75% of the country works in agriculture and herding. They produce grain, fruits, vegetables, pulses, qat (mildly narcotic shrub), coffee, cotton, dairy products, livestock (sheep, goats, cattle, and camels), poultry and fish. Others work in the service or industrial sector. The industrial sector has crude oil production and petroleum refining, small-scale production of cotton textiles and leather goods, food processing, handicrafts, small aluminum products factory, cement factories, and commercial ship repair.

There are many universities in Yemen however the information on there websites are in Arabic. Some of the universities are Hadramout University of Science and Technology, Sana'a University and Al-Ahgaff University. For more information visit the following websites respectively: <a href="http://www.hust.edu.ye/">http://www.hust.edu.ye/</a>, <a href="http://www.hust.edu.ye/">http://www.hust.edu.ye/</a>, <a href="http://www.ahgaff.edu/english.asp">http://www.ahgaff.edu/english.asp</a>.

### 4.2. Sediment Initiatives

The country of Yemen is has very little fresh water resources, as a result there is inadequate supply of potable waters. Due to climate changes, over grazing, and soil erosion the country is experiencing desertification.

Spate irrigation is used in semi-arid regions of the world. Flow from rivers beds (Wadi) is spread over large areas, refer to Figure 4B. Rivers such as Wadi Zabid and Wadi Mawr have high sediment flow, which are difficult to control. The lack of sediment control is due to the increase use of spate flows in the upper watersheds.

Flooding is a major problem in Yemen. The city of Taiz has many challenges due to the short time of concentration, and high sediment flows resulting from the regions storms. The situation has worsened due to roadway construction in the mountains with inappropriate erosion control. As a result sediment traps designed to intercept medium to coarse sediments are filling with fine sediment. Improved drainage and construction practices are necessary to improve the sediment and erosion situations.



Figure 4B - The spate of Wadi Zabid in Yemen.

The major environmental impacts associated with erosion and sediment within Yemen are: desertification, land degradation, over grazing and inadequate potable water supply.

### **South Asia**



### 5 Nepal

### 5.1. General Information



Nepal is located in southern Asia in the Himalayan Mountains. The landlocked country is bound between China to the north and India to the south, refer to Figure 5A. The capital of Kathmandu is located within the foothills of the Himalayan Mountains. The climate varies in Nepal due to the changing terrain. To the south there is the Tarai or flat river plain of the Ganges River, the center of the country has many hills and the rugged Himalayan Mountains are to the north. The southern portion has subtropical summers and mild winters where the temperature ranges from 4 to 42°C. However the northern portion of the country has cooler summers and severe winters where the temperature ranges from -6 to 28°C. The average annual rainfall is approximately 133 centimeters. The country is



Figure 5A - Map of Nepal

approximately 140,800 km² the size of Arkansas. The highest point is Mount Everest at 8,850 meters and the lowest point is Kanchan Kalan at 70 meters. There are numerous rivers that begin in the Himalayan Mountains. The main rivers in Nepal are Bagmati River, Kosi River, Narayani River (India's Gandak River), and Karnali River. There are numerous mountain lakes in Nepal formed from depressions in the mountains. Napali is the official language of the country, spoken by over 90 percent of the population. However, English is used to conduct business and by the government.

Over 80% of the country works in the agricultural sector. As a result the country produces ice, corn, wheat, sugarcane, root crops, milk and water buffalo meat. The industrial sector is composed of tourism, carpet, textile, small rice, jute, sugar, and oilseed mills, cigarette, cement and brick production.

The Institute of Engineering at Tribhuvan University has a civil engineering program. For more information about the university and the engineering program visit <a href="http://www.ioe.edu.np/colleges/wrc.php">http://www.ioe.edu.np/colleges/wrc.php</a>.

### 5.2. Sediment Initiatives

As mentioned previously Nepal is located in the Himalayan Mountains. Due to the mountainous landscape the country has large hydropower potential. Currently less then 1% of the country hydropower potential is being used. This is due to the high sediment load found in the rivers of Nepal. The rocks break and crumble easily, filling sediment basins. In addition, large concentration of fine sediments is found in suspension within the water. In addition to the mountainous terrain deforestation and land degradation is adding to the high sediment inflows.

The suspended sediments that do not settle are reducing the efficiency of dam turbines. The Kilimiti Hydropower plant on the Kilimiti River has many sediment related problems. Thus a flushing system was designed to remove sediments from the upstream settling basins and return it into the Kilimiti River. However the high concentration pulses are causing imbalance to the river system. In addition, the suspended sediment found in the water is causing the turbines of the dam to erode quickly. During the first year of operation the turbines has already eroded, requiring constant maintenance.

Nepal loses approximately 240 million cubic meters of sediment per year. The main three rivers are Karnali, Sapla Gandaki and Sapta Kosi, transporting 60, 73, and 143 million cubic meters of sediment per year respectively. The high rate of sediment has causes the rivers to meander and shift. Therefore, in the 60's India built a barrage at the border of Nepal to control the flooding and shifting of Sapta Kosi, refer to Figure 5B. The barrage is currently working, however the reservoir upstream of the barrage is filled with sediment and the river has aggraded significantly near the barrage. Due to the sediment depositions in the reservoir and the



Figure 5B – Kosi Barrage at the border of Nepal and India on the Sapta Kosi River.

river bed the flow is threatening to over top the barrage and cause massive flooding, loss of land and people in both India and Nepal. A dam is planned to be build called the Kosi High Dam to

protect the barrage however due to the high sediment concentration in Sapta Kosi the dam will silt up and problems similar to the barrage will occur. The project will cost \$2 trillion and produce 4,000 megawatts of electricity, interlink 37 rivers in India, provide flood control and irrigation during the dry seasons. This project is a large feat and will not be completed until 2012.

The Bagmati River flows through central Nepal. Population growth in the Bagmati watershed has resulted in deforestation, erosion, landslides, siltation in the upper and middle stretches of the river. As a result flooding and excess sediment is affecting the lower stretch. This is and will affect Bagmati Barrage and Kulekhani Reservoir. A study was conducted to asses the basin by the Water and Energy Commission Secretariat. However, the implementation of these programs to improve the effects of deforestation is difficult to administer. Education is necessary so that the people can truly understand the impacts they are creating on the environment.

The major environmental impacts associated with erosion and sediment within Nepal are: deforestation, drought, flooding, inadequate agricultural techniques, land degradation and soil erosion and water quality.

### **South East Asia**



### 6 Myanmar (Burma)



### 6.1. General Information

In 1989 the military authorities tried to change the official name of the country from Burma to Myanmar, however it was never truly excepted by everyone in the country and the world. The military unrest is causing lots of conflicts in Burma. The country is located in Southeastern Asia adjacent to the Bay of Bengal and Andaman Sea. The capital of Burma is Rangoon located along the Andaman Sea. Figure 6A depicts the location of Burma relative to the other Asian countries. The country is located in the tropical zone north of the equator and experience summer and winter monsoons. In the summer months (June to Sept.) there are southwest monsoons that are characterized by cloudy, rainy, hot and humid with temperatures around 26.9°C, however the winter months



Figure 6A - Map of Myanmar (Burma)

(December to April) there are northeast monsoons that are characterized by less clouds, scattered rainfall, temperatures averaging 25 °C, and lower humidity. Due to the long rainy season, the averages rainfall is approximately 251 centimeters. The lowest point is the Andaman Sea at 0 meters and the highest point is located at the northern tip of Burma called Hkakabo Razi at 5,881 meters. The terrain changes from central lowlands ringed by steep, rugged highlands. The following are the major rivers found in Burma: Irrawaddy River, Salween River and Chindwin River. Inle Lake is the major lake found in the country. The official language is Burmese.

Agriculture is the dominant source of employment. Burma produces rice, pulses, beans, sesame, groundnuts, sugarcane, hardwood, fish and fish products. The industrial sector processes agricultural products, knit and woven apparel, wood and wood products, process natural resources such as copper, tin, tungsten and iron, construction materials, pharmaceuticals, fertilizer and cement. Even through the country produces lots of industrial products the people are much more depended on their agriculture and fishing as a source of income.

In the capital of Rangoon there are two main universities, the University of Rangoon know as the University of Yangon and the Rangoon Institute of Technology now called Yangon Institute of Technology. Both have Civil Engineering programs. Visit the following webpage for more information: <a href="http://www.aun.chula.ac.th/u\_yangon\_mm.htm">http://www.aun.chula.ac.th/u\_yangon\_mm.htm</a> and <a href="http://welcome.to/YIT">http://welcome.to/YIT</a>. The webpage did not have much information on the faculty at the universities.

### 6.2. Sediment Initiatives

Due to deforestation, flooding, landslides and population growth Burma's lakes and rivers are rich in sediment. The people that live around Lake Inle have been saying that the lake is not as clear today as it had been in the past. Figure 6B shows some children riding an ox in the sediment rich Inle Lake. Due to the deposition of sediment the lake and its tributaries are becoming less navigable. Over 650,000 cubic meters of sediment entering the lake each year.



Figure 6B- Children riding an ox in the sediment rich Inle Lake

Irrawaddy River, which drains much of Burma is very high in sediment. It is estimated to produce 300 million tons of sediment per year making it the 5<sup>th</sup> highest sediment concentrated river in the world. The excess sediment is caused by deforestation and agricultural growth in the Irrawaddy River Basin. Mitigation measures need to be introduced to alleviate the situation and reduce the sediment losses.

The Salween River is one of the longest rivers in Southeast Asia. Figure 6C depicts the existing condition on the Salween River in Burma. Burma and Thailand have created a joint partnership to construct eight dams for electricity and water diversion structures along the Salween River. This will have many environmental impacts, such as preventing fish migration, blocking passage for land animals, changing flow and sediment continuity and flooding many communities. Siltation of these structures and downstream erosion will transpire. Mitigation measures are necessary to reduce impacts expected on the Salween River. Flushing gates to prolong the life of the dams and fish ladders to allow the continual migration of the fish are recommended.



Figure 6C - Current view of the Salween River, Burma

The major environmental impacts associated with erosion and sediment within Burma are: deforestation, drought, flooding, inadequate agricultural techniques, land degradation and soil erosion, over grazing and water quality.

## 7 Cambodia

#### 7.1. General Information

Cambodia is located in southeastern Asia. The southwest portion of the country borders the Gulf of Thailand. Refer to Figure 7A, which depicts Cambodia and its location relative to other countries in Asia. The capital of Phnom Penh is located at the confluence of Tonle Sap Lake and Mekong River. Cambodia is located north of the equator in the tropical zone. It is rainy during the monsoon season from May to November and dry from December to April. There is little seasonal temperature variation. with an average temperature of 27°C. The average annual rainfall is approximately 132 centimeters. The country is approximately 181,000 km<sup>2</sup> the size of Oklahoma. The highest point is Phnum Aoral in the Cardamom Mountains at 1,810 meters and the lowest point is Gulf of Thailand at 0 meters. The country is relatively low flat plains with some mountains to the southwest and north. The main river that flows through Cambodia is the



Figure 7A - Map of Cambodia

Mekong River, which originates in China. The major lake is Tonle Sap Lake located north of the capital. The official language is Khmer spoken by 95% of the population, however English is spoken by educated people, French is spoken by some of the older members of society and Chinese by many of the business people.

Over 75% of the country works in the agricultural sector, however it only makes up 35% of the gross domestic product. As a result the country produces rice, rubber, corn, vegetables, cashews, and tapioca. The industrial sector is composed of tourism, garment manufacturing, rice milling, fishing, wood and wood products, rubber, cement, gem mining, and textiles.

There are over 9 public higher education institutions in Cambodia. The Institute of Technology of Cambodia (ITC), Pannasastr University and University of Cambodia have civil engineering program. For information about the universities refer to <a href="http://www.uc.edu.kh">http://www.uc.edu.kh</a>, and <a href="http://www.pannasastra.org/">http://www.itc.edu.kh</a>, and <a href="http://www.pannasastra.org/">http://www.pannasastra.org/</a>.

### 7.2. Sediment Initiatives

Habitat loss and declining biodiversity is resulting from illegal logging activities and strip mining for gems within Cambodia. The destruction of mangrove swamps threatens natural fisheries. Many of the rivers are being illegally fished and over fished. The removal of tress is resulting in soil erosion and deforestation. The main water flow comes from the Mekong River.

Flow and sediment from China have dramatically impacted the waterways of Cambodia. Currently there are two dams on the Mekong River in China with the plans to build five more dams on the main stem of the Mekong and nine dams on the tributaries. The reduction of flow and nutrients rich in sediment will greatly impact Cambodia and Laos. It is currently evident that both agriculture and fisheries are being impacted by the Mekong River and Tonle Sap Lake due to the change in flow and sediment. Figure 7B shows the Mekong River in Cambodia. The dams will cause a reduction in fishing, which is a maior source of income and food for the people.



Figure 7B – Mekong River in Phnom Penh, Cambodia



Figure 7C- Stung Siem Reap in Northern Cambodia

Located in Cambodia is a deep canal called Stung Siem Reap. Figure 7C, shows the deep canal and the homes that line the river. Due to logging in Phnom Kulen Mountain over the years this beautiful canal has dried up and become a trickle. Erosion has caused sediment to fill the canal. With each rainy season water and sediment are transported in the cannel; however the sediment is depositing causing the canal to aggrade. Over the years the canal will flood due to the lack of transport capacity.

The major environmental impacts associated with erosion and sediment within Cambodia are: deforestation, drought, flooding, land degradation and soil erosion.

# 8 Laos

### 8.1. General Information

Laos is a land locked country located in southeastern Asia. Refer to Figure 8A, which depicts a map of Laos and its location relative to other countries in Asia. The capital of Laos is Vientiane located along the Mekong River is near the border with Thailand. Laos is located north of the equator in the tropical zone. It is rainy during the monsoon season from May to November and dry from December to April. There is little seasonal temperature variation. with an average of 27°C. The average annual rainfall is approximately 175 centimeters. The country is approximately 236.800 km<sup>2</sup> the size of Utah. The highest point is Phou Bia at 2,817 meters and the lowest point is the Mekong River 70 meters. The country is composed of rugged mountains, with some plains and plateau. The main rivers that flow through Laos are the Mekong, Nam Theum and Ou Rivers. The official language is Lao, however French and English are widely used within the country.



Figure 8A - Map of Laos

Over 80% of the country works in the agricultural sector, however it only makes up 50% of the gross domestic product. As a result the country produces sweet potatoes, vegetables, corn, coffee, sugarcane, tobacco, cotton, tea, peanuts, rice, water buffalo, pigs, cattle, and poultry. The industrial sector produces tin, gypsum, timber, electric power, agricultural processing, construction, garments, and tourism.

The main university in Laos is the National University of Laos. For information about the university and it's civil engineering program visit <a href="http://www.nuol.edu.la/nuolstart.jsp?id=1&lc=la">http://www.nuol.edu.la/nuolstart.jsp?id=1&lc=la</a>.

### 8.2. Sediment Initiatives

As in many countries deforestation is of growing concern. The removal of trees is causing soil erosion.

The main sediment concern in Laos is due to the proposed construction of the Nam Theum II hydropower dam. It is estimated that the project will cost \$2 billion. The initial sediment analyses indicate that the dam will store 260,000 cubic meters per year of sediment. However resent findings suggest that this is an underestimation. Due to population growth and land use changes the estimated



Figure 8B - Nam Theun River, Laos

sediment loading in the dam will be much higher. The construction of the dam will have many environmental impacts that may out weight the revenue generated from the hydropower.

Impacts from the Mekong Dam project in China will have impacts in Laos, similar to the impacts in Cambodia. Information is provided in sediment initiatives in Cambodia in Section 7.2.

The major environmental impacts associated with erosion and sediment within Laos are: deforestation, drought, flooding, land degradation and soil erosion and inadequate supply of potable water.

### **Eastern Africa**



### 9 Burundi



### 9.1. General Information

Burundi is a landlocked country located in Africa. Figure 9A depicts the location of the country relative to other African countries. Lake Tanganyika is located to the east, while Lakes Cahaha and Rweru are located to the north. The capital situated along Lake Tanganyika is Bujumbura. The main rivers that flow through Burundi are the Malagarasi , Ruzizi, and Ruvuvu River The country is slightly south of the equator creating a humid environment with an average rainfall of 86 centimeters and a temperature ranging between 17 and 23 degrees centigrade. The country is approximately 28,700 km², the size of Maryland. The highest point is approximately 2,670 meters above sea level in the Mitumba Mountains and the



Figure 9A - Map of Burundi

lowest point is 772 meters at Lake Tanganyika. The terrain is primarily hilly and mountains on the west and changes into plateaus and plains to the east. The official languages of Burundi are Kirudi and French.

The country is rich in many different natural resources. However, the country is more dependent on their agricultural product: coffee, cotton, tea, corn sorghum, sweet potatoes, bananas, tapioca, beef and hides. Many of these products are cash crops and are exported to other countries as a source of income. In the industrial sector the country produces blankets, shoes, soaps and processes food.

The University of Bujumbura, known as the Université officielle de Bujumbura (UOB) is Burundi's higher education facility. It was created when many different institutions merged together within the country. More information about the university and the engineering program can be obtained by visiting <a href="http://www.ub.edu.bi/">http://www.ub.edu.bi/</a>.

### 9.2. Sediment Initiatives

The country of Burundi is experiencing excess soil erosion. This is being caused by over grazing, agricultural expansion and deforestation. In addition, climate changes have occurred resulting in unexpected droughts, followed by heavy rains. These torrential rains have caused massive flooding and landslides.

Lake Tanganyika is one of the largest freshwater lakes in the world with a volume of 19,000 km³. It is shared by Burundi, Democratic Republic of the Congo, Tanzania and Zambia. Due to deforestation, agricultural practices, erosion, and urban pollution in the surrounding countries there is excess sediment and nutrient loading within the lake. Plans are underway to alleviate the situation; however the people of the country need to be trained in understanding how they are impacting the lake. Figure 9B depicts the deforestation that is evident is the mountains around Lake Tanganyika's eastern shore.



Figure 9B – Evidence of Deforestation on Eastern Shore of Lake Tanganyika

Even though Burundi has many rivers and other lakes no sediment problems have been reported. However, some of the issues to Lake Tanganyika are due to the rivers bringing in sediment from the upper watershed.

The major environmental impacts associated with erosion and sediment within Burundi are: deforestation, drought, flooding, inadequate agricultural techniques, land degradation and soil erosion and over grazing.



### 10.1. General Information

Eritrea is located on the Horn of Africa. The country is approximately 121,320 km2. Figure 10A depicts the location of the country relative to other African countries. There are a few rivers that flow through Eritrea. Flowing to the north are Anseba and Barka River, while the Gash (Mereb) and Tekeze Rivers flow along the Ethiopian border. The capital is situated in the center of the country The climate of country varies. Along at Asmara. the Red Sea the climate is hot and dry, it becomes cooler and wet in the central highlands and semiarid in the western hills and lowlands. The temperature ranges from 16 to 34°C. The average rainfall is approximately 51 centimeters above 2,000 and only 21 centimeters along the coast. The lowest point is the Denakil depression at -75 meters and the highest Soira 3,018 meters. The terrain of the country is quite diverse from coastal plains, to western lowlands and central highlands associated with the Great Rift Valley.



Figure 10A – Map of Eritrea

There is no official language in Eritrea. However Tigrinya, Arabic and English are spoken in commerce and national business. English is commonly spoken and is spoken in secondary and university education.

The country has limited amount of arable land; however the majority of the population works with agriculture and animals. The country produces sorghum, lentils, vegetables, corn, cotton, tobacco, coffee, sisal, livestock, goats and fish. In addition, the country does have industrial processing of food, beverages, clothing, and textiles, manufacturing of salt and cement, and repairing of commercial ships.

The only university for higher learning in Eritrea is the University of Asmara. The college of engineering has a civil engineering program. For information about the university can be found at <a href="http://www.uoa.edu.er/academics/colengineering/index.html">http://www.uoa.edu.er/academics/colengineering/index.html</a>.

### 10.2. Sediment Initiatives

Over the years the country has experienced soil erosion. This has been caused by over grazing, agricultural expansion and deforestation. The country has and continues to experience frequent droughts. This is detrimental to their livelihood of the people of Eritrea because so many of them rely on water to do their work.

As an arid country, Eritrea depends on reservoirs to provide necessary water for its people. Both large and small dams/reservoirs have been constructed throughout the country. However one of the major problems with the reservoirs is the loss of capacity due to silting. The following are some examples from the Food and Agricultural Organization of the United Nations associated with the problems with sediment filling the reservoir. Many of the dams built in the past are no longer operational such as the Foro dam. In the 1960's a new dam was built on the

Haddas River at Foro with a capacity of 23 million cubic meters, however by 1988 it was filled with sediment and non-operational. To irrigate the Alighider Estate near Tesseney, the Gash River was dammed, and has an eight million cubic meter storage capacity, however regular desilting is required to keep the reservoir operational. Figure 10B shows the Gash River in Tesseney.



Figure 10B – Gash River in Tesseney Eritrea.

The major environmental impacts associated with erosion and sediment within Eritrea are: deforestation, drought, inadequate agricultural techniques, land degradation and soil erosion and over grazing.



### 11 Ethiopia

### 11.1. General Information

In 1993 Ethiopia became a landlocked country in Africa. This was caused by a civil war, which resulted in Eritrea becoming an independent country. Figure 11A shows that Ethiopia is located on the Horn of Africa. The main rivers found in Ethiopia are the Blue Nile/Abay River, Awash River, Shebele River and Ghion River. Lake Tana is located in northern Ethiopia and is the headwaters for the Nile River. The capital of Addis Ababa is located in the Great Rift Valley that bisects the country. There are many lakes located in this region. Lake Chew and Lake Rudolf are located along the border of Kenva. The climate of the region varies; it is hot and humid in the lowlands, warm in the hills and cool in the uplands. As a result the temperature ranges from 5 to 25°C. The various climate and terrain result in irregular rainfall. In the north the average rainfall is 2 centimeters and to the south over 19 centimeters. The country is approximately twice the size of Texas encompassing 1,127,127 km<sup>2</sup>. The highest point is approximately 4.620 meters above



Figure 11A – Map of Ethiopia

sea level at Ras Dejen located in the Choke Mountains and the lowest point is Denakil Depression at -125 m located near the boarder with Eritrea. There are over 200 dialects spoken in Ethiopia. The official and national language of Ethiopia is Amharic or Amarënya. However English is widely spoken.

The country has limited arable land; however the majority of the population is still involved in agricultures and animal husbandry. As a result they produce cereals, pulses, coffee, oilseed, sugarcane, potatoes, qat, hides, cattle, sheep, and goats. It is believed that coffee, grain sorghum, and castor bean originated in Ethiopia. In addition, the country does have an industrial sector, which processes food, beverages, textiles, chemicals, metals, and cement.

Ethiopia has many higher educational institutions. Addis Ababa University and Bahir Dar University are the largest universities in the country. Background information on the Addis Ababa University can be found at <a href="http://www.ethioworld.com/Science&Technology/addisababauniversity.htm#AAU-Background">http://www.ethioworld.com/Science&Technology/addisababauniversity.htm#AAU-Background</a>. Information on the Civil Engineering Department at the Bahir Dar University can be found at <a href="http://www.telecom.net.et/~bdu/civileng.html">http://www.telecom.net.et/~bdu/civileng.html</a>.

### 11.2. Sediment Initiatives

Sedimentation and erosion is caused by natural sources, however development and expansion have increased the situation. Many parts of Ethiopia are experiencing deforestation, poor soil and improper farming techniques. This is resulting in excess sediment and nutrient loads causing fish to die and increasing algal blooms, which have been reported in the Great Rift Valley.

The Food and Agriculture Organization of the United Nation had done a study to look at the agriculture production in Ethiopia. They have determined that the degradation of natural resources have left the soil vulnerable. As a result 1.9 billion tons of sediment is eroding away each year off of agricultural land. Approximately 10 percent of the sediment is transported in the river and the remaining sediment is depositing in the highlands which are not suitable for agricultural growth.

In Ethiopia the Awash River which flows from the Great Rift Valley is an important source of water. The river flows through the Great Rift Valley, caring a high concentration of sediment. In the 1980's a canal was constructed to supply irrigation water to 10,285 hectares. A sediment basin was constructed to reduce the total sediment entering and filling the canal, however within the first year sediment has filled the settling basin and the upper reach of the canal. As a result the canal is not providing the necessary water for the agriculture land. There are many expensive improvements suggested (flushing and manual cleaning) to aid in assisting the Amibara Irrigation Project, however they are costly. Assistance is necessary to help provide water to this region for agriculture.

Lake Tana is located in northern Ethiopia. It is the head water for the Blue Nile River which carries 2/3<sup>rd's</sup> of the water that is transported by the Nile River. Increased growth in and around Bahir Dar is causing deforestation. As a result the sediment load entering the lake is increasing. It has been estimated that the soil loss from the area is between 8 to 41 million tons per year. Figure 11B depicts the Blue Nile River as it flows from Lake Tana. The evidence of urbanization and growth can be see along the river.



Figure 11B – Blue Nile River flowing from Lake Tana, Ethiopia.



Figure 11C – Example of sedimentation in Ethiopian Reservoir (Migae reservoir)

The urbanization and deforestation is also resulting in high sediment concentrations in the reservoirs of Ethiopia. Figure 11C is an example of the sedimentation found in the reservoirs. A study is being conducted at the Katholieke University Leuven in Belgium. The group of engineers and geomorphologist are investigating the sedimentation in reservoirs of Northern Ethiopia. They plan to identify the various factors contributing the variability in the sediment, determine the sediment rate, and develop methods to reduce the sedimentation in the reservoirs.

The major environmental impacts associated with erosion and sediment within Ethiopia are: deforestation, desertification, drought, inadequate agricultural techniques and over grazing.



### 12.1. General Information

Kenya is located in eastern Africa with the southeastern portion of the country along the Indian Ocean. Figure 12A depicts the location of the country relative to other African countries. The capital of Nairobi is located within the Great Rift Valley. The main rivers are the Tana River and Galana River in the east, and the Kerio. Turkwel, and Nzoia Rivers in the west. The Great Rift Valley is located to the west. The main lakes in Kenya are Lake Rudolf located to the north and Lake Victoria located in the west. The country is bisected by the equator, making the climate very tropical, with average temperatures approximately 26°C. Some parts of the interior are semiarid. The average annual rainfall is approximately 76 centimeters. The country is twice the size of Nevada approximately 582,650 km<sup>2</sup>. The highest point is Mount Kenya at 5,199 meters and the lowest point is the Indian Ocean at 0 meters. The terrain of the country varies from low plains rising



Figure 12A - Map of Kenya

into central highlands, then bisected by the Great Rift Valley. The plateaus to the west are very fertile. The official language of Kenya is English; however the national language is Kiswahili.

Over 75% of the country work in the agricultural sector, however the majority of the countries revenues are from the service sector. The country does produce tea, coffee, corn, wheat, sugarcane, fruit, vegetables, dairy products, beef, pork, poultry, and eggs. The industrial sector is composed of small-scale consumer goods (plastic, furniture, batteries, textiles, soap, cigarettes, and flour), processing of agricultural products, oil refining, aluminum, steel, lead, and cement manufacturing, commercial ship repair and tourism.

Kenya has many educational institutions. There are 6 public and 13 private universities. University of Nairobi, Jomo Kenyatta University of Agriculture and Technology (JKUAT) and Moi University Eldoret, Kenya have engineering programs. JKUAT does not have a website however information on the Moi University and University of Nairobi can be found at the following websites: <a href="http://www.mu.ac.ke/academic/faculties/technology/pages/Civill.html">http://www.mu.ac.ke/academic/faculties/technology/pages/Civill.html</a> and <a href="http://www.uonbi.ac.ke/">http://www.uonbi.ac.ke/</a>.

### 12.2. Sediment Initiatives

Over the years the country has experiences desertification and deforestation. Years of recurring drought, followed by heavy rains has caused sever flooding and erosion. As a result soil erosion has changed sediment continuity.

A sediment study in 1991 by Sutherland looked at the Katiorin drainage basin in Kenya. The purpose of the study was to determine sediment budget for small semiarid tropical basins. The analysis determined the high erosion was caused by minimal ground vegetation, steep slopes,

soil crust formation and erodible substrate and a well-integrated drainage network. The system could not achieve static equilibrium and more studies need to be conducted to understand the tropical watersheds and the impacts deforestation is having on sediment transport.

There are many dams in operation in Kenya: Kindaruma, Gitaru, Kiambere, Kamburu, Masinga and Low Grand Falls Dam. Currently the Low Grand Fall Dam is under construction. These dams are affecting the sediment continuity within the river system. Sediment is filling the dams due to upstream deforestation and agricultural practices. Dredging of many of the dams have occurred to prolong the life span of these structures. The Masinga and Low Grand Falls Dams have a periodic sediment flushing system to help sustain the downstream forests.

In Sub-Saharan Africa coastal deterioration is becoming an alarming problem. In Kenya an assessment of the impacts that sediment has on the ecosystem is being conducted. From the study it has been identified that that Sabaki Estuary is experiencing negative impacts to the coral reefs, sea-grasses, mangroves, and species diversification. In addition, the beaches are disappearing and the river sediment deposits are reducing the aesthetic quality. of the beach. A proposal has been submitted by multiple countries to address this problem. The total cost is estimated at \$30 million.



Figure 12B – Clear-cut mangrove area in Ngomeni, Kenya

Dredging of Kilindini Port has occurred due to high sediment concentration in Galana and Sabaki Rivers. The upland areas of these rivers are composed of agricultural land that have been poorly managed resulting in the erosion. High concentration of sediment is entering the rivers and causing siltation along the coast.

The major environmental impacts associated with erosion and sediment within Kenya are: deforestation, desertification, drought, flooding, heavy rain storms, land degradation and soil erosion and water quality.

# 13 Somalia

### 13.1. General Information

Somalia is located in eastern Africa along the Gulf of Aden and the Indian Ocean. Figure 13A depicts the location of the country relative to other African countries. Shabele and Jubba Rivers are the main rivers that flow southeast towards the Indian Ocean. The capital of Somalia is situated along the Indian coast is Mogadishu. Even though the southern tip of the country is cut by the equator, the climate is primarily dessert. From December to February there are northeastern monsoons with moderate temperatures to the north and very hot temperatures to the south. From May to October there are southwestern monsoons that are characterized by extremely hot temperatures. Between the monsoonal season the country experiences irregular rainfall, hot and humid periods. The temperature is approximately 27°C. The average annual temperature is approximately 432 millimeters. The country is approximately 638,000 km<sup>2</sup>, the size of Texas. The highest point is Shimbiris at 2,416 meters



Figure 13A - Map of Somalia

above sea level and the lowest point is the Indian Ocean at sea level. The terrain is primarily flat to undulating platus and mountains to the north. The official language is Somali. However, the people in Somalia also speak Arabic, Italian, and English.

The country is rich in many different natural resources. However, the country is more dependent on their agricultural product: cattle, sheep, goats, bananas, sorghum, corn, coconuts, rice, sugarcane, mangoes, sesame seeds, beans and fish. In the industrial sector the country has a few light industries (sugar refining, textiles, wireless communication).

Higher education began in Somalia in the 50's when the Italians created a satellite campus for the University of Rome. In the late 60's the military coup nationalized the country and changed the name to the Jaamacada Ummadda Soomaliyeed (the National University of Somalia, or NUS). The university has six colleges. There are also other government-sponsored post-secondary schools in Somalia. There is no website with information about this institution.

### 13.2. Sediment Initiatives

The country of Somalia is experiencing soil erosion. This is being caused by over grazing, and deforestation. As a result desertification is occurring. Over the years the country has experienced recurring years of drought and frequent dust storms. In the rain season the soil is dry and flooding occurs often. However there are no sediment problems identified. The major environmental impacts associated with erosion and sedimentation within Somalia are: deforestation, desertification, drought, flooding, land degradation and soil erosion, over grazing and water quality.



### 14.1. General Information

Tanzania is located on the eastern coast of Africa with the Indian Ocean bordering the coastline. Figure 14A depicts the location of the country relative to other African countries. The main rivers that flow through Tanzania are the Rufiji, Pangani and Great Ruaha Rivers. Lake Tanganyika and the Great Rift Valley are locate to the west. Lake Victoria is located to the north. Lake Malawi is locates to the south and the Indian Ocean is located to the east. The capital of Dodoma is situated in the center of the country. The country is located just south of the equator. The climate is tropical along the coast and temperate in the highlands. The average temperature is 26°C in the summer and 20°C during the winter. The average annual rainfall is approximately 105 centimeters. The country is approximately 945, 000 km<sup>2</sup>, twice the size of California. The highest point is Kilimaniaro at 5,895 meters and the lowest point is the Indian Ocean at 0



Figure 14A - Map of Tanzania

meters. The terrain of the country changes from plains along coast to central plateau and highlands in north and south. The official language of Tanzania is Swahili, however English is the primary language of commerce, administration, and higher education.

The country has a few natural resources with over 80% of its population working in the agricultural sector. As a result the country produces coffee, sisal, tea, cotton, pyrethrum (insecticide made from chrysanthemums), cashew nuts, tobacco, cloves, corn, wheat, cassava (tapioca), bananas, fruits, vegetables, cattle, sheep, and goats. In the industrial sector the country has agricultural processing (sugar, beer, cigarettes, sisal twine), mining and processing (diamond, gold, iron, soda ash), oil refining, shoe, cement, apparel, wood, fertilizer, and salt production.

University of Dar es Salaam is an independent national university located in Tanzania. Within the Civil and Environmental Engineering department there is a sub-department for Water Resources. For more information about the program visit the website at <a href="http://www.ce.udsm.ac.tz/">http://www.ce.udsm.ac.tz/</a>.

### 14.2. Sediment Initiatives

The soil quality is degrading due to over grazing, tree harvesting and agricultural expansion. The result is deforestation and desertification. Sediment is entering the ocean causing the destruction of coral reefs within the Indian Ocean, which is threatening marine habitats. The recent droughts affected marginal agriculture of the country. Flooding is very prevalent through the central plateaus during the rain seasons.

Tanzania is bordered by Lakes Victoria (north), Tanganyika (west) and Malawi (west). Lake Tanganyika is located in western Tanzania, for information on sediment concerns refer to the Sedimentation Initiatives on Burundi, section 9.2.

Lake Victoria is located in northern Tanzania. Sediment deposition is associated with deforestation, overgrazing, lack of land cover, steep slopes, soil textures and precipitation. The input of sediment and nutrients (phosphorous and nitrogen) into the lake are causing an abundance of water hyacinths to bloom, which is an invasive species.

Lake Malawi is located in southern Tanzania. The majority of the Lake is located within Malawi. A catchment study has been conducted to define fluxes of sediment and nutrients entering the lake. Bad agricultural practices, deforestation and burning have caused and are causing many ecological problems associated with sedimentation within the lake.



Figure 14B – Water hyacinths in Lake Victoria

A large portion of Tanzania is composed of coastline along the Indian Ocean. A proposal on Mitigation of Costal Erosion and Restoration of Degraded areas in Sub-Saharan Africa has been submitted and Tanzania is included with the countries on the list. Due to rising sea levels caused by global warming and excess sediment in the ocean an assessment is planed to study the present shoreline changes in Tanzania. There is also a design plan to test some protection measures at Dar es Salaam and Jambiani in Zanzibar an island off the coast of Tanzania.

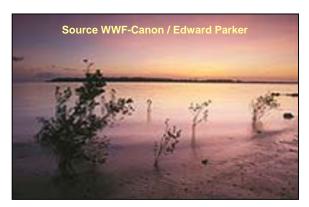


Figure 14C – Young Mangroves along the coast on Mafia Island

The Mafia Island Marine Park of Tanzania is located in the Indian Ocean. Due to overexploitation of mangroves, sediment loads are increasing in the ocean. As the mangroves are harvested, the soil is exposed causing erosion. The sediment is destroying the coastal reefs. Figure 14C shows young mangroves along the coastline on Mafia Island.

With the assistance from the Norwegian, Finish and Swedish agencies a \$128 million hydropower plant construction is planned. The power plant will be located on the Pangani Falls River. Due to the expected sedimentation, the life of the dam will be very short.

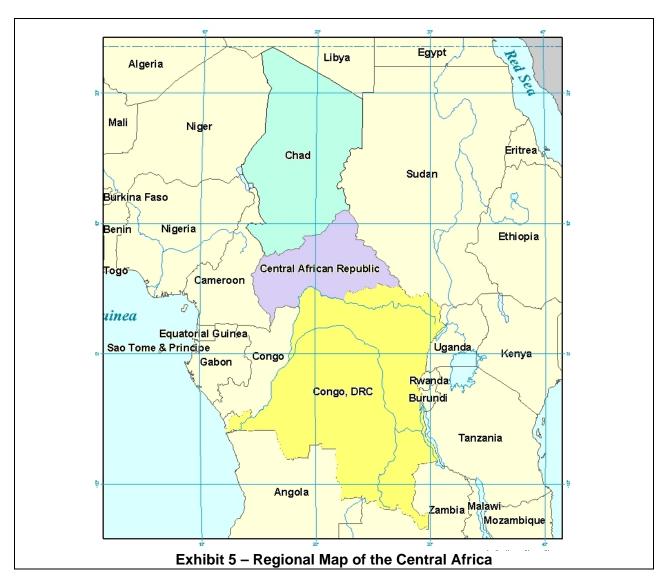
In 1999 the Lower Kihansi in Tanzania was dammed up with a gravity dam (Figure 14D). The project cost \$257 million. It includes loans from the World Bank and multiple European agencies. The design incorporates a radial gate to flush sediment from the bottom of the reservoir and a sliding gate flushes silt deposited from the bottom of the intake pipes. In order to flush the sediment flow rates need to be increased to a rate larger then the historical flow; as a result of the flushing there are many downstream impacts.



Figure 14D – Lower Kihansi Dam in Tanzania.

The major environmental impacts associated with erosion and sedimentation within Tanzania are: deforestation, desertification, drought, flooding, inadequate agricultural techniques, land degradation and soil erosion, and over grazing.

#### **Central Africa**



### 15 Central African Republic



#### 15.1. General Information

The Central African Republic is a landlocked country located in Central Africa. Figure 15A depicts the location of the country relative to other African countries. The capital situated along the Ubangi River near the boarder with the Democratic Republic of the Congo is Bangui. The main rivers in the Central African Republic are Bamingui and Ouham Rivers in the north and the Ubangi River to the south. The country is located north of the equator in the tropical zone with hot, dry winters and mild to hot, wet summers. The average temperature is approximately 25°C, with an approximate average annual rainfall of 151 centimeters. The country is approximately 623,000 km², the size of Texas. The highest point is Mont Ngaoui in the Karren Mountains at 1,420 meters and the lowest point is the Oubangui (Ubangi) River at 335 meters

above sea level. The terrain of the country consists of vast flat to rolling monotonous plateau with scattered hills in the northeast and southwest. French is the official language and Sangho is the national language of the Central African Republic.

The country has a few natural resources; however most of their revenue is from the agricultural sector. As a result the country produces cotton, coffee, tobacco, manioc (tapioca), yams, millet, corn, bananas and timber. In the industrial sector the country has gold and diamond mines, logging, brewing, textiles and footwear production, and the assembly of bicycles and motorcycles.

After the independence of the Central African Republic, the country was faced with having no higher education facilities, hence prospective students went to France. In 1969 a national university was created in the country. Currently there are only two public institutions, the

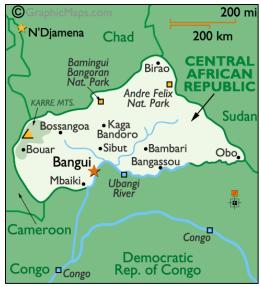


Figure 15A – Map of Central Africa Republic

University of Bangui and the National School of Administration and Judiciary (ENAM), and one private school, the International Preparatory College (College Preparatoire International, CPI). There are no websites for these schools.

#### 15.2. Sediment Initiatives

Over the years the country has experienced soil erosion. This has been caused desertification and deforestation from plant removal. However, there has been no reported sedimentation problem in the Central African Republic.

The major environmental impacts associated with erosion and sedimentation within Central African Republic are: deforestation, desertification, flooding, and inadequate potable water supply.



Chad is a landlocked country located in Africa. Figure 16A depicts the location of the country relative to other African countries. The major rivers of Chad are Chari and the Logone. They flow southeast into Lake Chad. The capital of N'Djamena is located within the African Sudan along the Chari River. Approximately 65% of the country is located in the Saharan Desert making the climate hot, dry and dusty. The southern portion of the country is tropical and located in the African Sudan. During winter the average temperature is 32 °C and during the summer the average temperature is 45 °C. The average rainfall is 57 centimeters. The country is approximately 1,284,000 km<sup>2</sup>, three times the size of California. The highest point is Emi Koussi in the Tibesti Mountains at 3,415 meters and the lowest point is the Diourab Depression at 160 meters above sea level. The terrain of the country is very diverse.

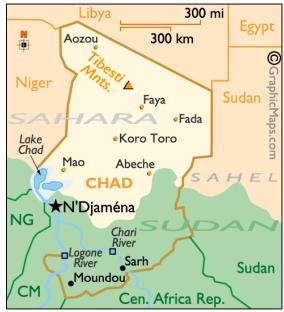


Figure 16A - Map of Chad

The northwestern portion is mountainous, the northern portion is a desert, the central portion is arid plains and the southern portion is fertile lowlands. The official languages of Chad are French and Arabic.

Over eighty percent of the workforces are farmers, herder and or fisherman creating many agricultural products. As a result Chad produces cotton, sorghum, millet, peanuts, rice, potatoes, manioc (tapioca), cattle, sheep, goats, and camels. In the industrial sector the country produces oil, cotton textiles, meatpacking plants, beer breweries, natron (sodium carbonate), soap, cigarettes, and construction materials

N'djamena University (NU) was formed in 1971 to fill civil servant positions. There are five schools that composed NU: the School of Law and Economics (FDSE), the School of Letters and Humanities (FLSH), the School of Exact and Applied Science (FSEA), the School of Health Sciences (FSS), and the National Institute for Human Sciences (INSH). There seems to be no engineering program in Chad and no website for NU.

#### 16.2. Sediment Initiatives

As many of the other countries in Africa, Chad is experiencing deforestation attributable to slash-and-burn agriculture and the use of wood for fuel. Lake Chad is one of the clearest lakes in Africa with little pollution problems, however due to upstream dams, water diversion, and droughts the water level in Lake Chad is very low. This is causing the lakebed to be exposed and the soil is being blown causing dust storms. The shrinking of the lake will effect the livelihood of the people in Chad.



Figure 16B - Fisherman on Lake Chad

The major environmental impacts associated with erosion and sedimentation within Chad are: desertification, land degradation and soil erosion, inadequate potable water supply and water quality.

#### 17 Democratic Republic of the Congo



#### 17.1. General Information

The Democratic Republic of the Congo is located in the central region of Africa. With a small portion along the Altantic Ocean. It is the 3<sup>rd</sup> larges country approximately 2,345,00 km<sup>2</sup>, a quarter the size of the United States of America. Figure 17A depicts the location of the country relative to other African countries. Along the eastern border of the Democratic Republic of the Congo are Lake Tanganyika, Lake Kivu, Lake Edward, Lake Mweru and Lake Albert. Located in the west is Lac Mai-Ndombe. There are many rivers that flow through the Democratic Republic of the Congo. The Uele, Ubangi and Bomu Rivers are located to the north. The Congo, Kwa, Fimi, Kassai, Sankuru River are located to the west and the Lualaba, Lukuga and Luva River are to the east. The capital of Kinshasa is situated along the Congo River. The equator bisects the country creating a tropical, hot and humid climate in the equatorial river region, a cooler and drier in the southern highlands and a



Figure 17A – Map of the Democratic Republic of the Congo

cooler and wetter climate in the eastern highlands. The rainfall averages 114 centimeters. The lowest point is the Atlantic Ocean at 0 meters and the highest point is Pic Marguerite on Mont Ngaliema (Mount Stanley) at 5,110 m. Due to the size and location of the DRC the terrain is very diverse from rainforests to mountainous terrain (plateaus, savannas, dense grasslands and mountains). The official language of the Democratic Republic of the Congo is French.

The country is rich in many different natural resources. Extensive mining is causing many environmental problems. Due to the rich natural resources the country has a very large industrial sector mining (diamonds, copper, and zinc), processing mineral, producing consumer products (including textiles, footwear, cigarettes, processed foods and beverages), making cement, and repairing commercial ships. Even thought there is limited arable land in DRC the country produces coffee, sugar, palm oil, rubber, tea, quinine, cassava (tapioca), palm oil, bananas, root crops, corn, fruits and wood products.

The Democratic Republic of the Congo is composed many different educational facilities. There are 3 universities (University of Kinshasa, Kisangani University, and Lubumbashi University), 18 Advanced Technical Institutes, 16 Advanced Pedagogical Institutes, and a School of Agronomy (Institut Facultaire des Sciences Agronomiques). Lubumbashi University has the Ecole Suerieure des Ingenieurs. More information about the university and its engineering program can be found at <a href="http://www.unilu.net/">http://www.unilu.net/</a>.

#### 17.2. Sediment Initiatives

The Congo River is one of the cleanest rivers of the world. Impacts from urbanization are evident in the costal region due to sediment. The sediment is destroying coral reefs and the beach line.

Many people in Africa do not have electricity. There is lots of potential for hydroelectric development along the Congo River. Through the assistance from the World Bank and private funding sources the \$50 billion Grand Inga Dam Project will be constructed. It involves restoring the existing Inga I and



Figure 17B - Inga Rapids along the Congo River

Inga II in the DRC which is estimated to cost \$550 million. Prior to the construction of the Grand Inga, the Inga III will be constructed. The Grand Inga will produce twice the amount of electricity that the Three Gorges Dam in China has the capability to produce. It will be able to produce enough electricity to light up all of Africa and also parts of Europe. There are many environmental impacts that are associated with the construction of a dam of this magnitude. One of the main concerns is the change in flow and sediment transport and the flooding of land. This is important because local farmers and fisherman depend on the river for irrigation, sediment and fish.

The major environmental impacts associated with erosion and sedimentation within Democratic Republic of the Congo are: deforestation, drought, flooding, inadequate agricultural techniques, land degradation and soil erosion, and water quality.

#### South Africa



#### 18 Comoros



#### 18.1. General Information

The Comoros Islands are located in Southern Africa. They are a group of islands at the mouth of the Mozambique Channel, located north of Mozambique. The total area is approximately 12 times the size of Washington DC at 2,170 km². Figure 18A depicts the location of the country relative to other African countries. The capital of Comoros is Moroni located on the Grand Comore Island. The country is located south of the equator, as a result the climate is tropical with a dry season from May to October and a wet season from November to April. During the wet season there are heavy rain and strong winds associated with the Indian monsoons, however during the dry season

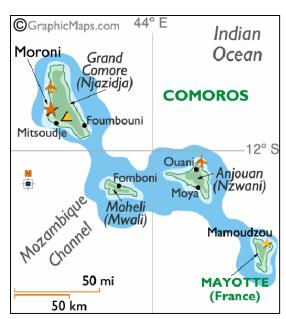


Figure 18A - Map of Comoros

the continental winds prevail from the southeast. The annual precipitation ranges from 1,100 millimeters to 5,500 millimeters depending on the location. The average temperature during the wet season (winter) is 23.3°C and during the dry season (summer) is 27°C. The lowest point is the Indian Ocean at 0 meters and the highest point is Le Kartala on the Grand Comore at 2,360 meters. The islands are composed of volcanic rocks. Thus the interiors vary from steep mountains to low hills. The official languages are French and Arabic.

Over 80% of the people in Comoros are involved in the agricultural sector. They produce vanilla, cloves, perfume essences, copra, coconuts, bananas and cassava. However these products only make up 40% of the gross domestic product. They have a large tourism market and perfumes distilleries.

The postsecondary education in Comoros is public. It only has programs in teacher training, agriculture, health sciences and business. Only two percent of the population attends the university.

#### 18.2. Sediment Initiatives

Similar to many of the other countries in Africa, the Comoros Islands face soil degradation and erosion. This is caused by crop cultivation on slopes without proper terracing. In addition deforestation is the occurring throughout the country. The soils lost from the hillsides due to improper farming techniques are depositing in the ocean. Excess sediment and nutrients are harming the coral reefs, and the biodiversity within the ocean.

The major environmental impacts associated with erosion and sedimentation within Comoros are: deforestation, topical storms, land degradation and soil erosion.

## 19 Madagascar

#### 19.1. General Information

Madagascar is an island of the coast of Mozambique in the Indian Ocean. It is twice the size of Arizona at 587,000 km<sup>2</sup>. Figure 19A depicts the location of the country. The capital of Madagascar is Antananriveo located in the center of the country. The rivers all originates in the Anaratra Mountains along the eastern coast and flow towards Mozambique Channel through a fertile valley. The main rivers are the Betsiboka, Tsiribihina, Mangoky, and Onilahy River. The largest lake in Madagascar is Lake Alaotra in the fertile rice growing region of the country. The country is located south of the equator in the tropical zone. The climate along the coast is tropical, temperate the inland areas and arid to the south. The temperature range is from an average of 21 °C during the summer and 14.5 °C during the winter. The precipitation ranges from 3260 millimeters along the eastern coast to 1203 millimterss along the western slopes of the country. The lowest point is the Indian Ocean at 0 meters and the highest point is Maromokoptro in Ankaratra Mountains at



Figure 19A – Map of Madagascar

2,876 meters. The terrain on the island varies from narrow coastal plain, high plateau to mountains in center of the country. The official languages are French and Malagasy.

As mentioned above Madagascar has very fertile land. As a result the following agricultural products are produced: coffee, vanilla, sugarcane, cloves, cocoa, rice, cassava (tapioca), beans, bananas, peanuts and livestock products. In addition they have an industrial sector that process meat, soap, breweries, tanneries, sugar, textiles, glassware, cement, paper, and petroleum. In addition, there are automobile assembly plants. The country has a large tourism industry as well.

There are 7 main universities in Madagascar. The Université de Toliara and Université Nord Madagascar have programs in Hydraulics. For more information about the engineering program visit <a href="http://www.refer.mg/madagect/edu/minesup/toliara/toliara.htm">http://www.refer.mg/madagect/edu/minesup/antsiran/antsiran.htm</a>.

#### 19.2. Sediment Initiatives

Agricultural is a major livelihood for the people of Madagascar. As a result the soil is degrading due to improper agricultural techniques. Additional land is necessary for production, hence slash and burn agricultural and wetland removal is occurring to provide more usable agricultural space. This is adding to the deforestation and sedimentation.

Lake Alaotra, the largest lake in Madagascar is the center for the countries rice growing industry. There are a wide variety of wildlife, and wetland vegetation around the lake. However, the forested areas that surrounded the lake have been cleared for farmlands. This is resulting in erosion, which is causing considerable sedimentation in the lake. Figure 19B shows sediment laden flows entering Lake Alaotra. Proper agricultural practices need to be taught to the people to insure the survival of the country.



Figure 19B – Stream flows into Lac Alaotra



Figure 19C – Sediment Laden Drainage, Betsiboka River, Madagascar

The main river in Madagascar is the Betsiboka River which flows approximately 525 kilometers. Portions of the river are navigable and there are many rice fields along the banks. However due to deforestation the rich red sediment that is caused from tropical weathering of the soil is entering the river ecosystem. As a result the sediment is damaging the river estuaries. Figure 19C depicts the sediment laden Betsiboka River.



Figure 19D – Gully Formation on hillsides in Madagascar

Over the past few decades deforestation has been occurring in Madagascar. The land that used to be able to absorb the torrential rains are running of the land creating gullies. These gullies are a large source of sediment. Figure 19D shows the formation of gullies along hillsides in Madagascar. The sediment from these gullies are filling and destroying the wetlands. In addition, sediment is eroding from river banks, construction sites, roadways and "borrow pits". Vetiver grasses are suggested in Madagascar to reduce erosion and siltation of wetlands, estuaries, rivers and lakes.

The major environmental impacts associated with erosion and sedimentation within Madagascar are: deforestation, drought, topical storms, land degradation and soil erosion, over grazing and water quality.

#### 20 Malawi

#### 20.1. General Information

Malawi is a landlocked country in Southern Africa. Lake Malawi, the largest lake in the country is located along the eastern border. The lake is shared with Tanzania and Mozambique. The country is approximately the size of Pennsylvania, encompassing an area of 753,000 km<sup>2</sup>. Figure 20A depicts the location of Malawi relative to the other African countries. The capital of Malawi is Lilongwe located in the center of the country. The Shire River and Songwe Rivers are the major rivers. The country is located in the subtropical zone south of the equator. The rainy season is from Noember to May and the dry season is from May to November. The average temperature range is 21.6°C during the summer and 15.2°C during the winter. The average annual precipitation is 915 millimeters. The lowest point is along the Shrine River near the international boundary with Mozambique at 37 meters and the highest point is Sapitwa located in the Mulanje Mountains. The terrain consists of



Figure 20A – Map of Malawi

narrow elongated plateau with rolling plains, rounded hills, and some mountains. The official language is Chichewa.

The country is rich in many different natural resources. However, the country is more dependent on their agricultural product such as: corn, sugarcane, cotton, tea, corn, potatoes, cassava (tapioca), sorghum, pulses, groundnuts, macadamia nuts, cattle, and goats. In the industrial sector the country manufactures and produces tobacco, tea, sugar, sawmill products, cement, and other consumer goods.

There are only 2 universities in Malawi, making it very difficult to gain admittance. The two universities are the University of Malawi (UNIMA) which has been in operations since the 1960's and Mzuzu University which has recently opened. The University of Malawi has the Malawi Polytechnic, which has a department of civil engineering. For more information refer to the following webpage: <a href="http://www.poly.ac.mw/">http://www.poly.ac.mw/</a>. The Mzuzu University does not have an engineering program.

#### 20.2. Sediment Initiatives

Malawi has many different environmental concerns. Over the year poor land management has resulted in land degradation and deforestation. The excess sediment from the previously forested area is causing the siltation of the spawning grounds of some endangered fish species.



Figure 21B – Turbidity in the Linthipe Delta Region

Information on the sediment issues with Lake Malawi can be found in section 14.2 the sediment initiatives of Tanzania. Sediments from the upper watersheds are entering the lake through the many rivers and tributaries. The sediment is depositing in the rivers and lake. As a result the rivers are blocked and it is prevent the flow of water in and out of the lake. Figure 21B depicts the sediment rich Linthipe River. The Linthipe, Songwe and Dwangwa Rivers have heavy sediment problems due to the impacts in the upper watershed. The agricultural and deforestation in the upper watersheds are causing the siltation of the rivers and the lakes.

The Shrine Rivers is the outlet of Lake Malawi. The flow from this river is the only source of electricity in Malawi. However due to reduced flows and the blockage of the river from sediment, the river is drying up. As a result the country will not be able to produce the necessary hydroelectricity that the major cities depend upon. Dredging or pumps are suggested to put water back into the Shrine River.

The major environmental impacts associated with erosion and sedimentation within Malawi are: deforestation, inadequate agricultural techniques, land degradation and soil erosion, and water quality.

## 21 Zambia

#### 21.1. General Information

Zambia is a landlocked country in Southern Africa. The main lakes are Kariba and Bangweulu. The southern tip of Lake Tanganyika touches Zambia. The country is approximately the size of Texas, encompassing an area of 753,000 km<sup>2</sup>. Figure 21A depicts the location of Zambia relative to the other African countries. Lusaka is the capital of Zambia. The Zambezi River, Kafue River, Luangwa River (south and east) and Luapula River (north) are the major rivers in Zambia. Zambia is also the location of Victoria Falls, one of the 7 natural wonders of the world. Victoria Falls is located along the Zambezi River. The country's located in the tropical zone south of the equator. The rainy season is from October to April. The average temperature range is 21.5°C during the summer and 16.3°C during the winter. The average annual precipitation is 838 mm. The lowest point is along the Zambezi River at 329 meters and the highest point is



Figure 21A - Map of Zambia

located in the Mafinga Hills at 2,301 meters. The terrain consists of mostly high platues and hills, with some mountains. The official language is English.

The country is rich in many different natural resources. As a result there is only a small agricultural sector producing corn, sorghum, rice, peanuts, sunflower seed, vegetables, flowers, tobacco, cotton, sugarcane, cassava (tapioca), cattle, goats, pigs, poultry, milk, eggs, hides and coffee. In the industrial sector the country has copper mining and processing, construction, foodstuffs, beverages, chemicals, textiles, fertilizer, and horticulture. The largest area is the service sector that created over 50% of the countries GDP.

The University of Zambia was created in the late 60's with the help of UNESCO. It has approximately 5,000 students. For more information about the university visit their website at www.unza.zm.

#### 21.2. Sediment Initiatives

As with many of the other African countries Zambia is experiencing deforestation, soil erosion and desertification. This is being caused by harvesting the trees, agricultural expansion, improper land management and excess runoff.



Figure 21B - Example of Deforestation

The Cahora Bassa Dam located in Mozambique is South Africa second largest man-made lake. The construction of the dam has affected the health of the Zambezi River. The health of the river depends on sediment loading, nutrient flows, and plant and animal interaction. Prior to the construction of the dam the river would spill over onto the flood plain, providing nutrient rich sediment for the grasslands and costal mangroves. The dam has blocked the sediment in the upper and middle Zambezi River. Even with the release of flows from the dam to mimic floods the same sediment transport is not occurring. The clear water leaving the dams has caused degradation and the lowering of the Zambezi River.

The Kafue River is one of the major tributaries to the Zambezi River. The river flows into the Kafue Flats, a major wetlands system. The wetlands are significant for groundwater recharge and discharge, flood control, sediment retention, water transport, and tourism. However the construction of dams along the Kafue River has drastically altered the river characteristics and caused the decline of many fish species. Figure 21C is a picture of the dam on the Kafue River. The area known as the Kafue Flats is now a stable river. with no flooding and minimal wetland characteristics. The clear water leaving the reservoir has caused an incised channel to form. The reservoir have drastically changed



Figure 21C - Dam on Kafue Rive, Zambia

the river flow pattern. United Nations Food and Agriculture Organization (UNFAO) is working to help restore this area.

Refer to sediment initiatives for Burundi section 9.2 on information regarding Lake Tanganyika.

The major environmental impacts associated with erosion and sedimentation within Zambia are: deforestation, desertification, drought, heavy storms, land degradation and soil erosion, and water quality.

#### **Western Africa**



### 22 Burkina Faso



#### 22.1. General Information

Burkina Faso is a landlocked country located in Africa. Figure 22A depicts the location of the country relative to other African countries. The capital situated in the center of the country is Ouagadougou. The main rivers are the Black Volta (Mouhoun), Red Volta (Nazinon), and White Volta (Nakanbe) Rivers. The climate is tropical, with warm, dry winters (24.8 °C) and hot wet summers (27.2 °C). The average rainfall in Burkina Faso is 81 centimeters. The country is approximately 274,200 km², the size of Colorado. The lowest point is Mouhoun (Black Volta) River at 200 meters and the highest point is Tena Kourou at 749 meters. The terrain is mostly flat, there are undulating plains, and hills to the west and southeast. French is the official language of the country.

Over 90% of the country works in the agricultural sector, however it only makes up 40% of the gross domestic product. The country produces cotton, peanuts, shea nuts, sesame, sorghum, millet, corn, rice and livestock. The industrial sector produces cotton lint, beverages, agricultural processing, soap, cigarettes, textiles, and gold..

Currently there are 11 higher training institutions in Burkina Faso. Of them only three are public institutions. The University of Ouagadougou established in the early 60's is the main university in Burkina Faso. For more information about the university visit their website at www.univ-ouaga.bf.



Figure 22A – Map of Burkina Faso

#### 22.2. Sediment Initiatives

As with all the other countries in this report Burkina Faso has erosion problems caused by overgrazing, deforestation and droughts. However there is no report on sedimentation issues within the country.

The major environmental impacts associated with erosion and sedimentation within Burkina Faso are: deforestation, desertification, drought, inadequate agricultural techniques, land degradation and soil erosion, and over grazing.



Guinea-Bissau is located on the western coast of Africa. It is the approximately 36,120 km<sup>2</sup>, three times the size of Connecticut. In addition, to the mainland of Guinea-Bissau the country encompasses the Bissagos Archipelago, which is a group of over 18 costal islands. Figure 23A depicts the location of the country relative to other African countries. The capital of Bissau is a coastal city situated along the Atlantic Ocean. The country is located in the tropical zone north of the equator. As a result the climate is hot and humid, with temperatures averaging 25.5°C. The country experiences monsoonal rains from June to November with southwesterly winds, during the dry seasons the winds are northeasterly. The rainfall averages approximately 188 centimeters. The lowest point is the Atlantic Ocean at 0 meters and the highest point is located northeast corner of the country at 300 meters. The terrain changes from low coastal plains to rising savannas to the east. The main rivers are the Cacheu



Figure 23A - Map of Guinea Bissau

(Farim), Mansoa, Geba, Corubal (principal river), Rio Grande and Cacine Rivers. The official language is Portuguese.

The country has some natural resources. The country has a rich petroleum reserve however they currently import this resource. However, agriculture is still the dominate source of employment. They produce rice, corn, beans, cassava (tapioca), cashew nuts, peanuts, palm kernels, cotton, timber and fish. The industrial sector is much smaller with the processing of agricultural products, beer, and soft drinks.

There is only one post-secondary education system in Guinea Bissau. It was created in 1979 by the Ministry of Justice. Currently it has programs in Law, Education, Nursing and Sports. There are no programs in Engineering.

#### 23.2. Sediment Initiatives

Over the years the country has experienced soil erosion. This has been caused by deforestation and poor land use management. There have been no reported sedimentation problems in Guinea-Bissau.

The major environmental impacts associated with erosion and sedimentation within Guinea-Bissau are: deforestation, land degradation and soil erosion.



Mali is a landlocked country located in western Africa. It is twice the size of Texas, encompassing 1,240,000 km<sup>2</sup>. Figure 24A depicts the location of the country relative to other African countries. The capital of Mali is Bamako located in southern Mali. The northern portion of the country is located in the Sahara, and the southern portion is located in the Sudan. Therfore the climate varies from arid to subtropical. It varies from hot and dry (February to June), rainy, humid, and mild (June to November) and cool and dry (November to February). The country is located in the tropical zone north of the equator. The average temperature is 26 °C, with an average rainfall of 10 centimeters. The lowest point is the Senegal River at 23 meters and the highest point is Hombori Tondo at 1,155 meters. The terrain varies from flat to rolling plains covered by sand to the north, savannas in the south, and rugged hills to the northeast. The main rivers are the Senegal River and Niger Rivers. The official language is French.



Figure 24A - Map of Mali

The country has some natural resources. However, agriculture is still the dominate source of employment and GDP. They produce cotton, millet, rice, corn, vegetables, peanuts, cattle, sheep, and goats. The industrial sector is much smaller with food processing; construction and phosphate and gold mining.

The University of Mali educates 25,000 students. Part of the school is the National School of Engineering. This facility has an engineering program however there is not website to determine if there is a civil engineering program at this university.

#### 24.2. Sediment Initiatives

As with many of the other African countries Mali is experiencing deforestation, soil erosion and desertification. This is being caused by harvesting the trees, agricultural expansion, improper land management and runoff.

Refer to sediment initiatives in Niger to find information about the Niger River.

The major environmental impacts associated with erosion and sedimentation within Mali are: deforestation, desertification, drought, flooding, land degradation and soil erosion and an inadequate potable water supply.



Niger is a landlocked country located in Africa. Figure 25A depicts the location of the country relative to other African countries. The capital situated along the Niger River is Niamey. The main river of Niger is the Niger River. A portion of Lake Chad is located to the southeast. The majority of the country is located within the Saharan Desert making the climate hot, dry and dusty. The southern portion of the country is tropical located within the Sahel of Africa. The average rainfall is 56 centimeters. The country is approximately 1,267,000 km<sup>2</sup>, twice the size of Texas. The highest point is Mont Bagzane in the Air Mountains at 2.022 meters and the lowest point is the Niger River at 200 meters above sea level. The terrain is primarily desert plains and sand dunes, with few flat to rolling plains in south and hills and mountains on the west which transition into plateaus and plains to the east. French is the official language of the country.



Figure 25A - Map of Niger

Over ninety percent of the countries workforce is employee in the agricultural sector. The country produces cowpeas, cotton, peanuts, millet, sorghum, cassava (tapioca), rice, cattle, sheep, goats, camels, donkeys, horses, and poultry. In the industrial sector the country has uranium mining, cement, brick, textiles, food processing, chemicals production, and slaughterhouses.

Abdou Moumouni University of Niamey has six areas of specialization: natural sciences, agronomy, social sciences, medicine, economics and law. The country does not seem to have a program in engineering. They do have a program in geomorphology. More information about the program can be obtained at

http://www.uni-hohenheim.de/~atlas308/gen\_info/html/english/uam\_engl.htm.

#### 25.2. Sediment Initiatives

The Niger River flows through Guinea, Mali, Niger, Benin, and Nigeria. These countries need to work together to preserve and restore the third largest river is Africa. Sediment continuity has changed due to deforestation, improper farming, infrastructure construction and dam construction. As flows have been reduced, the river has not achieved a new equilibrium. The University of Iowa is studying the sediment carried out by the rivers. It is being deposited as unproductive alluvial fans. Iowa has proposed reforestation and micro-catchments to reduce the sediment runoff and preserve the river. Figure 25B represents the sedimentation along the Niger River.



Figure 25B – Sediment and the Niger River

The major environmental impacts associated with erosion and sedimentation within Niger are: deforestation, desertification, drought, inadequate agricultural techniques, land degradation and soil erosion.

## 26 Nigeria

#### 26.1. General Information

Nigeria is located in western Africa. The southern portion of the country borders the Atlantic Ocean. Figure 26A depicts a map of Nigeria and its location relative to other countries in Africa. The main river is the Niger River. The major tributaries to the Niger River located in Nigeria are the Benue River (northeast), the Kaduna River (west), Sokoto River (northwest), and Anambra (southeast). Portion of Lake Chad touches the northeastern boarder of Nigeria. The capital of Abuja is located in the center of the country. The climate varies in Nigeria as you travel north. The climate is equatorial in the south, tropical in center, and arid in north. The average annual rainfall is approximately 183 centimeters. The country is approximately 923,800 km<sup>2</sup>, twice the size of California. The highest point is Chappal Waddi in the Shebshi Mountains at 2,419 meters and the lowest point is the Atlantic Ocean at 0 meters. The countries terrain contains lowlands merge into central hills and plateaus to the south. There are mountains in the eastern border and plains located to the north. English is the official language of Nigeria.

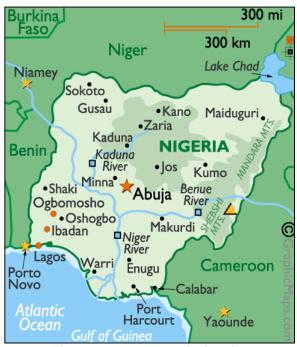


Figure 26A – Map of Nigeria

Over seventy percent of the country works in the agricultural sector, however it only makes up thirty six percent of the gross domestic product. The country produces cocoa, peanuts, palm oil, corn, rice, sorghum, millet, cassava (tapioca), yams, rubber, cattle, sheep, goats, pigs, timber and fish. The industrial sector produces crude oil, coal, tin, columbite, palm oil, peanuts, cotton, rubber, wood, hides and skins, textiles, cement and other construction materials, food products, footwear, chemicals, fertilizer, printing, ceramics, steel, small commercial ship construction and repair.

There are over 45 universities located within Nigeria. Of that twenty five are federal (including one defense academy), sixteen are state and four are private universities. The following are a few of the universities with engineering programs:

Obafemi Awolowo University (<a href="http://www.oauife.edu.ng/index.php">http://www.oauife.edu.ng/index.php</a>),

Abia State University Uturu (<a href="http://www.abia-state-uni.net/">http://www.abia-state-uni.net/</a>),

Bayero University, Kano (<a href="http://www.kanoonline.com/buk/fd/Technology/civil/default.htm">http://www.kanoonline.com/buk/fd/Technology/civil/default.htm</a>) and Abubakar Tafawa Balewa University (<a href="http://www.atbunet.org/pages/Academic 01.htm">http://www.kanoonline.com/buk/fd/Technology/civil/default.htm</a>) and Abubakar Tafawa Balewa University (<a href="http://www.atbunet.org/pages/Academic 01.htm">http://www.kanoonline.com/buk/fd/Technology/civil/default.htm</a>) and Abubakar Tafawa Balewa University (<a href="http://www.atbunet.org/pages/Academic 01.htm">http://www.atbunet.org/pages/Academic 01.htm</a>).

#### 26.2. Sediment Initiatives

Nigeria faces many of the same problems associated with deforestation and desertification as all the other countries in Africa. Soil erosion is degrading the land and affecting the agriculture and adding to the sediment in the ocean, rives and lakes.

The Niger River flows through Nigeria prior to outletting into the Atlantic Ocean. For Sediment Initiatives refer to the Niger for information on the Niger River section 25.2.

In 2004 an analysis was conducted at the Obafemi Awolowo University in Ile-Ife Nigeria on Storm runoff-sediment yield of 1st order stream basin in the degraded forested parts of Obafemi Awolowo University in Ile-Ife Nigeria. The analysis will be used to aid soil erosion control in forested watersheds of the area. The study showed that sediment yield did not increase with flow.

As in Kenya, Nigeria is also experiencing coastal degradation. They are also part of the following proposal: *Mitigation of Costal Erosion and Restoration of Degraded areas in Sub-Saharan Africa*. Many of the beaches are eroding along the Nigerian coast at an alarming rate. Due to climate changes and rising sea level the following costal cities are being affected Eket, Lagos, Forcados and Ondo. These cities will need to be restored as part of the costal restoration program.



Figure 26B – Victoria Beach Erosion, Nigeria

The major environmental impacts associated with erosion and sedimentation within Nigeria are: deforestation, desertification, drought, flooding, land degradation and soil erosion and water quality.



Sierra Leone is located on the western coast of Africa. It is the approximately 71,740 km<sup>2</sup>, the size of South Carolina. Figure 27A depicts the location of the country relative to other African countries. The main rivers are Kolenté (Great Scarcies), Kaba (Little Scarcies), Rokel, Jong, Sewa, and Moa Rivers. The capital is Freetown located along the Atlantic Ocean. The country is part of the tropical zone north of the equator. As a result the climate is hot and humid. Most of the rain falls in the summer, making the winters relatively dry. The average annual temperature is approximately 26°C, with an averages annual rainfall of approximately 360 centimeters. The lowest point is the Atlantic Ocean at 0 meters and the highest point is Loma at 1,948 meters. The terrain changes from mangrove swamps along the coast, wooded hill in the country, upland plateau, and mountains to the east. The official language of Sierra Leone is English.



Figure 27A - Map of Sierra Leone

The civil war had depleted the country natural resources due to extensive mining. Due to the natural resources the country has a very large industrial sector mining diamonds, small-scale manufacturing (beverages, textiles, cigarettes, and fo`otwear), petroleum refining, small commercial ship repair. Even thought there is limited arable land the country produces rice, coffee, cocoa, palm kernels, palm oil, peanuts, poultry, cattle, sheep, pigs and fish.

The main two colleges in Sierra Leone are Fourah Bay College and Njala University. Neither institutions of higher learning have programs in civil engineering. Njala University has an agricultural engineering program in the College of Agriculture.

#### 27.2. Sediment Initiatives

The rivers of Sierra Leone are rich is sediment. However, the sediment has many precious gems that are harvested. In January of 2004 Sierra Leone created an Environmental and Social Management Framework. They identified environmental impacts: deforestation, land degradation, and wetlands degradation. The study does not necessarily identify problem locations, however many of the areas are located in urbanized regions.

The coastal area of Sierra Leone is degrading. Suspended sediment is entering the Sierra Leone Estuary from Baunce River. As a result the estuary is becoming shallower and less effective.

Bumbuna Falls Hydropower plant on the Seli River was proposed for construction three decades ago. However, due to funding and civil unrest the power plant to this day has not been constructed. There is a current study being conducted with the World Bank to evaluate the potential for the Bumbuna Falls Dam. One of the major impacts anticipated due to the construction is sedimentation trapped behind the dam; hence improvements of agricultural practices are necessary in the upper watershed to reduce the impacts. The reduction of sediment downstream will impact the Seli River. It will cause river erosion, and provide less flow and sediment to the



Figure 27B - Bumbuna Dam, Sierra Leone

downstream farmers. The project is estimated to cost \$84 million. Figure 27B depicts a similar dam to the Bumbuna Falls Dam on the Seli River.

The major environmental impacts associated with erosion and sedimentation within Sierra Leone are: deforestation, inadequate agricultural techniques, land degradation and soil erosion, and over grazing.

#### 28 Togo



#### 28.1. General Information

Togo is located in western Africa with the southern portion of the country along the Atlantic Ocean. Figure 28A depicts the location of the country relative to other African countries. The major rivers in Togo are Oti, Kara and Mono Rivers. The main lake is Lac de Bé. The capital of Lome is a coastal city along the Atlantic Ocean. The country is located north of the equator, the climate in the south is hot and humid and the northern portion of the country is semiarid. The average annual temperature is 26°C, with an average annual rainfall of approximately 89 centimeters. The country is approximately 56,785 km<sup>2</sup>, the size of West Virginia. The highest point is Mont Agou at 986 meters and the lowest point is the Atlantic Ocean at 0 meters. The terrain of the country changes gently from rolling savanna in the north, hills in the center and plateau to the south. There are lagoons and marshes in the low coastal plains. The official language is French.

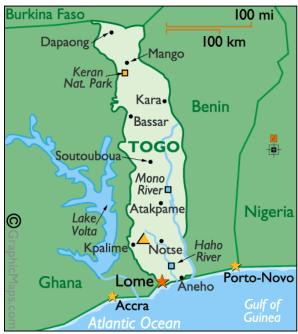


Figure 28A - Map of Togo

The country has a few natural resources with over 65% of its population working in the agricultural sector. As a result the country produces coffee, cocoa, cotton, yams, cassava (tapioca), corn, beans, rice, millet, sorghum, livestock and fish. Only 5% of the people work in the industrial sector mining phosphate, producing agricultural, cement; handicrafts, textiles, and beverages. Large parts of the population have service jobs.

The Universite de Lome au Togo is has been in operation for over 30 years. Within the university there is the Ecole Superiere Nationale d'Ingenieurs. Refer to the following website for more information about the university: <a href="http://www.ub.tg/">http://www.ub.tg/</a>. Another university is being constructed in Kara.

#### 28.2. Sediment Initiatives

Deforestation is attributable to slash-and-burn agriculture and the use of wood for fuel. Thus erosion is causing sediment to be transported into the Atlantic Ocean. In certain parts of the coast sediment is being deposited requiring dredging, however in other parts sediment is depleting. The construction of the Nangbeto Dam on the Mono River has depleted the sediment flowing into the ocean causing the degradation of the coastline. In addition, the reduction of sediment from other rivers in neighboring countries of Ghana and Benin are affecting Togo coastline. The beaches are retreat, sediment is washed into the ocean and harming the aquatic life. The World Bank in June of 2003 wrote an Urban Development Project for Lome in Togo. Part of the project scope is the dredging of Lac de Bé. The total cost for the project is \$26.2 million.

The major environmental impacts associated with erosion and sedimentation within Togo are: deforestation, drought, inadequate agricultural techniques, and water quality.

#### **South Pacific - Oceania**



#### 29.1. General Information

Kiribati is located in the South Pacific. Figure 29A depicts the location of the country. The capital is Bairiki is located on the Tarawa Island. Locate in the tropical zone the climate is hot and humid. The average annual temperature is 28°C. The average annual rainfall is 1915 millimeters. The country is approximately the size of Washington DC at 811 km². The highest point is Banaba at 81 meters and the lowest point is the Pacific Ocean at 0 meters. The terrain is primarily low-ling coal atolls surrounded but extensive reefs. There are no significant lakes or rivers within the country. The official language of the country is English

The majority of the countries income comes from the service sector. However there is a substantial agricultural sector which produces copra, taro, breadfruit, sweet potatoes, vegetables and fish. The industrial sector creates handcrafts and fishing.

8 mi **Kiritimati** 4 8 km London Tarawa Atoll Poland 15 mi Bairiki 15 km MARSHALL ISLANDS Christma arawa Jarvis I (U.S.) ≫Bairiki **EQUATOR** Gilbert' Islands Banaba Island 700 mi TUVALU 700 km Pacific Ocean GraphicMaps.co

Figure 5A – Map of Kiribati

There is no information about a university in Kiribati.

#### 29.2. Sediment Initiatives

Sediment is not the major source of pollutants in the South Pacific. There are more issues related to improper disposal of wastewater. The major environmental impacts associated with erosion and sedimentation within Togo are: tropical storms and water quality.

#### 30 Conclusion

This report provides a summary of major erosion and sediment impacts each country faces. Due to urbanization, and improper agricultural practices, which are causing rapid deforestation and land degradation is occurring in these regions. In addition there are many other factors that are associated with erosion and sediment. Table 30A is a matrix that summarizing the major environmental impacts associated with sediment and erosion that each of these countries experience.

Table 30A – Environmental Impact Associated with Sedimentation and Erosion										
Country	Deforestation	Desertification	Drought	Flooding	Heavy Rain/ Tropical Storms	Inadequate Agricultural Techniques	Land Degradation/ Soil Erosion	Over Grazing	Inadequate Potable Water	Water Quality
Afghanistan			X	X			X	X	X	
Burkina Faso	X	X	X			X	X	X		
Burma	X		X	X		X	X	X		X
Burundi	X		X	X		X	X	X		
Cambodia	X		X	X			X			
Central African Republic	X	X		X					X	
Chad		X					X		X	X
Comoros	X				X		X			
Democratic Republic of the Congo	X		X	X		X	X			X
Eritrea	X		X			X	X	X		
Ethiopia	X	X	X			X		X		
Guinea-Bissau	X						X			
Kenya	X	X	X	X			X			X
Kiribati					X					X
Laos	X		X	X			X		X	
Madagascar	X		X		X		X	X		X
Malawi	X					X	X			X
Mali	X	X	X	X			X		X	
Nepal	X		X	X		X	X			X
Niger	X	X	X			X	X			
Nigeria	X	X	X	X			X			X
Sierra Leone	X					X	X	X		
Somalia	X	X	X	X			X	X		X
Tanzania	X	X	X	X		X	X	X		
Togo	X		X			X				X
Uzbekistan		X					X			X
Yemen		X					X	X	X	
Zambia	X	X	X		X		X			X

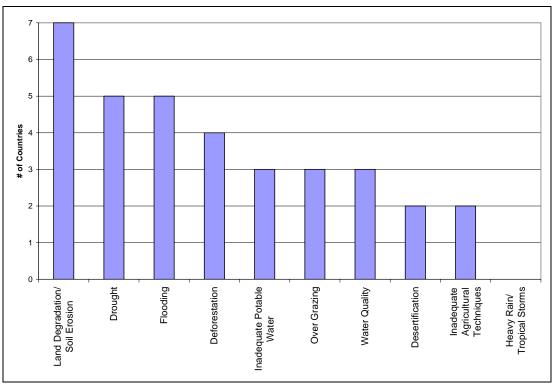


Figure 30A - Environmental Impacts Associated with Erosion and Sediment in Asia

Figure 30A indicates that the major issues associated with sediment and erosion in Asia are land degradation, droughts, flooding and deforestation.

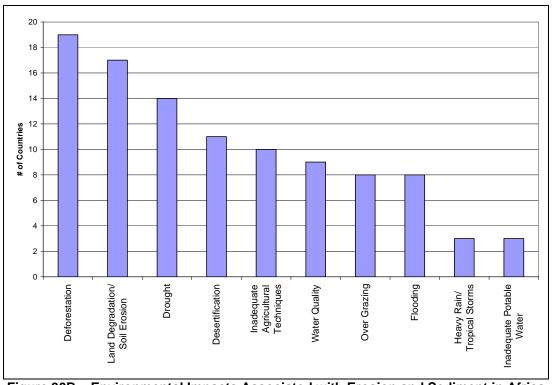


Figure 30B – Environmental Impacts Associated with Erosion and Sediment in Africa

Figure 30B indicates that the major issues associated with sediment and erosion in Africa are deforestation, land degradation, droughts and desertification. The differences are due to the regional issues each country faces.

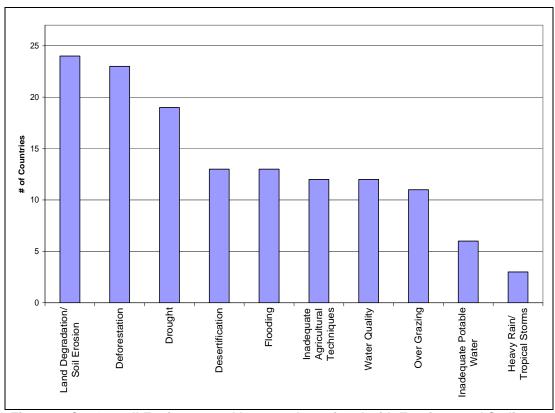


Figure 30C - Overall Environmental Impacts Associated with Erosions and Sediment

Figure 30 C identifies that land degradation, deforestation, and droughts are the leading cause of sedimentation and erosion within the poorest countries.

These countries primarily need of food, potable water, improved roads, irrigation, disease protection and prevention. Thus water is an import resource that they have used to create electricity, irrigation ditches and canals, and potable water usage. Many of these countries have and are constructing dams/reservoirs. These facilities will provide a source of power, water and income. However dams cause major downstream erosion, block sediment and the reduction flow. The rivers are no longer in dynamic equilibrium. Over the past few years many of these countries have faced years of drought, however when it does rain, heavy flooding in experienced. This occurs due to climate changes and the ground inability to absorb the mass quantity of water. Beautiful lush wetlands, mangroves and forests are being destroyed by the change in water patterns and forest removal for agricultural and urban expansion. Sedimentation and runoff from all these different sources are changing the characteristics of the rivers, lakes and irrigation canals. This is affecting the livelihood of the people in these areas, but there focus is not at the future but at the present situation.

Appendix A contains a detailed database for each of the countries analyzed in the report. Appendix B contains a database on the universities located in each of the countries and contact information.

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### Appendix A

**Data Base On the Poorest Countries of the World** 

# Appendix B Database on Universities