Center for Development Research
University of Bonn

Competition for Water Resources for Irrigation Development and Natural Resource Conservation

By C. Javier Puig and John Mduma

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Abstract

In this paper we offer descriptive assessments of how irrigation developments compete with natural resources conservation for water resources. We first show that most of previous irrigation developments in developing countries are destructive to the environment and in many places water resources use has not been efficient. We argue that many environmental distractions could be avoided by improving irrigation water use efficiency and thereby reducing unwarranted water abstractions from their natural courses. Secondly, on the basis of irrigation water use efficiency, we select the three most efficiency countries from Latin America and three countries from Africa and compare their actual (and potential) irrigation

1. Introduction

Demand for irrigation water is derived demand to feed the growing world population. At present, 31 %of the world's total cereal area is irrigated, and contributes 42 %of the total cereal production (IWMI, 2000). Irrigation accounts for about 70 percent of the freshwater withdrawals in the world and is usually seen as the main factor behind the increasing global scarcity of freshwater[1] (Faurès et al 2001). However, substantial amount of water extracted from rivers, lakes and aquifers for irrigation purposes is lost before reaching the crops due to inefficient irrigation systems used. On average, for the 90 developing countries, it is estimated that irrigation efficiency was around 38 percent in the reference period 1998, varying between 25 percent in Latin America and 44 percent in South Asia (FAO 2002a). The average for sub-Africa is 32%.

To meet the growing demand for food, particularly in developing countries in 2030, FAO (2000) estimated a 34% increase in irrigated area, and a 12% increase in irrigation (diversions). Similarly, Shiklomanov (1998) projected a 27% increase in irrigated diversions. From the sustainability viewpoint, current extraction of water should decrease by 8 percent by 2030 (Alcamo et al. 2000). Developing countries must increase their food production to improve food security, and this could be by increasing land under cultivation and water resource use. Globally, there is still untapped potential for use of land and water resources for agriculture.

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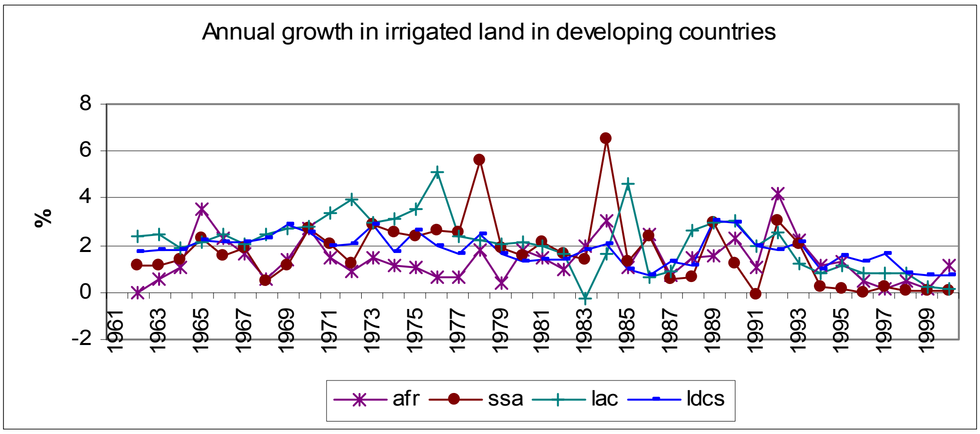
2. Trend in Irrigation

Irrigated area has continued to increase at a steady pace due to the expansion of irrigation on previously rain-fed lands. In the second half of past century water withdrawals increased between and 4% and 8 % annually. Globally however, that pace at which the net irrigated land has been growing has been reduced (Figure 1). The main factor for this reduction is that world demand for agricultural products has slowed, driven mostly by a decreasing rate of population growth and the fairly high levels of food consumption reached in developed countries (Faurès et al 2001). Though this has slowed down in developed countries, in some developing countries, extraction of freshwater from river basins is at rates approaching those at which the supply is renewed and from some underground aquifers at rates exceeding natural replacement (POPIN 1994).



Note: afr stands for Africa, ssa for Sub-Saharan Africa, lac for Latin America and ldcs for developing countries.
Source: FAO (2002a). AQUAST - Information System on Water and Agriculture.

Figure 1. Annual growth rates of irrigated land in four different regions for developing countries.

Nevertheless, the decline in the growth of irrigated areas in developing countries is expected to much slower to relatively high population growth. Since about two third of the net irrigated area is in developing countries, this will have profound effects on the water extracted for irrigation at the global level (Table 1). Competition[3] for water resources will be intensified not

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[3]Potentially, political conflict abounds because about 260 rivers flow through two or more countries and water is one long-standing military or financial wrangle for such neighboring countries (e.g. the Aral Sea region, Israel, Jordan and Palestine, CEDAR 2000).

only with natural resources, but also with increased demand from domestic needs and industrial development[4] (van de Giesen et al. 2001).

Table 1. Total irrigated land in the last 40 years

Year	Net irrigated Areas					
	World		Developed Countries		Developing Countries	
	Total M ha	Total growth %	Total M ha	Total growth %	Total M ha	Total growth %
1961	140	-	38	-	102	-
1990	242	73	65	74	177	73
1997	266	10	66	1	200	12
Source: Rijsberman and Molden (2001). Balancing water uses: Water for food and water for nature International conference on fresh water, Bonn						

Generally, economic development in most developing countries still depends on the agricultural sector. Invariably most of these countries would like to expand their agricultural production to provide the base for their insipient industrial sector and ensure food security. However, their potentials to face these needs will be limited by differences in their water endowments.

Table 2 shows that water resource endowments vary substantially in developing countries. Some regions, like North Africa and Near East, are already drawing 50 percent of their total renewable water resources. Irrigation expansion in such countries will likely come at the expense of other needs. Since it is hard to compromise with the growing domestic needs and industrial development, it is likely that less accord will be on the environmental needs. The only sustainable policy option is to emphasize on improving efficiency in water use, not only for irrigation purposes, but also for industrial and domestic uses. Latin America, with largest share of renewable water resources in developing countries is drawing only one percent of it quota. Therefore, potentials for expanding irrigations is abound. Table 2 also shows estimates of the water effectively withdrawal for irrigation.

[4] Global studies show projections of per capita all purpose water availability dropping from 1 000-5 000 cubic meters per year today to less than 1 000 cubic meters of water per year by 2030 in countries like Kenya, Uganda, Tanzania and Afghanistan (ANW 2002).

Table 2. Summary of agricultural water use and comparison with water resources

	Total renewable water resources (km^3)	Irrigation water requirements (km^3)	Water use efficiency	Water withdrawal for agriculture (km^3)	Water withdrawal as percentage of renewable water resources
Latin America	13409	45	24%	187	1%
Near East and North Africa	541	109	40%	274	51%
Sub-Saharan Africa	3518	31	32%	97	3%
East Asia	8609	232	34%	693	8%
South Asia	2469	397	44%	895	36%
90 developing countries	28545	814	38%	2146	8%

Source: FAO (2002a). AQUAST - Information System on Water and Agriculture.

According to FAO (2002a), irrigation efficiency (WUE) is the ratio between the estimated irrigation water requirements and the actual irrigation water withdrawal. Formally expressed as,

$$WUE = IWR / AWW$$

where:

WUE is the water use efficiency
IWR is the total irrigation water requirement for the country
AWW is the total agricultural water withdrawal from the country.

Levels of efficiency vary considerably. It is highest in the water scarce regions of North Africa and Near East, and lowest in water plenty region of Latin America. . Levels of efficiency are also relatively high in Asian regions, mainly because of population pressure on water resources. For example, Rijsberman and Molden (2001) show that the Chistian irrigated area in Pakistan's Punjab was 90 percent efficient.

There are three major irrigation techniques used, namely surface irrigation, sprinklers, and localized micro-irrigation. In most developing countries, surface irrigations dominate over the other two methods. In Latin America for example, the proportions of areas under surface irrigation range between 54 percent in Lesser Antilles to 96 percent in South sub-region and Andean sub region (Table 3).

Table 3. Irrigation techniques by sub-region Central and Southern America

Regions	Surface		Sprinkler		Localized	
	ha	%	ha	%	ha	%
Mexico	5 802 182	92.7	310 800	5.0	143 050	2.3
Central America	418 638	93.0	17 171	3.8	14 272	3.2
Greater Antilles	746 894	63.6	407 075	34.6	21 256	1.8
Lesser Antilles	2 890	53.8	761	14.2	1 725	32.1
Guyana Sub-region	201 314	100	0	0.0	0	0.0
Andean Sub-region	3 379 637	95.6	122 364	3.5	34 536	1.0
Brazil	1 688 485	58.8	1 005 606	35.0	176 113	6.1
South Sub-region	3 445 068	95.6	95 730	2.7	62 153	1.7
Latin America & Caribbean	15 672 050	86.7	1 960 365	10.8	453 105	2.5

Source: FAO (2002a). AQUAST - Information System on Water and Agriculture.

3. Irrigation and Natural Resource Conservations

Plants and animals in the environment also need fresh water to live. Uncontrolled withdrawals, diversions, dams, pollution and careless exploitation have generally resulted in disruption of freshwater biodiversity[5]. For example, dams may results in disappearance of some species and others forced to migrate (WCU 2002). In the long run, a balance must be sought to guarantee our survival by guaranteeing the survival of nature around us (Hagedorn 2002) by leaving water in ecosystems to maintain their functioning.

It is projected that by 2025, total water abstractions in Africa will increase by 54 percent of the current levels (FAO 2002a, Hagedorn 2002, and WCU 2002). More than half of this increase will be due to expansion in the irrigation. Expansion of irrigated land beyond the current 6 percent will cause further soil salinization and water logging and a further loss of valuable wetlands[6]. Dam construction may increase in resulting in loss of forests in river basins of 43 to 90 percent and groundwater resources will come under growing threat of overexploitation. Likewise, in Central and Latin America, the construction of small- to medium-size dams, which is projected to increase sharply during coming decades, is likely to affect freshwater biological diversity dramatically (Table 4)

[5] Studies show that freshwater biodiversity is relatively high in relation to the very limited portion of the earth's surface covered by freshwater and is concentrated in the tropics. Freshwater fish is 40% of all fishes and freshwater mollusks is 25% of all mollusks. Worldwide, the total number of freshwater species is estimated to be between 9,000 and 25,000 (WCU 2002).

[6] Farmers everywhere are pumping groundwater faster than nature is replenishing it. Water tables worldwide have been dropping 1.5 meters a year; rivers run dry for months before they reach the sea, including the Yellow River in China, the Indus in Pakistan, the Ganges in South Asia, and the Colorado in North America (CEDAR 2000).

Table 4. Threatened freshwater biological diversity due human extraction of freshwater (number of species)

	Fish	Amphibian	Reptile	Bird	Mammal
Africa	104	12	29	53	89
Central and Latin America	103	27	76	353	263
Source: WCU (2002). Vision for Water and Nature.					

To reverse the downward spiral of environmental degradation, there is need to understand and appreciate the wealth that healthy, functioning ecosystems represent in the form of both their intrinsic value and the many socio-economic benefits they provide. Human being as one important user of water resources, must be protected the environment by law and use water sustainably. For ecosystems to continue to produce their goods, a minimum amount of water must be left for its function.

In the subsequent sections we analyze water use efficiency levels in selected countries. We first present the methods used to selecting these countries and to analyzing the data.

4. Methodology

In order to articulate our analysis we select some countries two regions, namely Central and South America and Africa, following FAO- AQUASTAT project (FAO 2002). We select countries that have the highest level of efficiency of water management in the region because we need to have the best case scenario as our basis for analyzing the "scramble for water resources" between irrigation (agricultural) demand and natural resources. When region has several countries with the same levels of efficiency we selected those with the bigger land area. The idea is to have as many potential natural resource destructions as possible. (It is plausible to assume that natural recourse like species biodiversity is an increasing function of the area coverage).

We compare countries with high efficiency in Africa and in Latin America (Central, Caribbean and South America) with the same characteristics. The value of Total Renewable Water Resources divided by country surface (TRWR/surface) was used as indicator to make groups. Other competing indicators (e.g. water per capita) could be used also but they are already correlated with the level of efficiency and fail to show the potential areas that can that could be brought under irrigation.

We classify the countries in five categories according to their value of TRWR/surface. If a group had more than one country in a determined continent; we select those with bigger value in the range of the group. For comparative analysis, we do not take in consideration those groups without any representative country in both continents. Table 5 summarizes the results of our selections.

Table 5. Groups of countries with highest efficiency according to values of (TRWR/surface)

Group No.	(TRWR/surface)	Latin American Countries			African Countries		
1	x<1				Sudan	Egypt	Ethiopia
2	1<x<5	Mexico	Cuba		Mozambique		
3	5<x<10	Paraguay	Brazil		Congo D R	Madagascar	
4	10<x<15	Guyana	Peru				
5	15<x	Nicaragua			Sierra Leone		

Note: We multiply the range of values show in the column two (TRWR/surface) by 10000 for easy comparison.
The gray color means the groups or countries which are not selected for this study.
Source: FAO (2002a). AQUAST - Information System on Water and Agriculture.

According to this criterion, we identify 6 countries; country groups as summarized bellow.

	Africa	Latin America
Group 1	Mozambique	Cuba
Group 2	Madagascar	Brazil
Group 3	Sierra Leone	Nicaragua

On the one hand, we compare each of these groups in terms of irrigation facilities, techniques used, and planned irrigation projects and on other hand, actual and potential natural resource conservations or destructions. In each group, we assess how improved efficiency use of irrigation water could reduce potential distraction and enhance sustainability of natural resources. We draw most of the information as recompiled by (FAO 2002) as well as other information resources on the web.

5. Results

5.1 Group 1. Mozambique and Cuba

5.1.1 Irrigation systems and water demand

In Mozambique the relief influences the weather and the precipitation range is between 327 mm/year to 2611 mm/year. There is a significant variation in precipitation, with some years characterized by floods and others by dry periods.

Cuba has special shape of large island with a central mountain range, also more than 1600 islands conform the archipelago. The weather is relatively uniform allover the country, with average precipitation of 1375 mm/year.

The size of Mozambique is seven times bigger than Cuba Republic. However, the percentage of the area under irrigation respect to the total cultivation area is almost 5 times bigger in Cuba than Mozambique. Although Mozambique has a low proportion of irrigated area, its potential is big because more than 3.3 millions hectares could be irrigated using mainly the water of Zambezi river. Past social instability in Mozambique caused the irrigation systems to be in bad condition because most of the dams that were before the war were destroyed. All kind of irrigation systems can be found in Mozambique, ranging from basin irrigation to the furrow and sprinkler

The potentiality for expanding irrigation land in Cuba could only be possible by improving the efficiency because the limitation of water resources and aptitude land are important.

There is a significant difference in terms of water volume available in both countries. In Mozambique some of the big rivers such as the Zambezi and Limpopo of South Africa cross the country but Cuba has no large rivers and lakes and the main way to save water is the construction of small dams. The estimation of total water resources in Mozambique is 216km^3/year, instead in Cuba is 23.8km^3/year. The water withdrawal has important differences between both countries; in Cuba it is 8.6 times bigger than Mozambique. Table 6 gives descriptive statistics of the two countries.

Table 6. Comparative values between Mozambique and Cuba

	Area (km2)	Cultivated area millions ha	Cultivable area millons ha	Equipped irrigated area millions ha	% total land actually irrigated respect to total cultivated area	Potential irrigated area millons ha
Mozambique	801590	3.6	36	0.106	1.25	3.3
Cuba	110860	4.45	6.7	0.27	6.06	

	annual average precipitation (mm)	Volumen water km3	Total Renewable Water Resources km3/year	Water extraction (withdrawal) km3	use % Caws	Industrial	Agricultural
Mozambique	969	216		0.605			
Cuba	1375	23.8		5.21	15	35	50

Source: FAO (2002a). AQUAST - Information System on Water and Agriculture.

In Cuba the economic crisis suffered in the 1990s after the socialist block break down and the US economic blocking had affected the development and maintenance of the irrigation infrastructure in the island. Between 1991 and 1996 the area under irrigation declined by 18%. The area affected by salinization process is estimated to be 1,000,000 ha among fields with irrigation and those that have not.

5.1.2 Natural resources situation in Mozambique

According to the population projection and the availability of water, supply water is not a problem in Mozambique for the next 20 years. The total water available will be extremely bigger compare with the water demand. However, this accounting does not take into account the water needed by environmental and natural ecosystems. The environment is another major source of water use. Wildlife, wetlands, lakes, rivers, and other ecosystems need water to survive, meanwhile dams or field irrigation decrease the normal water flow required by the flood plain ecosystems on the Zambezi[7] (de Amorim 2002; Mpande and Tawanda 1988).

Any construction of dams for irrigation or electricity proposes may have widespread negative social and environmental impacts. Displacement of people and animals; burial of heritage sites, plants and animals, depletion of wetland habitats and aquatic life, increase in waterborne diseases and sedimentation are some of the main problems associated (IMERCSA 2000).

The lack of a water resource management on international rivers is one of the main causes for the occurrence of natural disaster. The floods in year 2000 over the river Limpopo, which is dammed in several places and countries and the lack of coordination between them where the cause for the devastating floods in Mozambique with important consequences in the population and natural ecosystems (Pearce 2000).

Other example was the Tugela Basin in South Africa which was defoliated due to overgrazing by cattle and drained for agriculture, without natural vegetation and wetlands to absorb water, the rain produced by the cyclone in 2000 brought massive flooding that flowed downstream into Mozambique territory with devastating effect (Hall 2001).

The eutrophication, pollution and proliferation of the water hyacinth weed are common process observed in many of the water bodies in Africa, included in Mozambique (de Amorim 2002). The use of fertilizer or cities water wasted is the main causes, affecting negatively the related ecosystems. Effluent collecting in the reservoirs may lead to eutrophication problems (Mpande and Tawanda 1988).

The reduction of caudal in the main rivers by the extraction of fresh water for irrigation or public consumption for the nine international rivers that share Mozambique, it had produced that the saltwater intrusion reduces the productivity of the estuaries ecosystems (de Amorim 2002).

5.1.3 Natural resources situation in Cuba

Cuba had suffered important changed in the management of natural resources after the social revolution in 1959. Cuba at the middle of last century was almost overexploited and few natural resources were left. The country was almost completely without forest before the revolution (Simeón Negrin 2001).

Several activities were done in order to guarantee a sustainable developing and the food supply of the island. One of the main activities proposed by the new government was reforested the island again and now the forest cover the 21.1% of the country (Simeón Negrin 2001). Other actions was the idea call "voluntad hidráulica", it involved the creations of the necessary dams

[7] The diverse ecosystem of the Zambezi River Basin also provides a wide range of natural resources that support the local population. Activities as forestry, wildlife, fisheries, and related tourist attractions are a source of livelihood for many peoples (Mpande and Tawanda 1988).

to do not permit that any drop of water reach the see. That was the obsession of the president Fidel Castro that Cuba increased the capacity to save water in 200 times. From 160000 ha irrigated in 1959 grow to more than 1000000 ha 30 years later (López V. 1998).

Cuba is one of the more advanced countries in the field of natural resources management (Kaimowitz 1996). Several actions were and are taken as national system of protected areas, sustainable agriculture, integrated watershed management, use of renewable energy sources; developing cleaner production, recovery of raw materials and lowering of ecological vulnerability by reducing pollution. The drinking water quality was improved and it is accessible by almost the entire urban and rural population (Simeón Negrin 2001).

Law as the "Decreto-Ley No.138" about terrestrial water promulgated in 1993 is a example of the governmental actions to protect, recovering, use and conservation of this natural resources expressed as well as superficial or subterranean water. This law takes in consideration as the definition of the catchments base, riverbed and the necessary hydraulic constructions to protect and secure access to the liquid constantly (Concepción 2001).

The country has improved the environmental quality during these last 42 years, but the lack of economics resources doesn't allow getting better levels in the management and protection of natural resources (Concepción 2001). Poor management of water resource are the over-pumping of fresh underground water for La Habana allowing the entry of salty water into the aquifer (Díaz D. and Antón 2002) or the waste of water from La Habana that until now flows without treatment to the ocean (López V. 1998). The tourism industry, in growing process in the archipelago, is becoming a important demander of fresh water, being competing with necessities of local people and crops (OIT 2001).

The habitat for the local fauna is in risk due to the use of agrochemicals, canalization of swamp areas and the modification of the rivers regimen (PHVA 2000).

5.2 Group 2. Madagascar vs. Brazil

Brazil is the biggest country (8,540,000km2) and covers more than one half of the Latin America. This area includes a very wide diversification of climate and population distribution. The precipitation varies between 900 to 4000 mm and according to the places in the country the necessities of water for irrigation are different.

Madagascar covers 587,040km2, the average in precipitation in the large parts if the country is between 1200 to 1500 mm per year, although in the south of the island precipitation can be between 400 – 600mm per year.

Currently the population in Brazil is estimated around 180 millions inhabitants. The population density varies according from region to region in the country, but on average is 20 inhab./km². Meanwhile in Madagascar the total population is 14.3 millions inhabitants (1998) and the density population is 28 inhab./km² (FAO 2000). Although the two countries have more or less the same density, there is large variations in Brazil; 3.3 inhab./km² in the north and 73.8 inhab./km² in the southeast.

Due to the big area of Brazil, the cultivated area also is big compared with Madagascar. The proportion of cultivated area respect to the total area of the country is 4.4% in Madagascar and 5.75% in Brazil. Of the cultivated area, 34.42% is under irrigation in Madagascar and only 5.7% in Brazil. The main reason is the well distributed of rain in most of the regions in Brazil, except in the northeastern of the country. The potential of irrigation land in Brazil is 29 millions ha considering availability of water and excluding areas of high ecological value, the most promise area is the Cerrados region.

Although the Internal Renewable Water Resources in Brazil is 15 times bigger than in Madagascar the water withdrawal is only 3.3 times bigger. Madagascar use most of the water for agricultural propose (99%), instead Brazil takes only the 61 % for irrigation. The irrigation techniques differ according with the region in Brazil. Some places in the south prefer more surface irrigation and in the southeastern and northeastern the sprinkler is the most used technique. A descriptive statistics for the two countries are summarized in Table 7.

Table 7. Comparative values between Madagascar and Brazil

	Area (km2)	Cultivated area millions ha	Cultivable area millon ha	Equipped irrigated area millons ha	% total land actually irrigated respect to total cultivated area	Potential irrigated area millons ha
Madagascar	587040	2.6	8	0.108	34.42	1.5
Brazil	8540000	49.1			5.7	29.3

	annual average precipitation (mm)	Volumen water km3	Total Renewable Water Resources km3/year	Water extraction (withdrawal) km3	use % domestic	Industrial	Agricultural
Madagascar	1200 -1500		337	16.3			99
Brazil	900 - 4000	8172	5323	54.9	21	18	61

Source: FAO (2002a). AQUAST - Information System on Water and Agriculture.

5.2.1 Natural resources situation in Madagascar

Madagascar has over 200,000 species of plants and animals not found where else on earth. The island is classified as one of the world's top three "hotspots" for biodiversity (GEDE 2002). Madagascar mountains biodiversity is very important and also is one of the 25 'hot-spots' for species extinction (Kakabadse 2002). Seventy-five percent of its original growth forests have been destroyed (Sweigart and Miller 1999).

The main problems observed in the environment in Madagascar are soil erosion results from deforestation and overgrazing; desertification; surface water contaminated with raw sewage and other organic wastes. This has led the lost of several species of flora and fauna unique to the island (CIA 2002). "Slash-and-burn" farming is practiced by some of the poorest and marginalized mountain communities in Madagascar (Gicchuki 2002; Sweigart and Miller 1999).

Like others coastal countries the mangrove forest in Madagascar is exploitation to several proposes, being the shrimp farming one of the main activities that had destroyed or eliminated considerably the coastal forest during the last ten years (Rivo 2001). The loss of habitat is a serious problem, especially when combined with damage from the periodic cyclones, droughts and locusts that have hit the island (Evans 2002).

Madagascar faces periods of tropical storms or hurricane and drought. Hurricanes have effects on natural environment. Trees are uprooted by winds and rains create landslides and massive erosion on hillsides. About 70,000 ha were damaged in the north of the district of Antalaha and major plains (Andapa, Maroantsetra) were completely flooded during the hurricane Hudah in year 2000 (ESA-GSC 2000).

Some enterprises have been developed in the island in order to secure the water supply to field crops and rural population; one example is the micro-irrigation systems in the high central plateau. The aim of these enterprises is to repair or improve small irrigation reservoirs and channels in the rice paddies, aided by villagers who are called on to form water consumer groups (AUEs). This initiative is leader by the Ministry of Agriculture's Rural Engineering Department. In the last 20 years it has helped some 80,000 rural families, created more than 77,000 ha of rice paddies and increased average yields by half. The controlled water areas also are useful to breed fish or grow crops (EUO 2002).

5.2.2 Natural resources situation in Brazil

Brazil is the richest country in the world in terms of freshwater resources holding the 17% of the available freshwater in the world. Also has the largest continental wetland area in the world, the Pantanal; and the Amazon is the largest flooded forest in the planet. However, Brazil is characterized by poor management of water resources such as overexploitation and pollution. All this stress not only affects people but also endangers animals and plants life (WWF-Brasil 2002).

Crops, city waste and industry pollute the water of rivers. Also the soil erosions have immediate consequence on the fluvial flora and fauna and the eutrophication process in lakes and reservoirs (Artigos 2000). Twelve percent of Brazil surface is affected by water erosion (Marcoux 1998).

Most of the rains in Brazil are concentrated in the Amazon region, while there are areas with deficit in the northeastern part of the country. Of that total water that flows in rivers, about 90 % are in the Amazonian region, where only 15 % of the population live. The rest of the water is found in the Northeast, South and Southeast regions where concentrate 85 % of the

The Atlantic forest was almost eliminated from the natural area; only 8% of the area has some relicts. The forest was transform during colonial times to coffee, sugar and cocoa plantations, but during the past 50 years even more forests were cutting down to produce wood materials for cattle ranches. Also these lands have the 50 percent of Brazil's population and 80 percent of its economic activity of the country (Salgado 2002).

During modern time Brazil government had built roads, railways, gas and oil pipelines, industrial waterways, mining operations and hydroelectric dams in the Amazon forest. This development will increase exports and economic growth in the short-term, raising per capita income of the average Brazilian. However, the long-term health of the Brazilian economy will be threatened by this economic development as natural resources are depleted without replenishment (Rocha, 1997).

During the last years Brazil had faced an energy crisis; which exposed the weakness and inefficient in the water use and management systems. Until late 1970s most of the Brazilian dams were built with the exclusive objective of generating electricity. Other water uses were not taken into consideration (Garrido 2001).

The government has been developing strategies to guarantee the supply of water to population and crops (World Bank 2002a). In 1998, Brazil launched the initiative: PROAGUA**,** a national program to manage water resources sustainably. Also the new National Water Agency (ANA) has taken the logical next step and uses the resources it has for pollution control not to build treatment plants, but to pay for results (in this case, treated effluent) (World Bank 2002b).

5.3 Group 3. Sierra Leone vs. Nicaragua

Sierra Leone is located in the southwestern part of West Africa and covers the area of 72 000 km^2. About 74% of the land is suitable for crop cultivation. The estimation of population for year 2000 is 5,232,624 inhabitants and the population density is 73 inhab./km^2.

Nicaragua has 130,000 km^2 and is located in the Central America isthmus. The population is 4794000 inhabitants and the its density is 37 inhab./km^2. Most of the fertile areas are located in the Pacific region, covering 15.2 % of the territory.

Sierra Leone is situated at the northern limit of the equatorial rainforest zone with an average in the rainfall of 2690 mm/year.

The main proportion of the population is rural (68%) and they obtain water from surface sources, such us streams and ponds.

The water withdrawal in Sierra Leone was about 0.37 km^3 in 1987. The suitable land to develop agriculture is about 807,000 ha, ignoring environmental aspects. Only 155,360 ha have a kind of water management activities[8]. Nevertheless the predominant type of farming in Sierra Leone is the bush fallow system, where there are not irrigation activities.

Nicaragua has several climates, registering precipitation between 500 to 5,000 mm per year, with the average of 2280 mm. The Internal Renewable Water Resources is estimate in 189.7 km^3/year. The pacific region, the driest and more populated area, has important stores of underground water with a potential use of 16 km^3/year. The estimation of water withdrawal is 1.3 km^3/year, which is divided 84% in agriculture, 14% in domestically sector and 2 % in industry.

In Nicaragua the 7.15% of the cultivated area is irrigated. This is about 61,365 ha. This value is much less lower than in Sierra Leone (155,360 ha), although the irrigation areas in Nicaragua have important improvement using pump, surface, sprinkler and macro irrigation. In Sierra Leone systems is quite undeveloped.

Considering the water resources and land properties the potential of irrigated area in Sierra Leone is 807,000 ha and in Nicaragua 273,175 ha. More characteristics of these two countries as summarized in Table 8

Table 8. Comparative values between Sierra Leone and Nicaragua

	Area (km2)	Cultivated area ha	Cultivable area millon ha	Equipped irrigated area millions ha	% total land actually irrigated respect to total cultivated area	Potential irrigated area millons ha
Sierra Leona	72000			0.155		0.80
Nicaragua	130000	714396		0.061	7.15	0.27

	annual average precipitation (mm)	Volumen water km3	Total Renewable Water Resources km3/year	Water extraction (withdrawal) km3	use %		
					Domestical	Industrial	Agricultural
Sierra Leona	2690	160		0.37	7	4	89
Nicaragua	2280		189.7	1.3	14	2	84

Source: FAO (2002a) AQUAST - Information System on Water and Agriculture.
POPPIN, 1994.

5.3.1 Natural resources situation in Sierra Leone

Sierra Leone is one of the most humid countries of Africa and some of the most important rivers of Africa cross the country (FAO 1997). Almost all year there are rains having no constrain to rain fed agriculture, except during the short intervening dry season (FAO 2001).

In the sedimentary basins of the shores large volumes of underground water are found in the aquiferous strata of Quaternary sediments (Biémi 1996). According with FAO (2002a) Sierra Leone is classified as one of the countries with a lower competition on water resources between people to ensure food for year 2025 (POPIN 1994).

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[8] It is the specific control of all human intervention on surface and subterranean water. Every planning activity that has something to do with water can be looked upon as water management in the broadest sense of the term. (FAO 2002a)

Other important natural resource in Sierra Leone is the tropical forest which extends to the neighbor countries. They have global importance as the last significant remains of the structurally complex and species-rich forests of the west equatorial rainforest zone (UNEP 1997). The per capita area of forest/woodland in 1993 was 0.50 ha (Marcoux 1998).

Several environmental problems were identified in the country as deforestation, poor housing and unsanitary environmental conditions, overexploitation of fisheries, over harvesting of timber, expansion of cattle grazing, and slash-and-burn agriculture have resulted in deforestation and soil exhaustion, civil war depleting natural resources, pollution of water resources from mining and household wastes (Marcoux 1998; CIA 2002, POPIN 1994).

The land degradation by chemical way occurs in 95% of the country and deforestation 47% of the surface (Marcoux 1998).

The mangrove forest also faces deforestation, large areas of rice grown in the mangrove swamps and in river estuaries during the wet season. Twenty thousand hectares of mangrove swamps are already cropped (FAO 2001).

According to UNEP and the World Conservation Union, they estimated than over of 80% of the wild habitats in Sierra Leone had already been lost (WEC 2001)

Sierra Leone has suitable area for agriculture development; it is estimated at 807000 ha, ignoring environmental aspects of wetland development (FAO 1997). With respect to water issues, the efforts should be focus on develop water control and drainage rather than irrigation *per se*, although supplementary irrigation can be practiced particularly for crops (FAO 2001).

5.3.2 Natural resources situation in Nicaragua

Nicaragua has the water resources to supply the future necessities of the country, but lamentably most of this water goes through poor quality lands for agriculture to Caribbean Sea. Only 3.3 % of the total water originated in Nicaragua goes to the Pacific Ocean when most the population and productivity activities are. The internal lakes of Nicaragua have the amount of water able to supply the necessities of the land in the pacific region for agricultural propose (water for irrigation is not full utilized) (Sánchez 2001).

Although there are enough water in the country the distribution also of the precipitation is irregular 93% is the Atlantic and 7% in Pacific region where exist hydric stress some periods of the year (ADC et al 1998).

The underground water for the pacific and central regions is estimated in 2300 millions of meters cubic per year (Sánchez 2001). But some experienced showed that the pumping of underground water reduced it level until the point that rivers and neighbor’s lagoons became dry (i.e: lagoons Nejapa and Tiscapa) (ADC et al 1998).

Several problems face the water resources in the country. Contaminated water goes downstream affecting the fauna and flora of local ecosystem (ADC et al 1998). The main reasons of this contamination are the spill organics material, agrochemicals, untreated sewage, cattle activity, industrial gas emissions and evacuation of toxic remainders of the industry. More of 90% of the population throws waste to rivers and swamp (mangrove areas) (UICN 1998). A clear example is the untreated sewage and industrial waste of Managua that it is discharged into the lake Managua (Danida 2000).

Respect to forest cover in the country this was practically conserved during 10-year civil war in the 1980s, but the relatively stability of the 1990s open the possibility to use and exploit the natural resources. Logging concessions were granted but the control activities and corruptions were not helpful to save the forest. On the other hand the advance of the agricultural frontier into the hinterlands continued, forested areas was slashed and burned, clearing them to make room for cattle ranching (Cooke 1998).

The Hurricane Mitch showed how big the consequences of movement of human agricultural frontier and deforestation could be. During the October 1998 storm, rainwater and mud flowed 904,000 people (RCA, 2002)

The deforestation in Nicaragua has different consequences as the lack of forest products, un-stabilization of watersheds, microclimatic changes, soil degradation and lost of biodiversity (ADC 1998).

There are multiple plans for reforestation along the slopes of watersheds in recognition of the need to manage these in a better fashion to ensure a supply of drinking water into the future (Cooke 1998).

6. Summary, Conclusion and Policy Implications

6.1. Summary

The fear of food shortages encourages greater use of water resources for agriculture. In the future, more waters will be diverted to growing crops. But as the need to divert water for irrigation development, demand from other sectors such as domestic and industrial development also increase. Allocation of water to these sectors should take into account water needed to protect the resource and the ecosystem. Many believe this conflict is one of the most critical problems to be tackled in the early 21st century.

The projected 54% increase in water abstractions in Africa, and elsewhere in the developing countries by 2030 is mainly due to expansion in the irrigation. But such expansions will be associated with further soil salinization and water logging and a further loss of valuable wetlands. Dam constructions will result in loss of forests in river basins, killing and displacing other ecosystems. In many places, groundwater resources will come under growing threat of overexploitation. Improved efficiency water use in irrigation can play significant role in reducing water abstractions and spare water for the environment.

6.2. Conclusion and Policy Implications

For sustainable development, there is urgent need to reverse the downward spiral of environmental degradation caused by overexploitation of water resources. Policy makers must understand the wealth of functioning freshwater ecosystems, intrinsically and socio-economically and appreciate benefits they provide. The environment, as one of the users of water resources must be protected by law and sustainably managed. For ecosystems to continue to produce their goods, a minimum amount of water must be left for the ecosystems to function. One way to achieve this is to increase efficiency use water in the largest water consumer, the agricultural sector.

In developing countries where agriculture is dominated by small-scale farmers, the biggest challenge would be to provide incentives for communities to undertake self-help projects that direct the people towards safe and sustainable exploitation of water resources. In many places effort has been directed to ensure a more positive involvement of local communities in the conservation and management of their water resources and the environment. This mobilisation of popular participation, with able organizers and appropriate information support, may offer a great opportunity for sustainable management of water resources.

In case of large scale projects, water management measures should consider storage of surface or groundwater, aquifer recharge, water desalination, water recycling, reduction in wastage and water pollution control. The economic measures of pricing policies that control and limit wastage or control pollution and incentives such as tax exemptions to promote rational water use should also be recommended. It can take the form of water tariffs - a direct consequence of the water-as-an-economic-good principle which can also help to transform the typical water user into a rational user.

Setting priorities for certain uses of water must be coordinated across the length and breadth of a river basin. In cases where water demand grows beyond what is immediately accessible, management should deal with competition between various interests and allocate set amounts to such interests. Land and water uses, rural and urban interests and upstream and downstream areas should be integrated with the help of formal institutions. All affected parties should jointly and responsibly decide on the allocation of water throughout the basin. This also applies to cross-boundary water resources, although the process will now involve (require) higher authorities in the countries involved.

There is also need to change wasteful practices of the water use in all sectors. There should be concerted effort towards increasing public awareness and knowledge concerning water use and environmental education, in general.

7. Reference

ADC-Fundación Acceso-UICN (1998). Memoria del 1er Taller de la Red de Nicaragua Presentación del Proyecto Iniciativa Centroamericana en Población y Ambiente (POAM). Asociación Demográfica Costarricense-Fundación Acceso-Union Mundial para la Conservación de la Naturaleza. 25th June. Managua, Nicaragua. http://www.poam.org/articulos-estudios/actividades/memoriani.pdf

Alcamo, J., T. Henrichs and T. Rosch, (2000). World Water in 2025: Global Modeling and Scenario Analysis, in Rijsberman (ed), World Water Scenarios Analyses, Earthscan Publications, London.

de Amorim, M. (2002). “Environment and Peace: An Important Nexus for Sustainable Development in Africa”. United Nations Environment Programme, Regional Office for Africa. http://www.globesa.org/amorim.htm

Artigos (2000). A brief report on water resources in Brazil. Nov. 2000.http://planeta.terra.com.br/educacao/pnrh/artigo/abrief.htm

Biémi, J. (1996). Water Crises and Constraints in West and Central Africa: The Case of Côte D'Ivoire. In: Water Management in Africa and the Middle East. Challenges and Opportunities. Ed. by Rached et al. International Development Research Centre. Ottawa, Canada. http://www.idrc.ca/books/focus/804/chap6.html

Brito (2001). Country Profile – Brazil. International Commission on Irrigation and Drainage. .http://www.icid.org/index_e.html

CEDAR (2000). CEDAR Newsletter Sept. 2000. http://www.cedarfund.org/eng/newsletter/2000/09/section1.htm.

CIA (2002) World Fact Book: Field Listing - Environment - current issues. USA Central Intelligence Agency. http://www.cia.gov/cia/publications/factbook/fields/2032.html

Concepción, D. 2001. Legislación de los Recursos Hídricos. 1ra Feria del Agua de Centroamérica y el Caribe. 25th to 28th Oct. Panama. http://www.feriadelagua.org/ documentos/FORO/D_Concepcion.PDF

Cooke, N. (1998). Environment under Fire. Nica News 14, Vol. 2, No 4-14 (June 1998). Managua, Nicaragua. http://www.nicanews.com.ni/nn14/environment.html

Danida (2000). Water Resources Management. Ministry of Foreign Affairs Dec. 2000. http://www.um.dk/upload/publikationer/WaterResources.rtf

EUO (2002). Madagascar. European Union Online. http://europa.eu.int/comm/development/publicat/indian/pdf/madagascar_en.pdf

Evans, R. (2002). Madagascar biodiversity threatened. BBC Documentary, 16th Jan., 2002. http://news.bbc.co.uk/1/hi/world/africa/1761893.stm

FAO (1997) Irrigation potential in Africa: A basin approach. FAO Land and Water Bulletin 4. FAO Land and Water Development Division. http://www.fao.org/docrep/W4347E/w4347e0v.htm

FAO (2000). Mission to Assess the Impact of Cyclones and Drought on the Food Supply Situation in Madagascar 1 June 2000. FAO/WFP. Global Information and Early Warning System on food and agriculture. Special Report Alert. http://www.fao.org/WAICENT/faoinfo/economic/giews/english/alertes/2000/SRMAD500.htm

FAO (2001). Smallholder Irrigation Technology: Prospects for Sub-Saharan Africa. International Program for Technology and Research in Irrigation and Drainage. Knowledge Synthesis Report No. 3 - March 2001. Rome. http://www.fao.org/DOCREP/004/ Y0969E/y0969e06.htm

FAO (2002). AQUASTAT - Information System on Water and Agriculture. Accesses on Nov. 6, 2002. http://www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/main/index.stm.

Faurès, J.M.; Hoogeveen, J. and J. Bruinsma (2001). The FAO Irrigated Area Forecast for 2030. http://lnweb18.worldbank.org/ESSD/essdext.nsf/18DocByUnid/18A78C3BF51F68D585256BE9007535F2/$FILE/Faures_Hoogeveen_Bruinsma.pdf

Garrido, R. (2001). Water Resources National Policy in Brazil. Ministry of Environment, Brazil. Prepared for Thematic Review V.3: River basins-institutional frameworks and management options. http://www.damsreport.org/docs/kbase/contrib/ins226.pdf

GEDE (2002). Genesis of Eden Diversity Encyclopedia http://www.dhushara.com/book/upd3/2002a/bbc1/bbc4.htm.

Gichuki, F.N. (2002) Water, Environment and Development in Mountain Areas and Surrounding Lowlands. Africa High Summit Conference, UNEP, 6-10th May 2002, Nairobi. http://www.mtnforum.org/resources/library/gichf02a.htm

van de Giesen, N., M.C. Andreini, A. van Edig and P. Vlek (2001). Competition for water resources of the Volta basin. Regional Management of Water Resources (Proceedings of a symposium held during the Sixth IAHS Scientific Assembly at Maastricht, The Netherlands, July 2001). IAHS Publ. no. 268.

ESA-GSC (2000). MADAGASCAR - Hurricanes Gloria, Eline and Hudah (Feb-April 2000). European Space Agency-Geoscience Consultants. http://earth.esa.int/applications/dm/GSP/magagasc.htm.

Hagedorn, K. (2002). Water resources and water management as a global problem under different economic, natural and political conditions. Humboldt University of Berlin, (http://www.agrar.hu-berlin.de/wisola/fg/ress/Lehre/umress2/opoku.doc)

Hall, J. (2001). Southern Africa Unites against Water Poverty. 10/19 : GloboalizeWatch: Tobacco, Cloning, Coke Vs. HIV/AIDS, Water. ActionLA Affinity Group. http://www.peacenowar.net/GloboalizeWatch/Oct%2019%2002%20Updates.htm

IMERCSA (2000) State of the Environment Reporting in the Zambezi Basin (SOEPROZ). State of The Environment Zambezi Basin. India Musokotwane Environment Resource Centre for Southern Africa. http://www.sardc.net/imercsa/zambezi/zambezi2000/summary/energy.html

INPE (2000). Monitoring of the Brazilian Amazonian Forest by Satellite 1998-1999. Instituto Nacional de Pesquisas Espaciais, Ministerio da Ciéncia e Tecnologia. http://www.inpe.br/Informacoes_Eventos/amz1998_1999/index_amz.htm

IWMI (2000). World Water and Climate Atlas. http://www.iwmi/atlas/atlas.htm .

OIT (2001). En busca de un turismo socialmente responsable. Organización Internacional del Trabajo. No. 39, June 2001. http://www.ilo.org/public/spanish/bureau/inf/magazine/39/tourism.htm

PHVA (2000). Memorias del taller Cocodrilo Cubano: Análisis de la Viabilidad de la Población y del Habitat. 21th-25th Jan. 2000. Isla de la Jiventud, Cuba. http://www.cbsg.org/reports/exec_sum/cuban_croc_phva.pdf

Kaimowitz, D. (1996). “La investigación sobre manejo de recursos naturales renovables para fines productivos en América Latina”. Inter-American Development Bank. No ENV 104. Washington D.C. http://www.iadb.org/sds/doc/env-104s.pdf

Kakabadse, Y. (2002). The height of trouble. Our Planet.United Nation Environmental Program (UNEP). http://www.ourplanet.com/imgversn/131/kaka.html

López V., M. (1998). “Cuba 20 Temas Para una Agenda Verde”. Conferencia de Ética y Cultura del Desarrollo 31 May - 6 June 1998. La Havana, Cuba. http://www.afsc.org/cuba/ grnagnds.htm.

Marcoux, A. (1998). Population Change - Natural Resources - Environment Linkages in East and Central Africa. Sustainable Development Department, FAO. http://www.fao.org/WAICENT/FAOINFO/SUSTDEV/Wpdirect/ Wpan0021.htm

Mpande, R.L and M. Tawanda, 1988. Water and Population Dynamics: Case Studies and Policy Implications. CASE STUDY: SOUTHERN AFRICA Population Dynamics and the Emerging Competition for Water Use in the Zambezi River Basin. http://www.aaas.org/international/ehn/waterpop/southaf.htm

Pearce, F. (2000). “Unheeded warnings”. New Scientist, 2229, 11 March 2000. http://www.geodata.soton.ac.uk/ hypermail/envsci2000/group6/topic2/0009.html

PIP (1998). *Population Reports*. Population Information Program, Center for Communication Programs, The Johns Hopkins School of Public Health. Volume XXVI, Number 1, Sept. 1998. http://www.jhuccp.org/ pr/m14/m14print.stm

POPIN (1994). Population and water resources. United Nations population information network. http://www.un.org/popin/fao/water.html

RCA (2002). Fool’s Gold. Cash-strapped governments squander natural wealth for IMF credit. Resource Center of the Americas. http://www.americas.org/News/Features/200004_IMF_Environment/index.asp

Rijsberman, F.R. and D. Molden (2001). Balancing water uses: Water for food and water for nature. International conference on fresh water, Bonn, Germany. http://www.water-2001.de/co_doc/Water_for_food.pdf

Rivo, R. (2001) “Madagascar: Mangrove importance and threat”. World Rainforest Movement, WRM's bulletin No. 51, Oct. 2001. http://www.wrm.org.uy/bulletin/51/Madagascar.html

Rocha, J., *The Guardian,* London, cited in *Infoterra - News Service of the United States Environment Program,* Sept. 1997). http://www.geog.ouc.bc.ca/geog/day/g310/ 4_1.htm.

Díaz D., C. and D. Antón (2002) Sequía en un mundo de agua. Capítulo 8: “El uso humano del agua y su impacto sobre los sistemas naturales”. Red Temática de Ciencias de la Tierra de España. http://tierra.rediris.es/ hidrored/ebooks/sequia/cap08.html

Salgado, S. (2002). How to help. Insituto Terra. http://www.terra.com.br/sebastiaosalgado/e1/e_howtohelp.html

Sánchez, E.(2001). Plan para acabar con la sequía. El Nuevo Diario. Managua, Nicaragua. http://www-ni.elnuevodiario.com.ni/archivo/2001/septiembre/21-septiembre-2001/nacional/nacional9.html

Shiklomanov, L. A., (1999). World Water Resources: An Appraisal for the 21st Century. IHP Report. UNESCO, Paris.

Simeón Negrin, R.E. (2001). World Environment Day 2001: Message from Cuba. http://www.ourplanet.com/ imgversn/121/cuba.html

Sweigart, J. and D. Miller (1996). "Classic Dum's." in Wells, Jerry G. (eds.) The Living Boas. T.F.H. Publications, Neptune City. http://members.tripod.com/boas-dumerils/id35.htm

UNEP (1997). Africa:Major Environmental Concerns. Global Environment Outlook-1. Global State of the Environment Report 1997. United Nations Environmental Program. http://www.grida.no/geo1/ch/ch2_3.htm

UICN (1998). Ordenamiento Ecológico de los Ecosistemas Costeros del Golfo de Fonseca. Unión Mundial para la Conservación de la Naturaleza. Boletín de Humedales y Zonas Costeras Volumen 1, No. 2. http://uicnhumedales.org/boletin/archivo/no2/proyecto1.htm

WCU (2002). Vision for Water and Nature, World Conservation Union.

WEC (2001). Living in One World: Stresses and Projected Stresses on Our World. World Energy Council. London, UK. http://www.worldenergy.org/wec-geis/publications/reports/ liow/stresses/land.asp

World Bank (2002a). Water Resources Management at a Glance. (http://lnweb18.worldbank.org/ESSD/essdext.nsf/43DocByUnid/4913038219ADEF1985256C36007AC78F/$FILE/WaterResourcesManagementAtAGlance.pdf

World Bank (2002b) Sector Strategy Paper:Water Resources. SSP Consultation Draft of 25th March 2002. International Commission On Large Dams. http://icold-cigb.net/Water2.pdf

WWF-Brasil (2002). Freshwater Program. World Wildlife Fund - Brazil, http://www.wwf.org.br/english/projetos/default.asp?module=tema_freshwater.htm

Yamauchi, H. (2002). Global Fresh Water Resources, Supply and Use. Leadership for Environment and Development (LEAD). London, Great Britain. http://www.lead.org/lead/training/international/okinawa/papers/hiroshi.htm