Rainfall variability and continental water resources : the CATCH project over West Africa

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Abstract We are entering into the 30th year of drought in West Africa, with strong consequences for the hydrological cycle and the water resources of the region. A regional pilot project (CATCH : *Couplage de l'Atmosphère Tropicale et du Cyde Hydrologique*) is being set up over a region encompassing the continuum of West African climates. Experimental studies are applied on monitored sites over sahelian and sudanian regions. Such initiative could provide the spring board toward a GEWEX scale experiment in West Africa.

Résumé La sécheresse persistante qui affecte l'Afrique de l'Ouest depuis 30 ans a de graves répercussions sur le cycle hydrologique et les ressources en eau de la région. Un projet pilote régional (CATCH : *Couplage de l'Atmosphère Tropicale et du Cyde Hydrologique*) est en cours de réalisation sur une région offrant une large palette des différentes zones climatiques de l'Afrique de l'Ouest. Des sites d'observations hydro-météorologiques intensives ont été mis en place en zones sahélienne et soudanienne. Ces initiatives pourraient servir de base à la définition d'une opération GEWEX en Afrique de l'Ouest.

INTRODUCTION

"*The subsaharan drought of the early 1970s attracted widespread attention. Particularly proeminent was the suggestion that it was not likely to disappear in the near future, and could even persist into the next century*" (Lamb, 1982).

This statement of Peter Lamb sounds somewhat prophetic today when we are entering into the 30th year of drought in West Africa, with strong consequences for the hydrological cyde and the water resources of the region.

The continuing drought over West Africa constitutes a challenge to the scientists who have 2 questions to answer :

I) what are the causes of the drought ?
II) how can the climatic variability be taken into account to improve water resources management strategies.

In order to contribute to answering these 2 questions, a regional pilot project (CATCH : Couplage de l'Atmosphère Tropicale et du Cyde Hydrologique) is being set up over a 6°x9° window covering the continuum of West African climates (fig. 1).

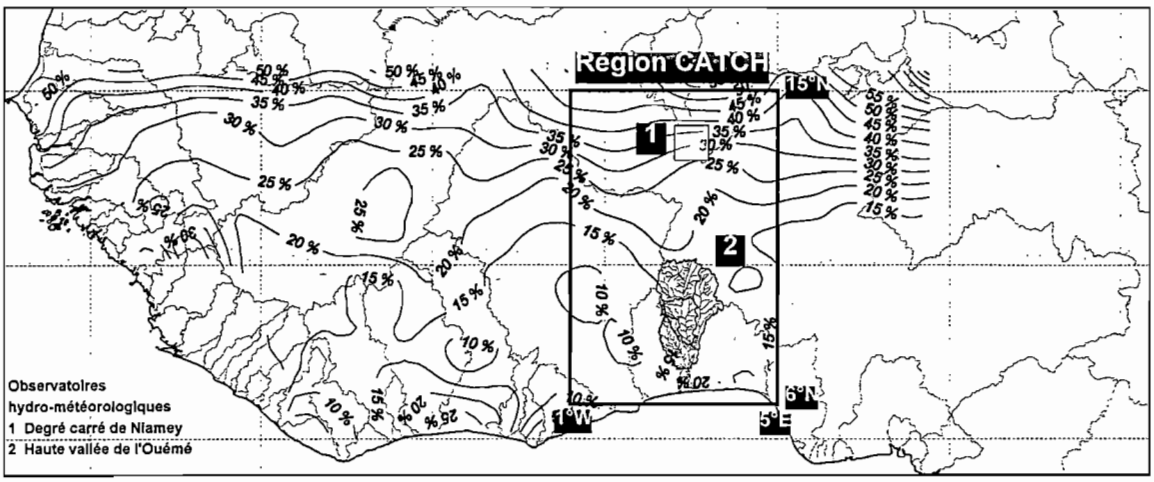

Fig. 1 Regional window and mesoscale hydro-météorological observatories of the CATCH Project in West Africa(% of rainfall deficits since 1970 and main watersheds are shown on the map)

The average rainfall deficit over West Africa since the early 1970s is 180mm/year. All climatic zones, from the Sahel down to the Gulf of Guinea, are affected regardless of the type of events considered, monsoon type rainfall or squall lines. This had a drastic effect on river water discharges which overemphasized water shortage with a deficit of more than 50% (fig. 2).

The Niger, far more the largest river in West Africa, dried up for several weeks at Malanville (1.000.000 km^2) in 1985 (fig.3). This was a consequence of a one year lag of the lowest rainfall and runoff (1984) recorded since the begining century in the upper catchment.

The significant infiltration deficit also had also eflect on water tables (fig.4). On the other hand, evaporation was not significantly affected by rainfall deficit.

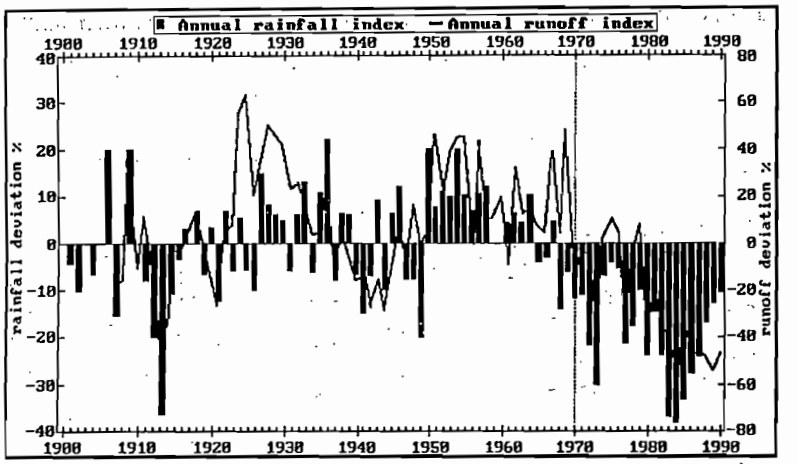

Fig. 2 Drop of the annual runoff index on the upper Niger

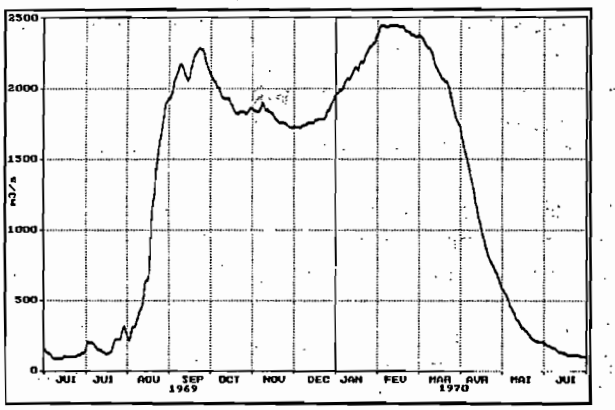

Fig. 3 Hydrograms of the Niger river at Malanville (Benin) in 1969-70 and

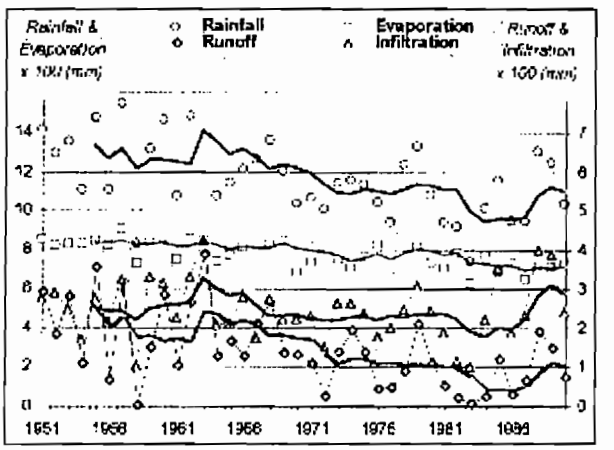

Fig. 4 Annual water balances at Pont de Savé on the Ouémé river (Benin)

Two specifics of approaches can be defined : "mesoscale" approch and "regional" approach (fig. 5).

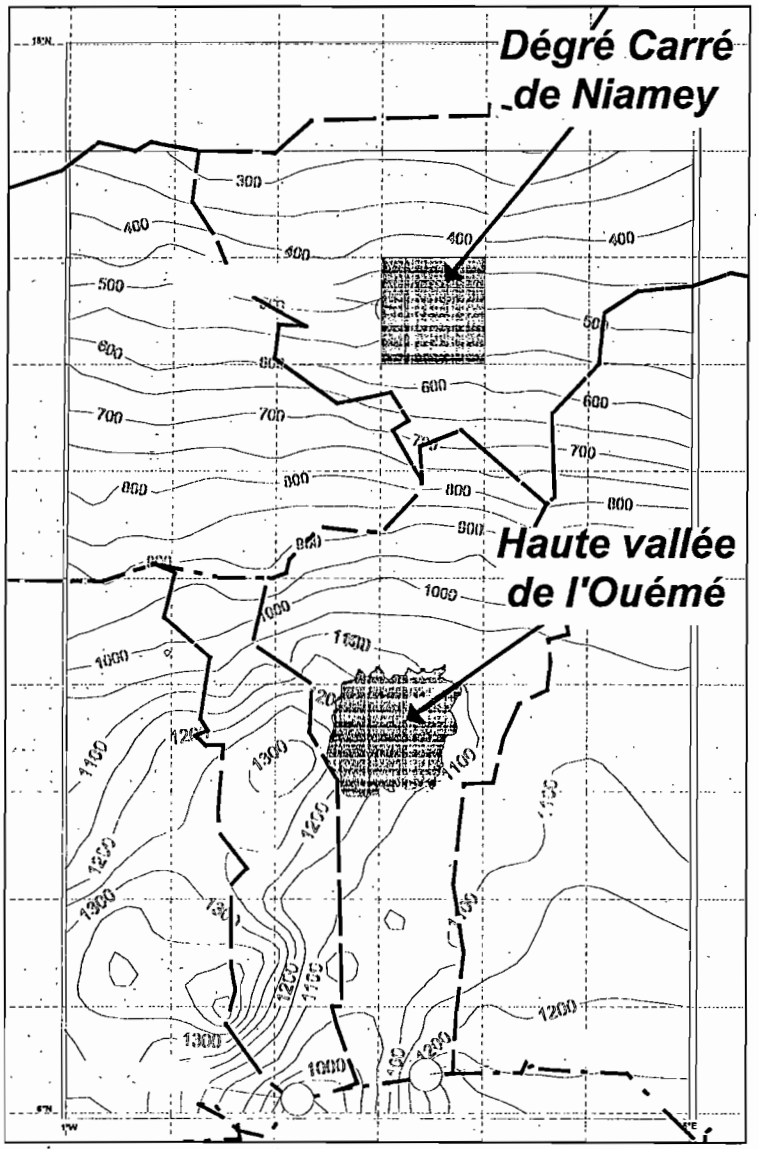

Fig. 5 Mean annual rainfalls (1960-1990) over the CATCH regional window and location of the two mesoscale hydro-meteorological sites.

MESOSCALE : the case of EPSAT-Niger Experiment

The EPSAT-Niger experiment (1990-1999) carried out over the Niamey hydro-meteorological site (so-called "degré carré de Niamey") has revealed the strong variability of the Sahelian rainfall over a range of scales.

In the annual scale, for instance, rainfall gradients close to 300mm/10km were observed in 1992 (see at below). The general pattem of these annual rainfall maps is markedly different from the dominant pattern of the 10-year scale (E-W oriented isohyets and positive N-to-S gradient). The analysis of the EPSAT-Niger data has shown that the spatial distribution of the Sahelian rainfall results from :

I) the internal characteristics of the mesoscale convective systems (MCS'S) which provide 90% of the annual ,raingauges rainfall in this region of the world,

II) the location of these systems and their linkage to the general atmospheric circulation.

Depending on the time scale considered, the rainfield variability is primarily controlled by either the intemal or the external characteristics of the MCS'S. Simulation and downscaling models have been developed on the basis of these considerations. A major result of this research is that the variability of the Sahelian rainfall at the intraseasonal and interannual scales is linked to the fluctuations of the number of MCS'S rather than to fluctuations of their rainfall efficiency.

A similar data base is needed over the Sudanían region, where the rainfall climatology is more complex than over the Sahel and where rainfall estimatlion is made more difficult by the mixing of at least two types of rainfall events : large MCS'S linked to the easterly atmospheric circulation and monsoon rainfall. A new hydro-météorological site (so-called "haute vallée de l'Ouémé") is progressively equipped in the soudanian zone since 1996.

REGIONAL SCALE

A climatic transect from the Gulf of Guinea coast (Cotonou) up to the Sahel (Niamey) suggests that the 10-year scale rainfall variability is predominantly linked to the fluctuations of the mean number of rain events per year. This is especially true over the Sahel (Niamey) and also, even though less markedly, over the Sudanian region (Parakou). Under the Guinean climate (Cotonou) significant fluctuations of both the number and magnitude of the rain events are observed.

The rainfall component of the CATCH project seeks to improve our knowledge of the links betvveen these regional features and the mesoscale rainfield characteristics that are of great importance to the hydrological cycle.

THE Ouémé upper valley EXPERIMENTAL SITE

Bénin is entirely within the regional window of the CATCH project. The raingauge and hydrometric networks of Benin offer a wide range of hydrological and

environmental data sets available for calibration and validation purposes (fig. 6). Nevertheless, the Ouémé upper valley was selected as a pilot hydro-meteorological site entirely under sudanian dimatic control.

The mean annual rainfalls over the Ouémé catchment range from 1100 to 1300 mm/year, associated with one rainy season from May to November. The geological basement is made of crystalline rocks on which a peneplain developed with gentle slopes and some inselbergs. Wooded savanas are dominant, apart from dense forest vegetation along the main streams.

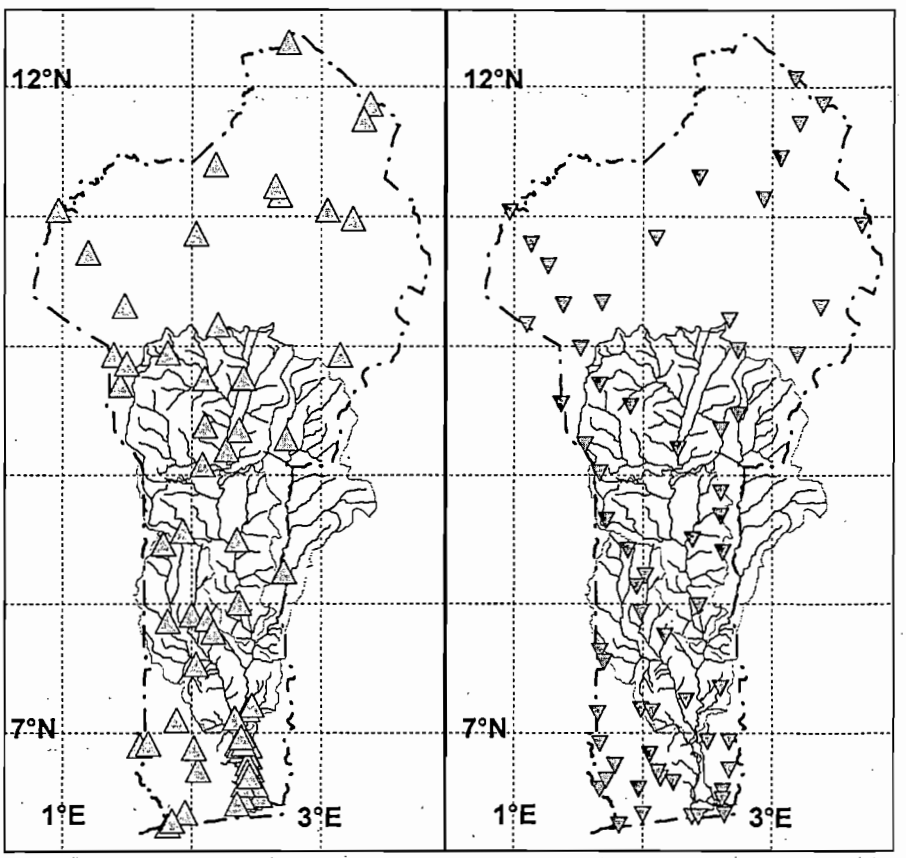

Fig. 6 National hydrometric (left) and rain gauges (right) networks of Bénin

An intensive rainfall monitoring network is being installed since 1997 on the Ouémé upper valley, which covers an equivalent 1°x1° square (Fig. 7).

Its components are as follows :

I. a basic network whose density will be progressively equal to those of the long term EPSAT/Niger network (30 gauges/12.000km^2),
II. a 10x10km "super-site" equipped with 7 gauges.
III. a transect of gauges for radar measurement validation.

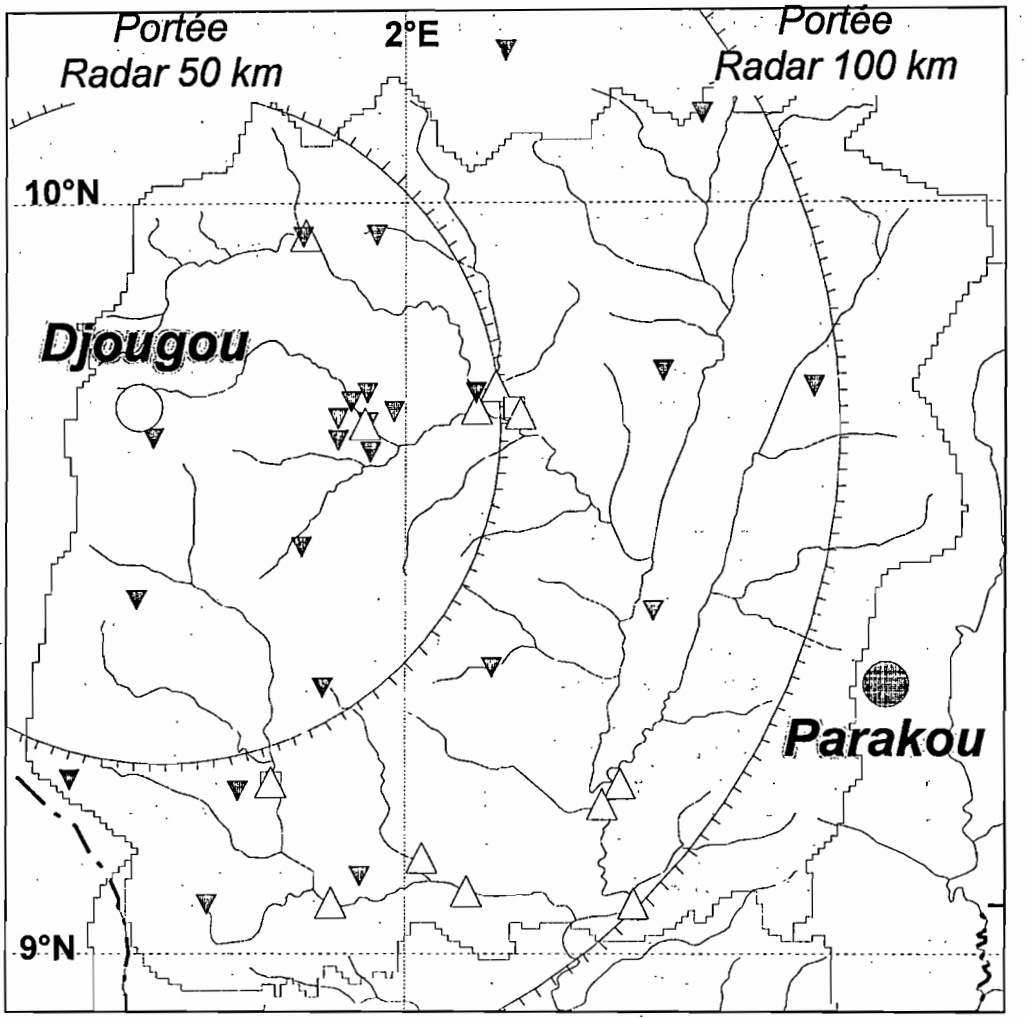

Fig. 7 The Ouémé upper valley hydro-meteorological site in 1998 (hydrometric station▽ rain gauge)

A set of nested catchments ranging from 200 to 10000 km^2, are being monitored for transcaling modelling of water budgets and hydrologic responses.

A Meteororological radar is expected to be installed in 1999 or 2000 for rainfield structure evaluation on both squall lines and monsoon typed rainfalls.

Environmental data base :

A multi-scaled raster-based DEM is used for hydrographic depictions and hydrological parameters estimations. It is combined with various raster or vector typed environmental data such as geological basements, soils, vegetations and landuses. This environmental data must be interfaced with time series of distributed rainfall-runoff data for simulation or modelling purposes.

Hydrological modelling :

Low density of rainfall network and non availalbility of detailled environmental surveys at the regional scales enforces the necessity of stochastic approaches for hydrological modelling. Those apprroaches can be calibrated on the two hydro-meteorological sites.

Two types of modelling are expected to be reliable over the sudanian zone :

I. an event-scaled approach based on stochastic differential equations (SDE) modelling combining the use of simulated and/or observed rainfall data (fig. 8),
II. a seasonal to interannual model for water budgeting appliable at regional scale.

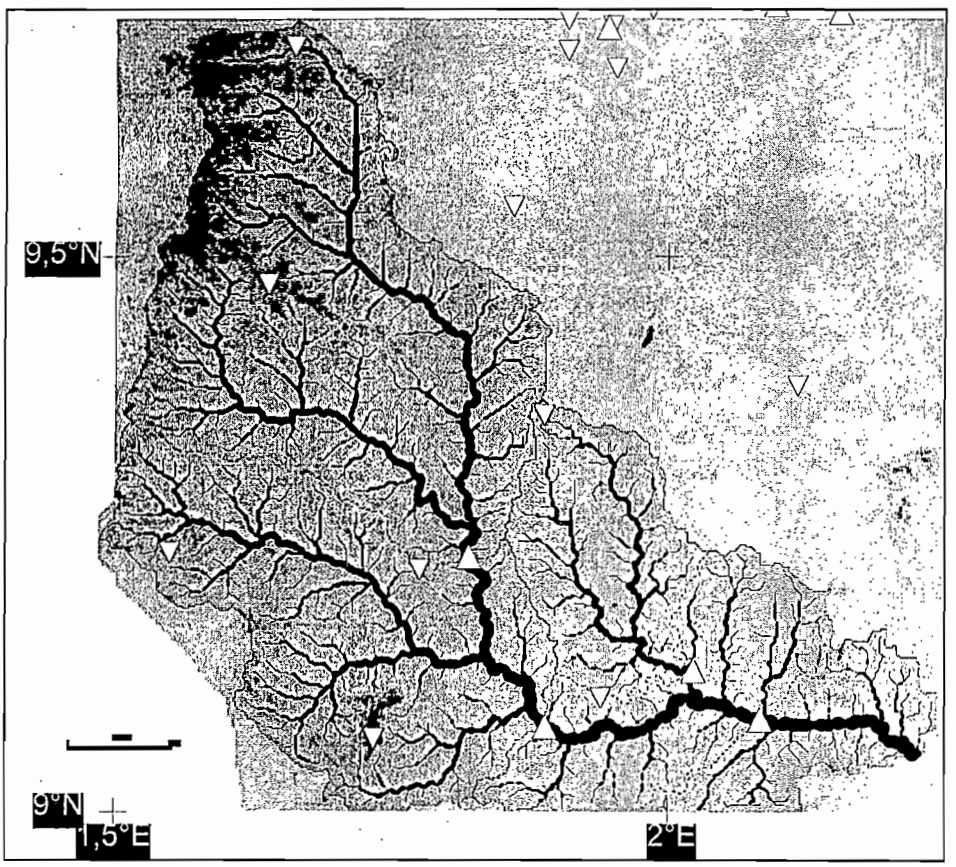

Fig. 8 The experimetal catchment basin of the Térou river within the Ouémé upper valley (river network extraction and channel width estimation from DEM)(hydrometric station, rain gauge)

CONCLUSION

CATCH is an emerging project currently funded by *Direction de l'Hydraulique* (Cotonou, Bénin), *Université Nationale du Bénin* and ORSTOM. Such initiative could provide the spring board toward a GEWEX scale experiment in Africa. In order to

fullfil the various requirements of such experiment, expertises and resources are needed from the regional and the intemational communities especially on the meteorological aspect. A more detailed project can be provided to all interested scientist or institution.

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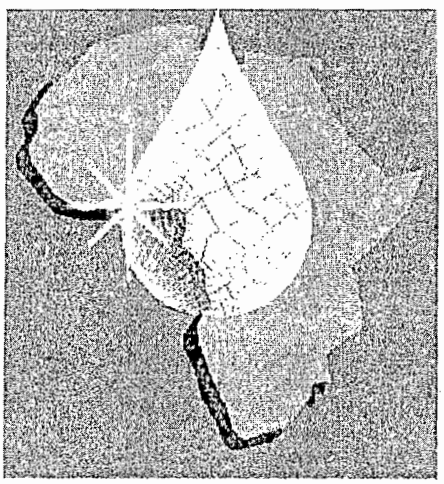

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