An assessment of the sustainability of water resource development and use in the Chad Basin of Cameroon

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ABSTRACT

Water is an important resource necessary for development of agriculture and life especially in dry lands. The use of surface and groundwater resources by traditional and modern irrigation systems in the Chad Basin raises questions of their sustainability. The paper uses a combination of primary and secondary data to assess the sustainability of these development actions based on the ecological, economic, social and political components of sustainable development. It concludes that traditional irrigation methods are already foundering in the face of the actual socio-economic realities and therefore, cannot satisfy the demands of water delivery capable of supporting intensive and extensive cultivation on a year round basis. The current blend of traditional and modern irrigation systems and rapidly changing socio-economic conditions have rendered the ecological, social, economic and political operational goals of sustainability obsolete. Finally, the paper recommends that sustainable water use could best be achieved by adopting a combination of flood irrigation and pump irrigation. This will require a holistic and integrated planning of the development and use of the water resources of the basin.

Key words: Water resources use, sustainable development, traditional irrigation methods, modern irrigation methods, assessment, components of sustainability. Chad Basin of Cameroon.

RESUME

L'eau est une importante ressource pour le développement de l'agriculture, mais surtout pour la vie en général. Les systèmes d'irrigation traditionnels et modernes dans le basin du Lac Tchad, posent aujourd'hui le problème de leur durabilité. Cet article utilise les combinaisons des données primaires et secondaires pour apprécier la durabilité de ces actions de développement. Cette appréciation est basée sur des critères écologiques, économiques, sociaux, et politiques. Vue les réalités socio-économiques actuelles, les systèmes d'irrigation traditionnels ne peuvent plus satisfaire la demande en eau pendant toute l'année, de l'agriculture intensive et extensive. L'article enfin, démontre que l'utilisation durable de l'eau peut être mieux réalisée par l'adoption des systèmes de pompage d'eau souterraine et du système d'inondation. La gestion durable de l'eau nécessite un planning de développement global et intègré, conclut l'article.

Mots clés : exploitation de ressource en eau, développement durable, système d'irrigation traditionnel, système d'irrigation moderne, évaluation, composantes de la durabilité, Bassin du Lac Tchad.

INTRODUCTION

Current concerns about global warming and desertification and their impacts on environmental resources are concerns in the discourse of sustainable resource development and use. Water is an important resource necessary for the development of agriculture and life. Cunningham and Saigo (2001) record some rivers in the world that sometimes dry up completely because of human diversions and excess consumption. These include the Colorado in the U. S. A, the Amu Dar'ya and Syr Dar'ya in Kazakhstan, the Ganges in India, the Yellow River in China and the Nile in Africa. The drying up of these once mighty rivers is only a symptom of a larger dilemma. In many countries around the world water shortages are increasingly common. Signhonnou (1996) and Molinier et al (2000) concluded that the management of the water resources of the Chad Basin of Cameroon is below expectation. The United Nations warns that water supplies are likely to become one of the most pressing resource issues of the twenty-first century (Cunningham and Saigo, 2001). Sustainable water resource development and use therefore is a global concern. Overall social development is only sustainable if no deterioration occurs in the medium and long-term in the ecological social, political and

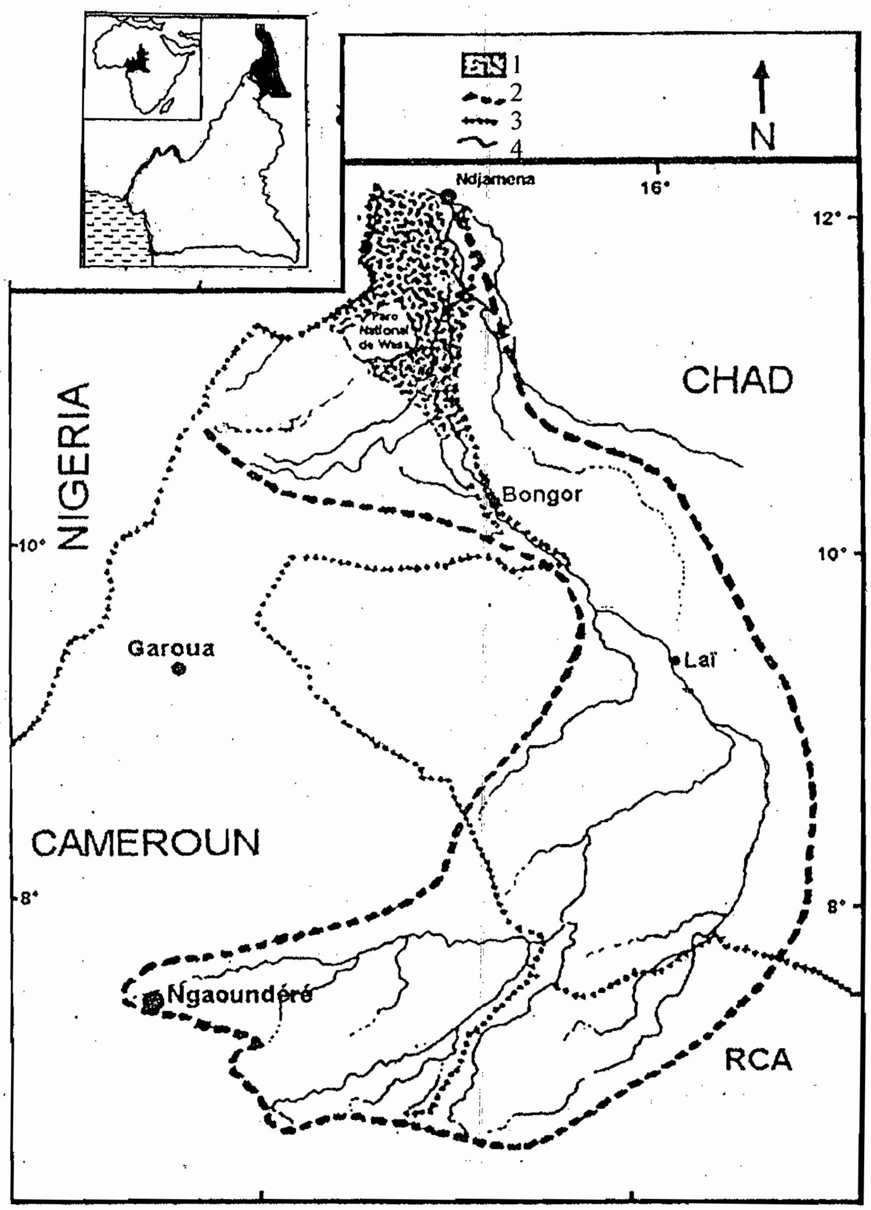

Fig. 1: Location of the study area: The Chad Basin of Cameroon: 1 = seasonally flooded zone, 2 = drainage basin limit, 3 = frontier, 4 = rivers.

economic sectors. The content of the concept of sustainable development varies according to culture, time and perspective, and can be understood only by adopting an integrated approach (Kohler, 1996; Chifos, 2006). It represents a major challenge to geographers, because geography in particular is the science which can sensibly combine the social and economic aspects. With this in mind, the paper seeks to assess the sustainability of water resource development and use in the Sudano-Sahelian regions using the Chad basin of Cameroon as case study.

STUDY AREA AND PROBLEM BACKGROUND

The Chad Basin of Cameroon is located within latitudes 10^0N and 13^0N and longitudes 100E and $12^0$50'E. It has a land surface area of 323,310 km^2 with an average population density of 58 inhabitants / km^2 (Neba, 1999). The area is semi-arid with 7 or more months of drought, a mean annual rainfall of about 900 mm in the South and 400mm in the Lake Chad shore. Mean annual temperature is 28^0C with a mean annual range of 7.7^0C (Moby, 1979). The Logone River and its tributaries originate in areas of high rainfall (Figure 1). Upon reaching the region's plains their gradients are sharply reduced and sediments are deposited, creating the swamps of the Logone River flood plain and the Chad Basin.

Three broad morphological units exist, namely, the alluvial plains, Diamare plains and the Mandara Mountains. The relief is largely below 500 m above sea level and is developed on the Quaternary deposits of the Chad Basin colonized by Steppe savanna. It is a mosaic of wooded savannas, thorn bushes, farmlands and natural pastures. These have been intensively degraded by over-grazing, slash-and-burn cultivation and deforestation resulting in runoff, gullying and alluvial processes.

Since sediment deposition causes channel aggradations and division, during the wet season the rivers become wide, shallow, slowly moving sheets of water subject to enormous losses by seepage and evaporation (Morin, 1979). Floods generally result from a single large storm, which does not necessarily coincide with a year of exceptional high annual rainfall. Ledger (1964), Fulton et al. (1974) and Olivry (1979) found that vegetation, along with slope and soil permeability is important in controlling peak flows in the streams and rivers. Vegetation cover is the most important (Pahai, 1979). Rainfall considered as a resource can only be evaluated within the framework of complex hydrological and geological relationships. An estimated 9,800 km^2 of land in the Logone - Chari alluvial plain is flooded every year by bank overspill and by runoff.

The region was an important antiquity area characterized by large kingdoms (Marliac, 1979). Agriculture was based on a sophisticated system of terraces and water harvesting techniques in the Mandara kingdom. The Logone - Birni and the

Table 1: Frequency of Variability of Annual Rainfall (1970 - 1988) and mean annual total number of rainy days (1940 - 2060)

Probability of rainfall greater than the threshold indicated	Threshold rainfall (mm)			
	Kaele	Maroua	Garoua	Toubouro
0.8	622	631	820	987
0.5	655	675	883	1054
0.2	781	780	1014	1247
Average for the period	666	752	951	1180

Mean total number of rainy days computed from trend lines						
Stations	1940	1960	1980	1995	2030	2060
Maroua	72.8	71.8	70.8	70.1	68.4	66.9
Garoua	82.1	79.7	77.2	75.4	71.1	67.4

Kotoko kingdoms developed irrigation techniques based on the flooding of fields. These indigenous irrigation and water harvesting techniques have survived to date. Economic development in the region therefore depends on the use of water for agriculture purposes.

Lake Chad is shared by Cameroon, Chad, and Nigeria. The surface area of the lake has decreased from 24.00km^2 to 12.00km^2 and the average depth hardly exceeds 4m. The volume of water in the lake is shrinking due to alluviation, evaporation, infiltration and losses due to natural overflow at Bahre-el-Ghazal, which drains northwards into the Bodele depression (LCBC, 1972). This raises concerns on the sustainability of water resources in the Chad Basin. Global warming and desertification also call for an assessment of the sustainability of the water resources, their rational development and usage.

STUDY METHODS AND CONCEPTUAL CONSIDERATIONS

The study collates data obtained from primary and secondary sources to assess current water development and management strategies as they relate to questions of sustainability. Primary sources include field observations and irrigation - related land use activities in three villages using aerial photographs from the National Geographic Institute (IGN Mission 67 - 68 CAM 01/200 No. 189 and IGN Mission 78 CAM 131/200 No. 54). Data on climatic parameters investigated was obtained from the Provincial Meteorological station in Maroua. This was complemented by secondary data. The soil moisture balance was estimated using the Piche Method. Hydrological characteristics were obtained from the archival material of SEMRY (Yagoau Rice Development Authority) and other documented sources. Field observations in three villages yielded data on water use techniques and water resource potentials. The data so obtained was used to assess issues of water development and management related to the ecological, economic, social and political components of sustainable development.

The discourse of sustainable development is concerned with identifying models of development that facilitate the equalization of benefits across time and space. This necessitates the rethinking of the relationship among natural, social, cultural, political, economic and built systems as they act and are acted upon along a pathway of change (Chifos, 2006). The discourse opens an arena to reexamine our conceptions of progress and to re-define trajectories that will enable that progress for more people both today and long into the future (Meadowcroft, 1999).

WATER RESOURCE AVAILABILITY AND USE IN THE CHAD BASIN

The region is characterized by a Sudano-Sahelian climate with 7 dry months and a 5 months wet season. July and August rainfall accounts for 66% of the total annual rainfall. Inter-annual rainfall variability is also typical. (Figures 2 and 3). Inter-annual average rainfall before 1970 was 700mm. after 1970 it dropped to 500mm following a general fall in the rainfall regime in the whole of tropical Africa (Olivry, 1986; Mahe and Olivry, 1991; Olivry, 1993 and Olivry et al. 1994).

Table 1 presents the frequency of rainfall variability for the period 1970 to 1988 and the mean number of rainy days computed from trend lines (Ayonghe, 2001) for the period 1940 to 2060. According to Ayonghe (2001) high rainfall was evident from 1951 to 1967, 1977 to 1980, and 1989 to 1995, while low rainfall was observed

Table 2: Evaporation rates in some weather stations

Station	Evaporation (mm/month)											
	J	F	M	A	M	J	J	A	S	O	N	D	**Total**
Poli	236	279	323	225	127	66	55	56	51	81	149	202	**1850**
Maroua	228	296	365	304	203	199	81	60	83	143	229	213	**2396**
Kousseri	345	389	506	451	362	265	149	74	96	206	353	341	**3519**

Source: *Maroua: Provincial Meteorological Station*

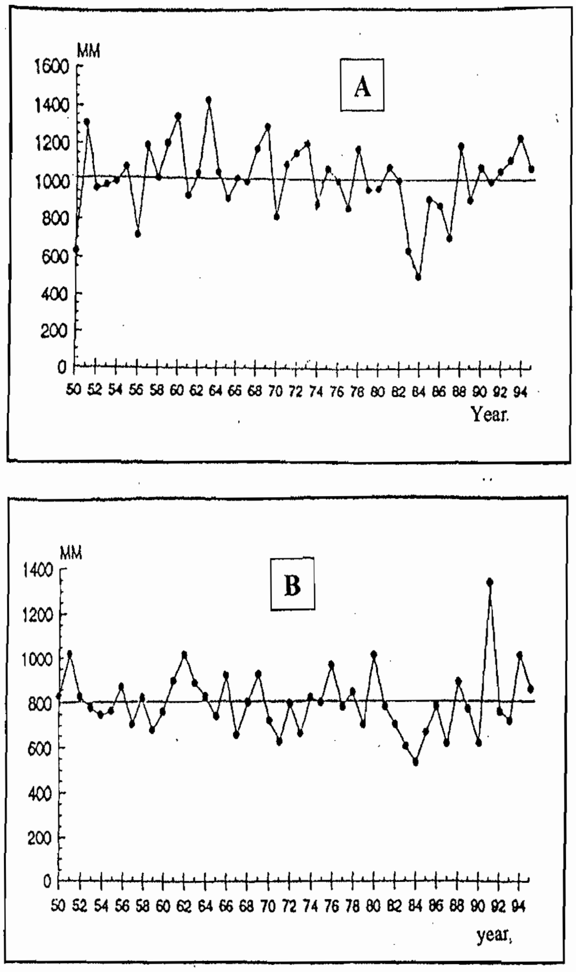

Fig. 2: Evolution of annual rainfall in some stations: A = Garoua from 1950 to 1995 and B = Maroua from 1950 to 1995 (after Donfack, Boukar and M'Biandoun, 1996)

from 1930 to 1950, 1968 to 1976 and 1981 to 1988. In general the mean total number of rainy days for the period 1940 to 2060 is on the decline. The rainy season lasts three to six months depending on the location and it is characterized by inter-annual variability of rainfall. Figure 3 presents the frequency of the total annual rainfall with a probability of 8 out of 10 years for the period 1952 to 1969 and 1970 to 1989. It again depicts inter-annual variability.

Figure 2 presents the inter-annual variability of rainfall in Maroua and Garoua. Table 2 presents the evaporation rates for some stations in the area. Evaporation rates are high and large water deficits occur (Figure 4). The moisture available to plants is related to the capacity of the soil to absorb and retain water. Data from the Maroua weather station was used to estimate the moisture balance in well drained upland soils (Figure 4). In figure 4 the average monthly rainfall (R), potential evapotranspiration (PE) and actual evapotranspiration (AE) were estimated using the Piche Evaporimeter. The annual values of PE, AE and rainfall are 1744mm, 969mm and 968mm respectively.

The moisture in the soil at the end of each month was calculated by adding the amount of available moisture at the end of the previous month. For

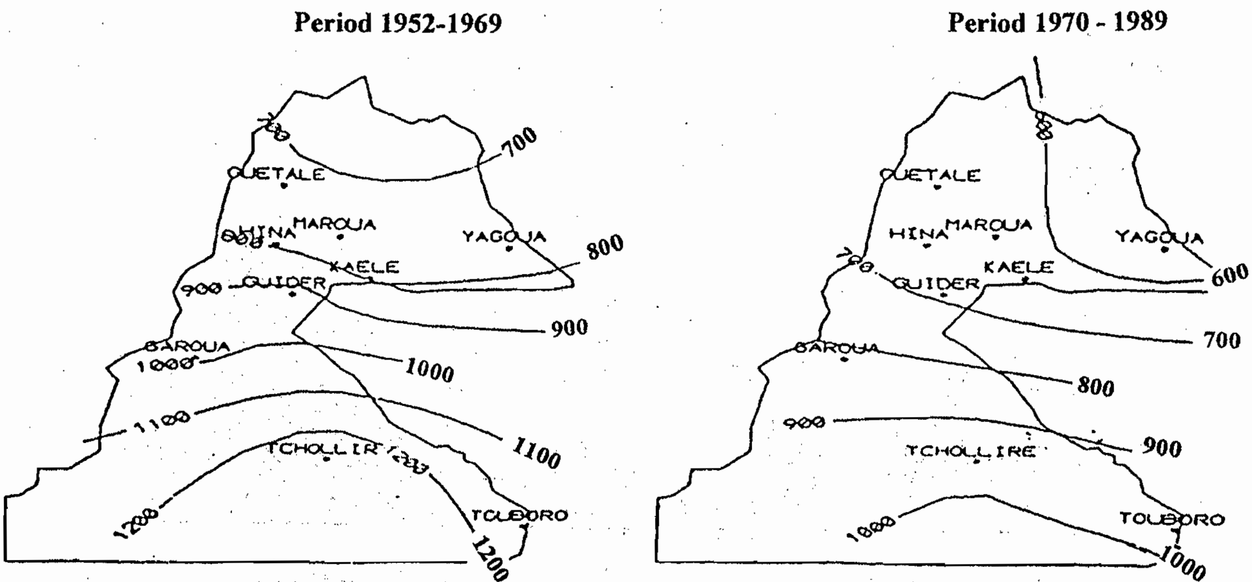

Fig. 3: : Frequency of total annual rainfall (mm): 8/10 years (After Mbiandoun, 1990).

example, at the end of June about 25mm of moisture available to plants was stored in the soil. During July rainfall was about 250mm and plants utilized about 140mm of moisture. At the end of July approximately 135mm of moisture were stored in the soil [(25mm + 250) - 140mm]. This then was the amount of available moisture for use by plants in August. The shaded part shows the amount of moisture in the soil that is available in plants. For about 110days from July through October, the available moisture in the soil exceeds PE, and plant growth is rapid. The unshaded part below the PE graph shows that growth is restricted by lack of moisture until the next period of high rainfall. For soils that retain less than the maximum available moisture for plants (about 260mm at Maroua) this period is shorter because excess water moves through the soil to replenish the ground water. The rainfall is concentrated in a very short time of the year. Evaporation rates are equally very high: Maroua has 2396 mm/year while its rainfall is only 804mm. within this

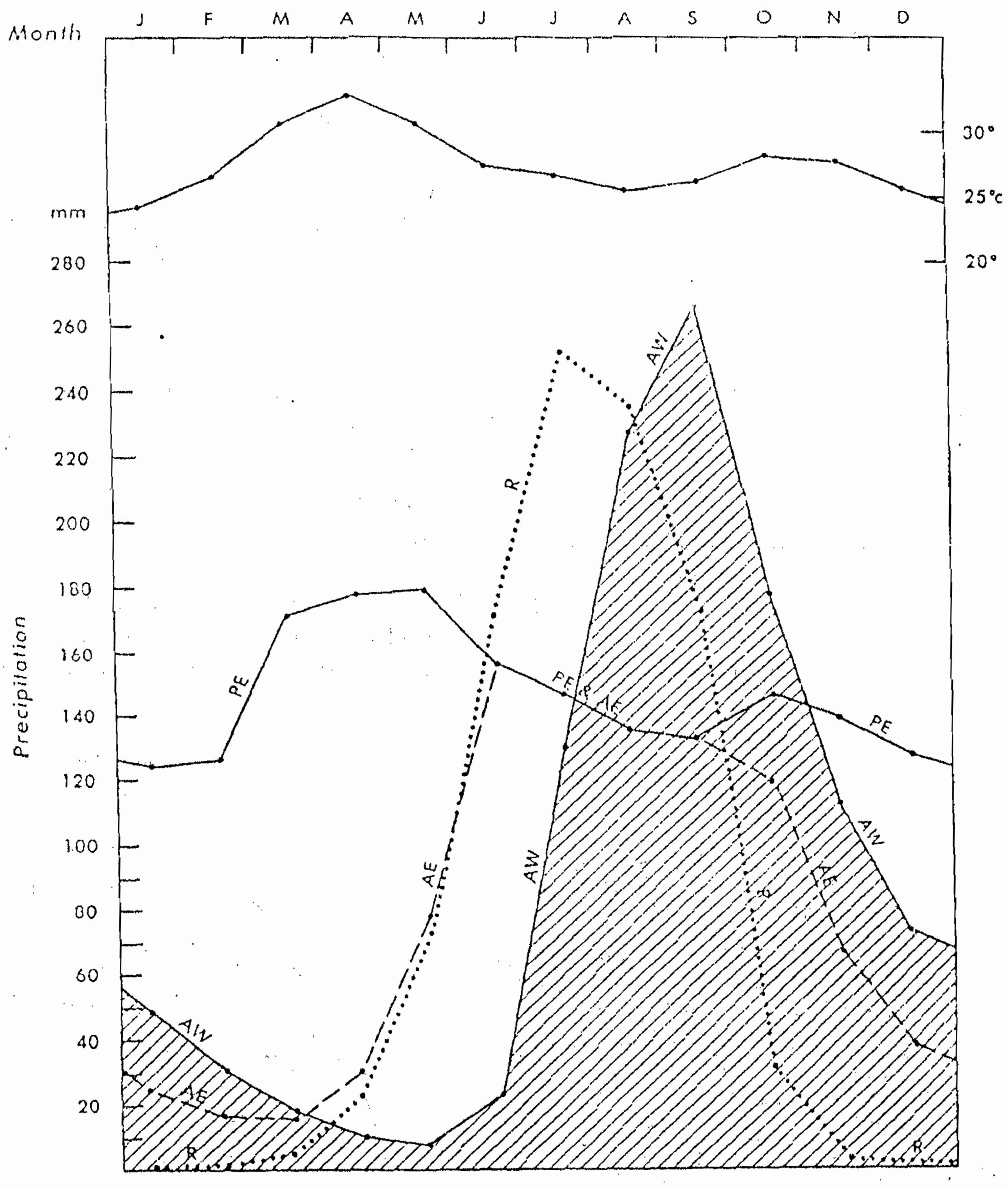

Fig. 4: : Climatic balance and soil moisture balance in Maroua for the dry lands of Cameroon. (Elevation: 421m)

climatic context the possibilities of reconstituting ground water reserves and the availability of water to plants are very limited. The area experiences deficits between evapotranspiration and rainfall, which is practically concentrated in 3 to 4 months of the year.

The consequences of this climatic situation are a biological rhythm with two phases:

- An active vegetative phase of very intense growth of about 5 months. The reconstitution of ground water reserves is essentially achieved from July to August when rainfall exceeds evapotranspiration. This reserve is rapidly depleted as soon as the dry season sets in (November to May)
- The wet season is followed by a dry and hot season during which ground water reserves are exhausted by high rates of evaporation. The physiological activities of plants are very restricted and much of the vegetation dries out.

Streams and rivers are characterized by irregular flow rates. The plains consists of numerous small elongated, sub-watersheds that are parallel to the broad alluvial plain of the Logone River. These discharge runoff water and deposit sediments in a network of outwash splays. The typical hydrological features are:

- An intermittent flood flow during the wet season (June to October) and total drying up of streams and rivers during the dry season. (November to May).
- The disappearance of channel characteristics in downstream areas where the gradient drops (December to May); and
- Deposition of large volumes of sediment in the vast flood plain of the Logone River. The river regime is determined by the rainfall. Fulton et al (1974) observed that the normal discharge of Logone River in 1974 was $65 m^3/s$ while the peak discharge was $92 m^3/s$. Molinier et al (2000) observed that the decrease in rainfall between 1970 and 1984 was reflected in the drying up of the river. In 1984 the average discharge was $551 m^3/s$, the flood discharge was $2740 m^3/s$ while the low stage was $50 m^3/s$. The inter-annual variability of the discharge is a reflection of the rainfall characteristics.

The lower section of the Logone River consists of a broad, level plain. A slight increase in the rate of channel flow causes overflooding of the stream. This allows water to spread over the broad

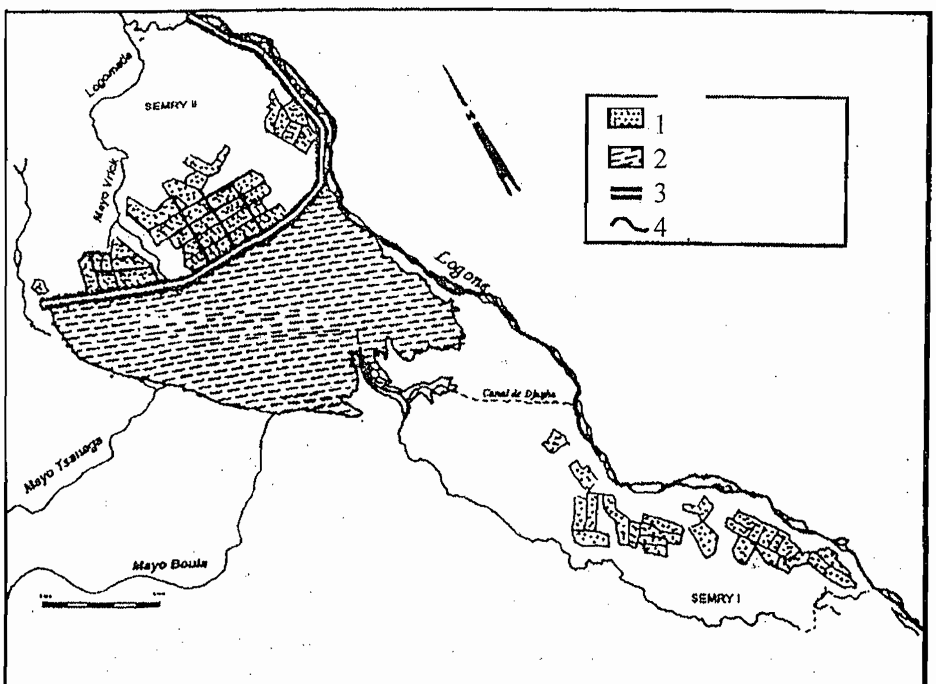

Fig. 5: : Location of Maga reservoir and irrigated zones: 1: irrigated zones, 2 = reservoir, 3 = dykes, 4 = streams/rivers *(**Source:** Molinier et al, 2000).*

alluvial plain behind natural levees. Widespread flooding results and a large volume of water is exposed to evaporation. Annual average evaporation rates in some stations are: Poli 1815mm/year, Maroua 2396mm/year and Kousseri 3519mm/year. The flooding of the alluvial plain commonly gets to a height of 80 - 120 for a period of 3 months in broad reaches and continuously in enclosed depressions (Beauvilain, 1985; Roupsard, 1985). This provides a reliable supply of water for irrigated rice in March and April, that is, during the low stage. (See figure 6, 7 and 8). A number of interrelated factors are important in considering drainage measures to increase the productive capacity of the area. Benefits from such measures include:

- Rice could be effectively grown where flooding is not excessive or where it can be controlled;
- Management of receding surface water will allow cultivation of dry season sorghum in a non-rainfall period;

In the early 1970s the seasonally flooded areas of the Logone flood plain experienced a 60% reduction in their land surface area. This was attributed to droughts (Fulton et al., 1974). This adversely affected agriculture and fishing. There was crop failure due to the lack of rainfall. Rivers also dried up. The government of Cameroon was

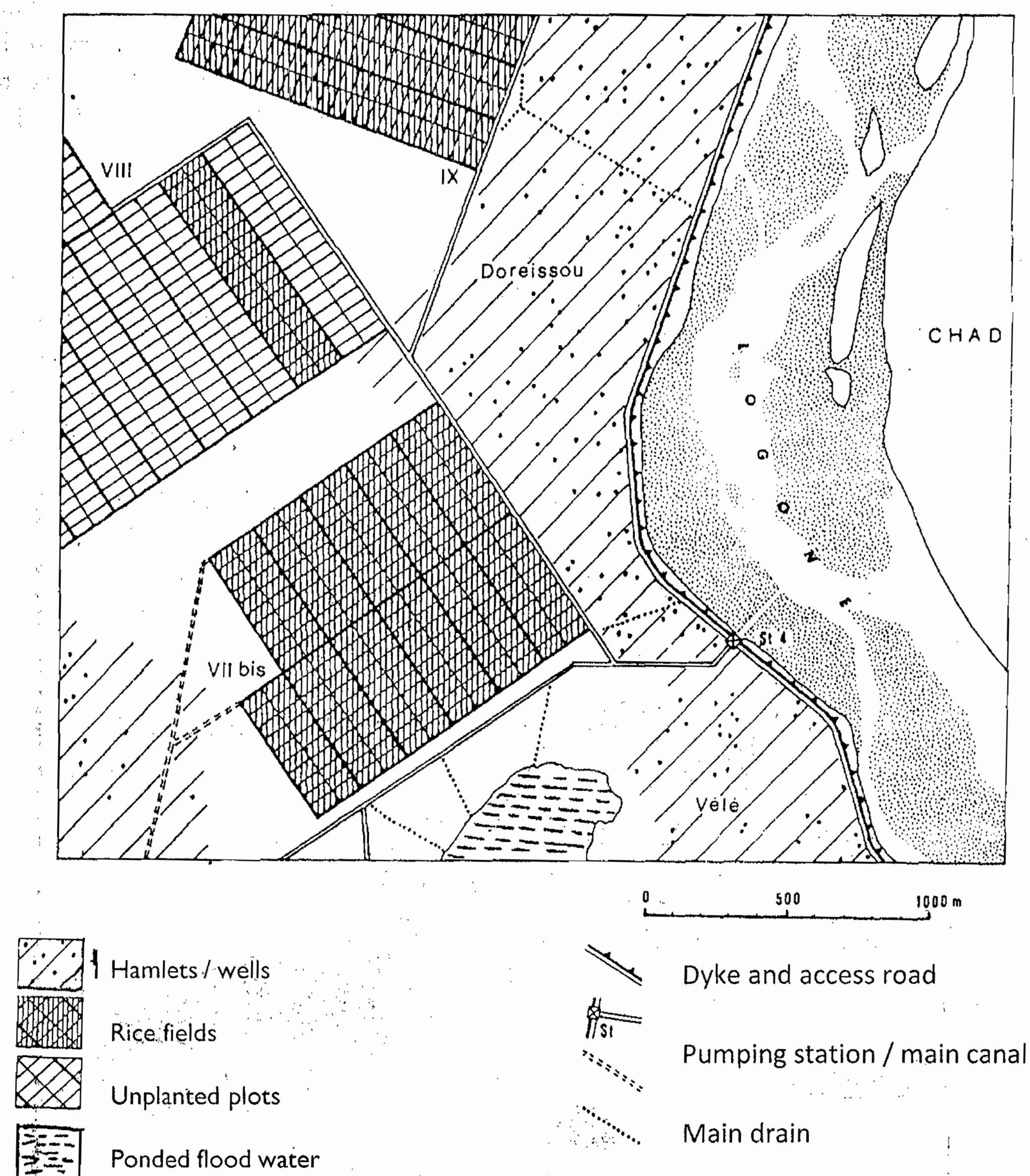

Fig. 6: Layout of irrigated rice fields in Doreissou village (Source: National Geographic Institute aerial photograph IGN 78 CAM 131/200 No. 54)

obliged to modify the traditional use of water resources in the region through the creation of a water management authority known as the Yagoua Rice Development Authority. It was charged with the development of irrigated rice in the area based on the management of flood water and the construction of a reservoir at Maga in 1979 (Figure 5). The reservoir has a capacity of 600 million cubic meters of water and covers a surface area of 39.000hectares.

Studies by Naah (1990) reveal that these efforts have not been fruitful. Despite the construction of the reservoir the water requirements for agriculture have not been met for about 25years due to the continuous drop in the volume of rainfall. The recharge of groundwater resources results from the Logone River, flood waters and the seasonal streams in the flood plain (Naah, 1990). It is therefore logical to conclude that the absence of considerable flood waters contribute to a reduction in phreatic water necessary for dry season irrigation.

Farmers depend on traditional forms of irrigation, namely (See figures 6, 7 and 8):

- Using the rainy season floods to grow crops as the flood waters recede;
- Water may be obtained from streams, rivers and natural ponds and stored in reservoirs for eventual

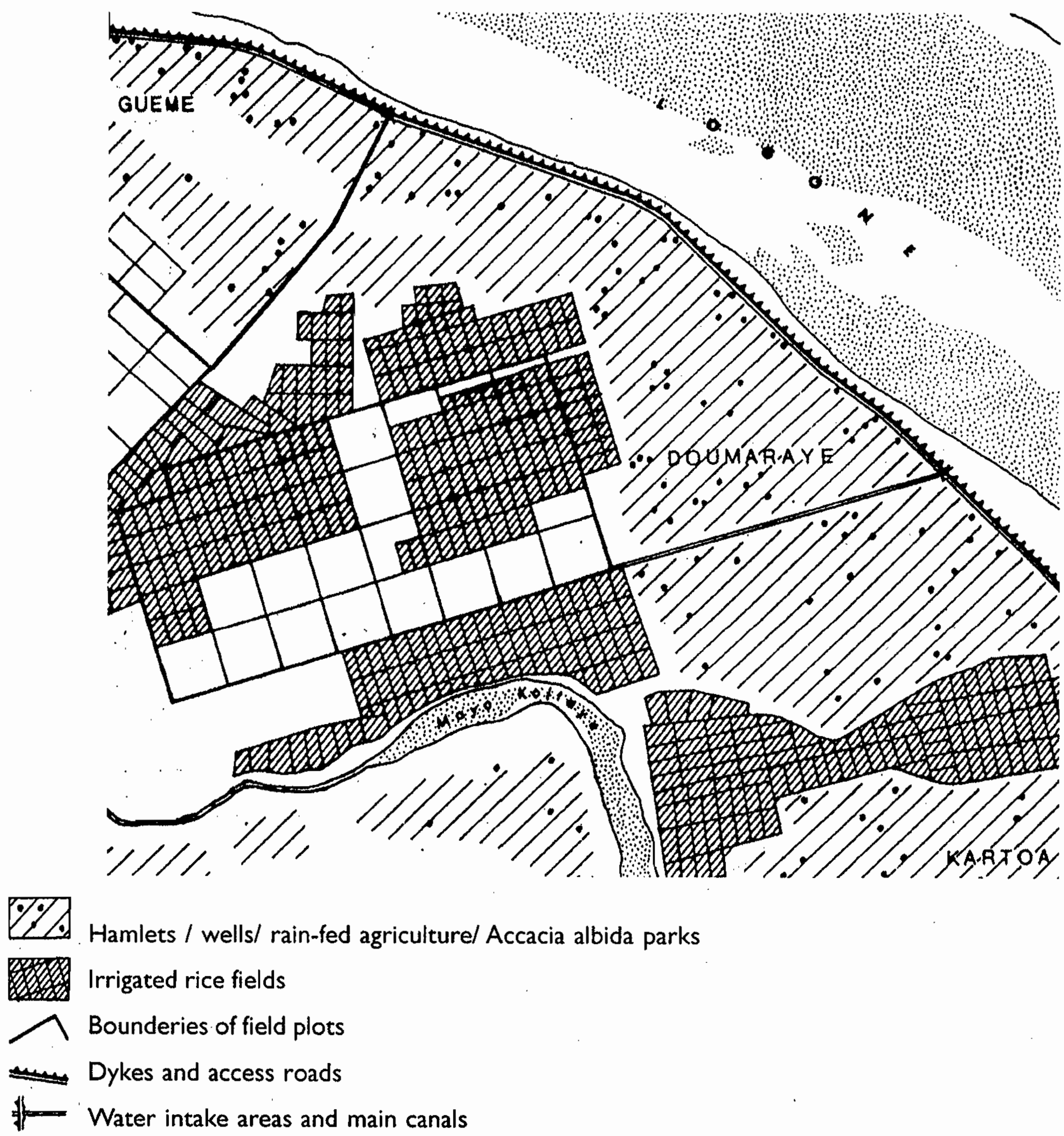

Fig. 7: : Layout of irrigated rice fields in Doumaraye village (Source: National Geographic Institute aerial photograph IGN 67 - 68 CAM 01/200 No. 189).

distribution via canals;

- Water may also be drawn from natural ponds or rivers by use of the "shadouf" system of irrigation;
- Alternatively, water can be drawn directly by hand from wells or natural ponds and poured into canals. A large number of diversion systems and canals have been constructed; and
- Under the water management authority water is pumped into canals for distribution through a network of canals and dykes (Ndembou, 1981; Roupsard, 1985).

The irrigation technique used is mainly flood irrigation. The techniques used by farmers have remained unchanged for centuries. (Pahai, 1979). It is therefore a system embedded in the indigenous knowledge and culture of the local people.

ISSUES OF SUSTAINABILITY IN WATER RESOURCE EXPLOITATION

The Lake Chad Basin Commission (1972) reports that by 2020 an area of 260.000hectares can be irrigated using water from Lake Chad sources. It is estimated that this will require 3.9 x $109m^3$ of water, or 0.5 litres /sec /ha. If we assume year round cropping at 1 litre/sec/ha. This will lower the equilibrium level of the lake by 76cm. The potential from the rest of the basin totals 18.000 ha, much of which is seasonal. In a drought, it is expected that most of the seasonal agriculture would be eliminated.

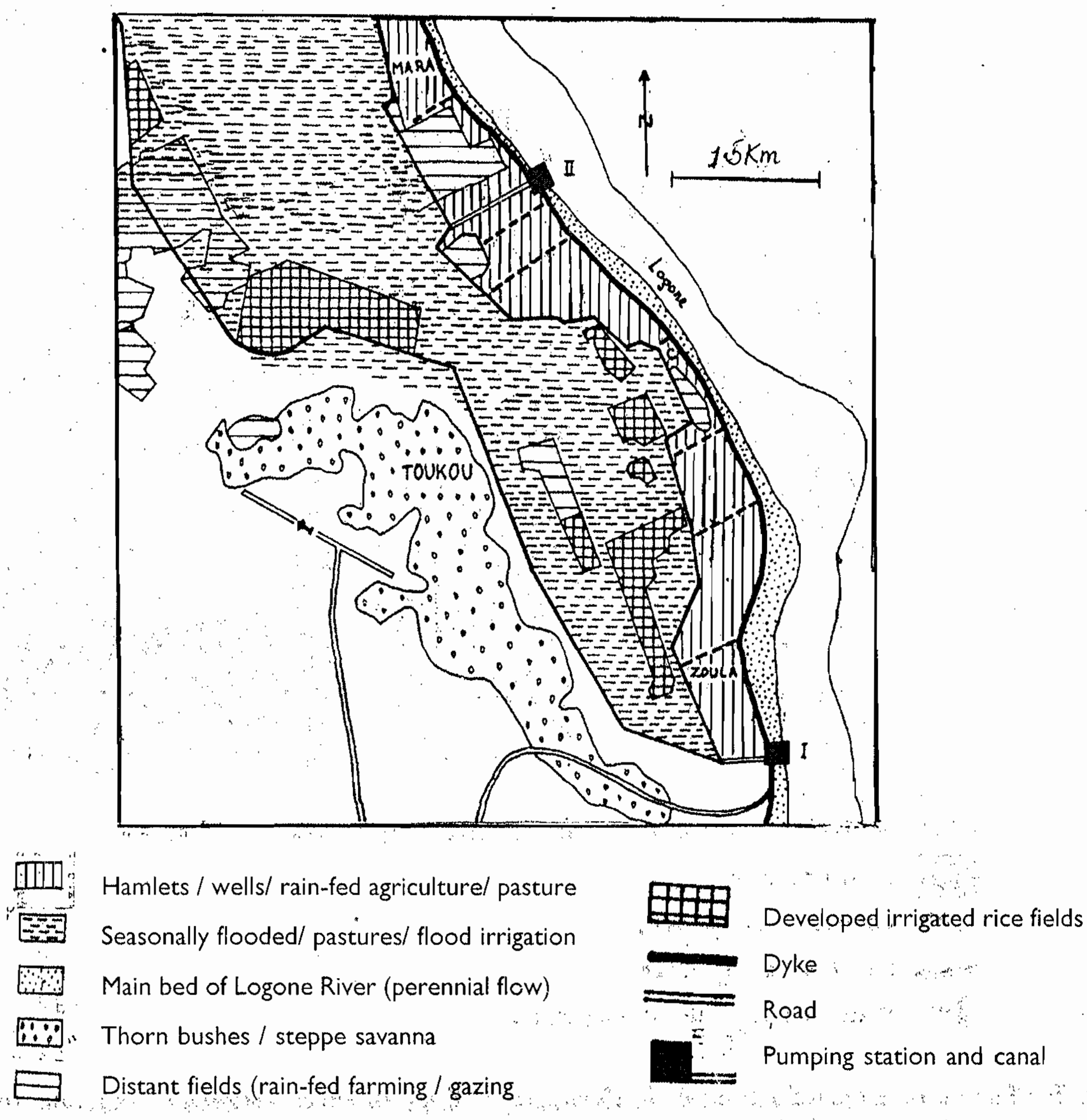

Fig. 8: : Layout of irrigated rice fields in Vounaloum village (Source: IGN Yaoundé, air photographs).

Hydrologists have advised against the large scale use of artesian ground water to avoid depletion of reserves that are a part of the delicate balance sustaining Lake Chad. Any plan for the use and management of deepwater sources should take into account the extravagant use of groundwater reserves in the Chad lowlands in neighbouring Nigeria. Many wells are only a few kilometers outside the national frontier of Cameroon.

The use of ground water for small, local irrigation projects is feasible in the Diamare plains and northwards where the surface of the water table is within 10 m of ground level and where water can be raised by simple and inexpensive means, for example, by an animal-operated Persian wheel or by mechanical pumping. Potential for development of ground water is highest in the Logone - Chari delta area. The potential is also good for riparian irrigation on the flood plain soils north of Logone Birni.

Grainger (1986) estimated that every additional person in dry lands requires one more hectare of land to supply him or her with the 250kg of grain needed for subsistence per year. With a current population growth rate of 3.8 percent the demands made on the water supply clearly reveal the disadvantages of traditional irrigation technology. With the construction of highways, the Trans-Cameroon railway and the re-opening of the Garoua river port, economic links have been increasingly forged beyond the boundaries of the region. This has promoted the cultivation of cash crops for which an irregular or only seasonal supply of water is neither adequate nor suitable. The problem is also compounded by limited available potential agricultural land.

Traditional irrigation in the basin depends on the occurrence of floods. In drought years farmers depend on groundwater. Access to water for irrigation becomes difficult due to the high cost of drilling boreholes and procurement of diesel-powered pumps. Water delivered by pumps is applied to crops using flood irrigation techniques. Kohler (1996) notes that this modern and expensive method of pumping of water, combined with an inefficient distribution method, can exist only for as long as sufficient quantities of the water resource are available. More efficient systems of water distribution such as drip irrigation are rarely used, because with apparently plentiful reserves of groundwater, there is no urgent need to invest in such technology. Pump irrigation also means that farmers are no longer dependent on the periodic supply of floodwater, because groundwater is available all year round. Thus the merit of adopting pump irrigation as an innovation is twofold: to intensify agriculture and to eliminate the risk of unpredictable floods. The regular and reliable supply of ground water in peri-urban areas and for cash cropping in rural areas has resulted in dynamic, economic development. But, if this development is to be seen as an improvement for future generations, capable of providing inter-generational equity, it should not deplete the natural resource base in the short-term without providing an adequate substitute for these resources.

An analysis of future prospects must focus either on short-term economic development or on long-term sustainability in all sectors:

"**Ecological sector:** Traditional irrigation systems in the area use resources in an ecologically sustainable manner, because the rate of water consumption cannot be influenced. No over-use is possible but some changes may occur in the water budget of the basin. On the other hand, irrigation systems based on the pumping of ground water have a high degree of water over-use, salinization of the soil and of the remaining ground water. Lake Chad; an inland drainage lake is already shrinking in size. The lake Chad Basin Commission (LCBC) charged with the management of the natural resources in the area is trying to strike a balance between water withdrawal and regeneration. This requires limiting the amounts of water withdrawn; a measure which is being frustrated by inefficient irrigation systems.

"**Social sector:** Traditional irrigation systems depend on common access to surface water resources whose impact on sustainability is not possible to assess. Despite the risk of a "tragedy of the commons" situation, these systems are very compatible with social structure and indigenous knowledge base or culture. On the other hand, modern irrigation systems based on groundwater extraction are not compatible with the culture of the people. Surface water sources are common access resources while access to groundwater sources depends on land ownership and the ability to procure diesel pumps.

"Political sector: Traditional water use systems correspond to the political structures and institutions of the ancient kingdoms. Ancient kingdoms own and use water resources. Access to these resources depends on the strength and structure of indigenous political institutions and the social and political status of individual members.

"Economic sector: Traditional systems of water use are characterized by inefficient use of capital and labour, and no possibility of development. All the systems have negative and positive aspects. Traditional systems have a high long-term sustainability but are capital and labour intensive. Modern systems require large investment. Modern systems require large capital investments in the construction and operation of pumping equipment. However, the cultivated crops are of high value, hence they are more marketed.

Which irrigation technology will therefore guarantee sustainable development? The traditional irrigation methods are already foundering in the face of the actual socio-political realities. These systems cannot satisfy the demands for water delivery capable of supporting intensive and extensive cultivation on a year round basis. The possibility to create added value from agricultural production to help support economic development is limited. Pumped irrigation permits all year round cultivation of cash crops (rice, cotton, groundnuts, onion and beans) which are marketed outside the region. If the yields of such a diversified agricultural economy are high and the irrigation techniques made more efficient, one can talk of sustainable development despite overexploitation of the water resource. Sustainable water use in the social, political and economic sectors could best be achieved by adopting a combination of flood irrigation and pump irrigation. This is possible because the lower section of the Logone River consists of a broad, level plain. With excessive rise of water from headwater sources. Water is diverted by natural spillage across the low saddle into the Benue River by way of the Mayo-Kebi. This causes an annual loss of water from the Logone supply of 40 million cubic metres. Investments to harvest this spillage by building reservoirs will compensate for the lack of water during the dry season. Diesel - pumped water will be delivered to the same fields during the dry season in order to extend the agricultural calendar, this will result in advantages of traditional methods (ecological sustainability, low investment and operating costs) being combined with the benefits of diesel - pumped irrigation (all year round reliable supply of water), without excessive over - use of the water resource.

CONCLUSION

The hydrological resources of the Chad Basin of Cameroon exhibit inter-annual variations and a general tendency towards shrinking groundwater and surface water resources. Water supplies are increasingly becoming a pressing resource issue. The concept of sustainable development is a vision which delivers the general orientation with which operational goals can be defined in specific situations. The current blend of traditional and modern irrigation systems and the rapidly changing socio-economic conditions have rendered the ecological, social, political and economic operational goals of sustainable development obsolete. The development and use of water resources in Cameroon's Chad Basin is therefore unsustainable. More holistic and longer-term orientations are required to assist in negotiating operational goals. This will contribute to the evaluation of the effects of economic measures on the ultimate goal of sustainable development, and will serve as an aid to dialogue by drawing attention to the ecological, social, economic and political view points, that is, the social negotiation process of development.

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