EFFECTS of DEFORESTATION on WATER BUDGET

and

CLIMATIC CONSEQUENCES.

CATCHMENT HYDROLOGICAL MODEL

for TROPICAL ZONE

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Parametrisation of land-surface characteristics.

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Rainfall into a landscape is an entry of water that initiates changes in the soil and vegetation water continuum. Little has been done about the quantification of the hydrologic processes in the humid forest regions of the tropical zone.

Water budget studies provide baseline data on which analysis of climatic characteristics are based.

This late exchange process is determined by the energy budget-Bowen ratio method using micrometeorological techniques. The calculation requires the amount of total radiation absorbed by the surface : net radiation. This radiation budget depends upon the surface characteristics : albedo for the short wave radiation and the emitted radiation a function of the surface temperature.

This work was conducted in the tropical forest zone of Ivory Coast, West Africa.

Micrometeorological measurements have been undertaken over forest at OUSROU, near ABIDJAN, during 3 years with the objective of examining the importance of the evapotranspiration process by the forest surface.

The same experiment has been conducted on agricultural crops to determine the effects introduced by these new surface characteristics on radiation and energy budgets. These physionomical modifications affect the water balance.

These micrometeorological and biophysical data measured on forest and different field crop surfaces have been used to model some of the soil-plant-atmosphere interactions. With the hydrological data collected on instrumented catchments at TAï, in the south-west forest zone of Ivory Coast, the simulation of the hydrological behaviour of forested and cultivated catchments was undertaken.

Priestley and Taylor (1972) equation is used. It is based on large scale data rather than on micrometeorological results : the quantity of energy required for evaporation comes predominantly from net radiation. The effect of the water vapour pressure deficit is low, thus neglected.

Micrometeorological results shows that :

1. dry forest canopy transpires less than the P&T equation (ET_o) predicts for this humid regions;
2. the transpiration process depends on the soil water availability in the root zone (SWd / SWc)

Catchment Water Balance :

- $\underbrace{P = WBF + R + Vws}_{\text{liquid}} + \underbrace{Pi + ET}_{\text{vapour}}$

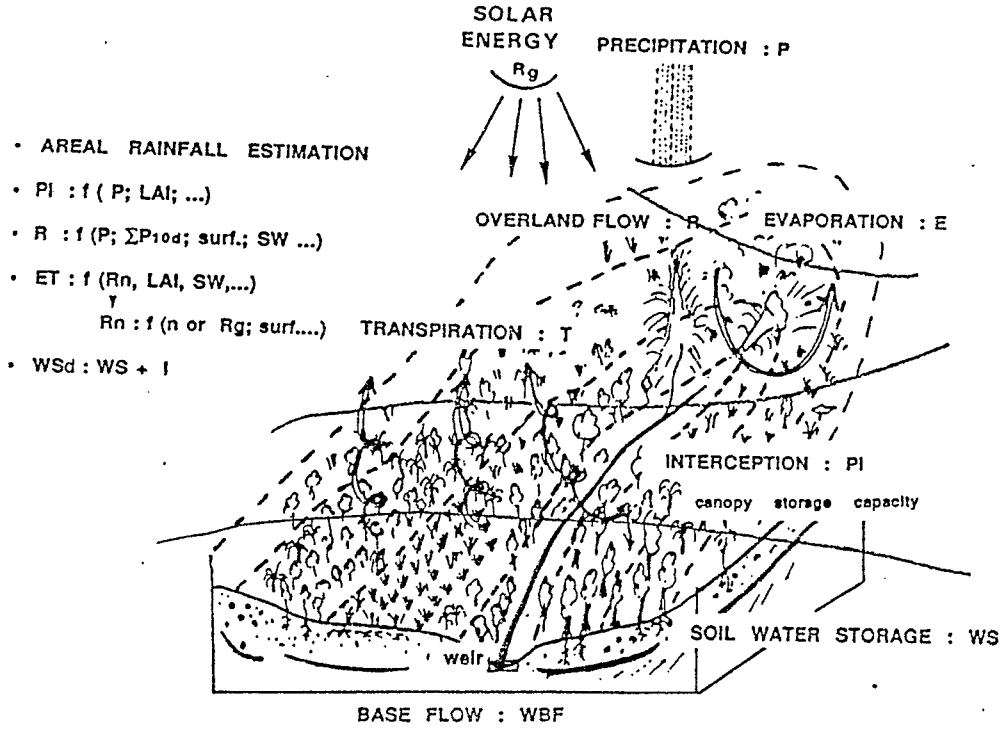
- Energy Budget : (simplified)

$$ET = Rn - C$$

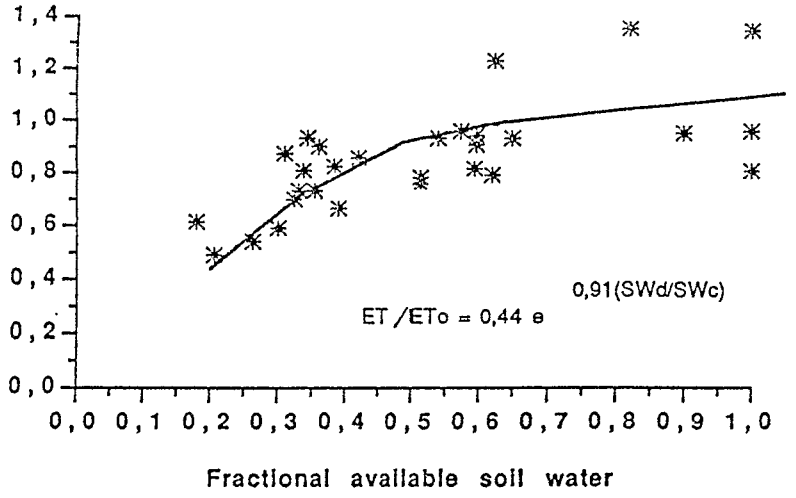
- Radiation Budget :

$$Rn : (1-a)\,Rg + (Ra - Rt)$$

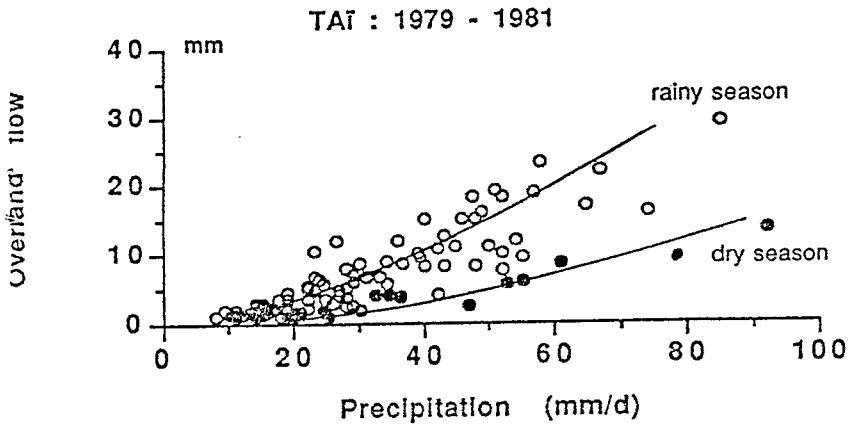
Generally instrumented watersheds provide water input-output budgets and by difference the net watershed loss is inferred. This loss is due mainly to evaporation of intercepted rain water (Pi) and to transpiration (ET) by the forest canopy.



Schematic representation of a watershed and the measured components of the hydrological budget. (photos)



Forest relative evapotranspiration rate (ET/ETo) response to soil water depletion (SWd/ SWc).



Overland flow depends on the soil surface characteristics for a rain intensity of 60 mm/h : (*COLLINET,* 1984).

(1) ...dry forest soil has high water speed

At a regional scale, difficulties arise in relation with the importance of data needed to define the flows and storage levels for detailed modeling. Our approach is to consider that the same processes are operating as in smaller experimental catchment : a single soil storage capacity retaining a fraction of rains (SW) and the excess flowing as overland flows (R) and as drainage to the watertable which runs over to the watercourse as base flow (WBF). These exceding water are in relation with precipitation quantity.

A daily water budget model is developed that satisfactorily simulates evapotranspiration and interception losses by forest, as well as the stream and the overland flows. Input required are daily rainfall, global radiation, soil water depletion.

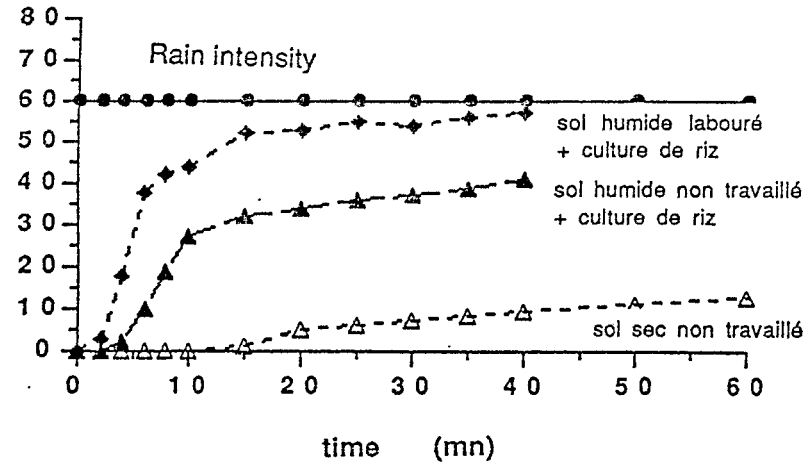
The mean soil water capacity in the root zone of forest trees must be known. The structure of the model is shown in the framework. The different components (submodels) of the model are as follows :

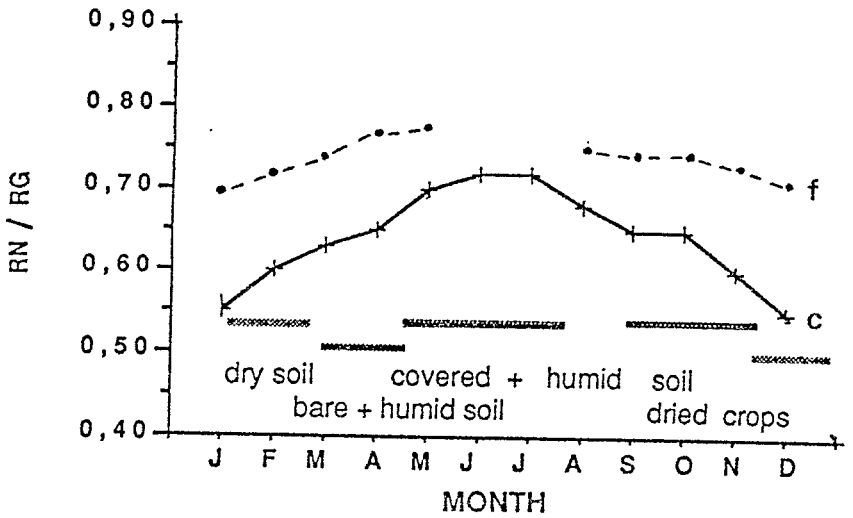
- **interception** : in relation with the daily precipitation quantity ;
- **evapotranspiration** : related to the absorbed radiation (Rn) and the soil water availability in the root zone (SW) ;
- **overland flows** : rainfall of sufficient intensity and duration when exceeding the soil surface infiltration capacity (soil hydraulic conductivity) induces overland flows ;
- **soil water status** of the catchment determines the volume of overland flow generated. A distinction between dry and rainy season is introduced, separating wet or saturated from more dry soil conditions.

The data concerning such parameters are based on average values from a representative regional catchment.

(2) ...undisturbed humid forest soil induces overland flow when rainfall intensity exceeds the soil surface infiltration capacity;

(3) ...disturbed humid forest soil (deep tillage or compacted by heavy rains) presents high overland flow rate due to the destruction of the multichannel macropore system and his rapid saturation.



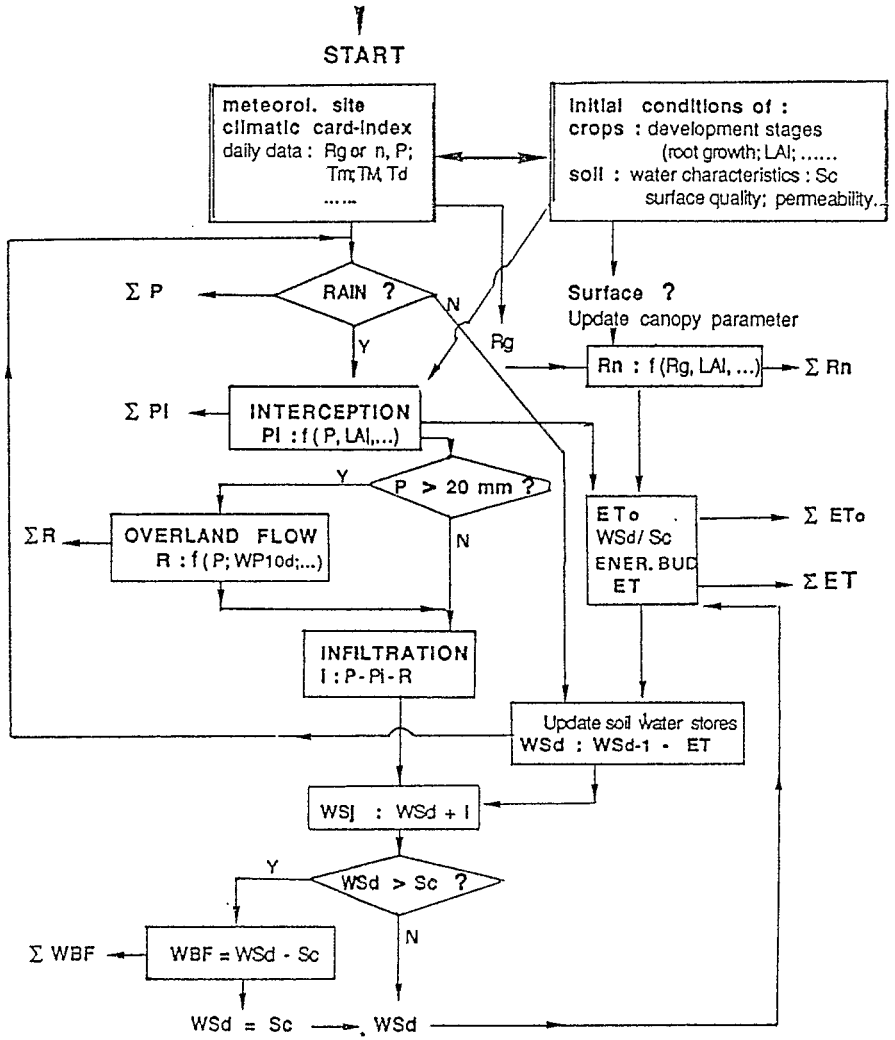


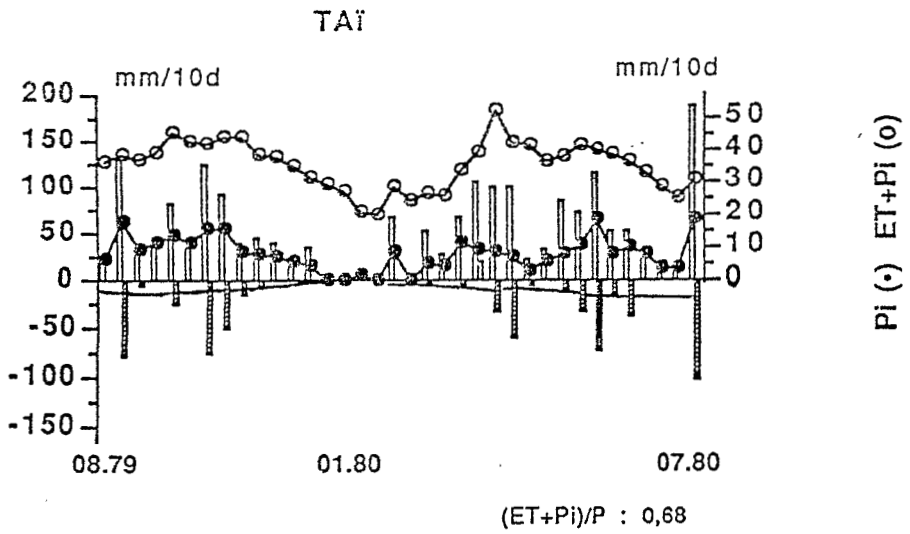
Variation of the available radiation amount (Rn/Rg) during the year for forest and cultivated crops (rice, Zea, cassava).

FRAMEWORK of the

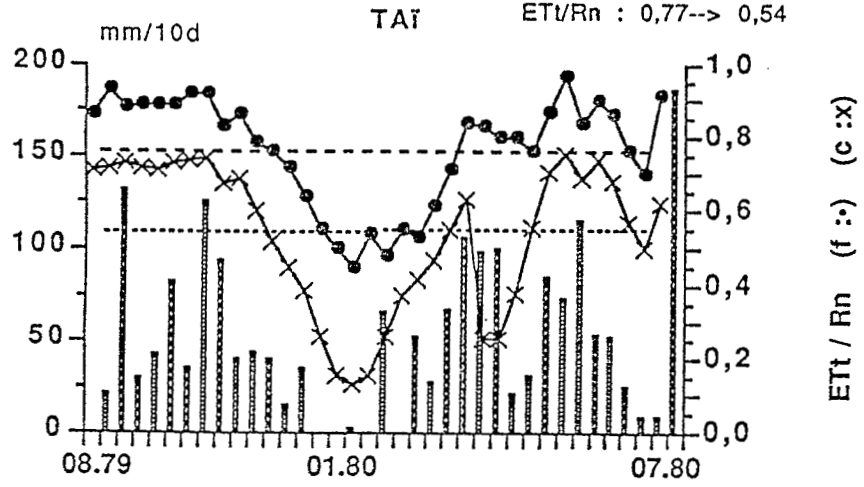
CATCHMENT HYDROLOGICAL MODEL

used to simulated the forest (or cultivated) watershed behaviour.





Results of the hydrological budget simulation of a watershed located in the humid forest zone of Ivory Coast.



Evolution of the water consumption of a forest (• : f) and cultivated land (x : c). Forest surfaces transfer the equivalent of 77% of net radiation back to the atmosphere as water vapour and the crop surfaces the equivalent of 54 %.

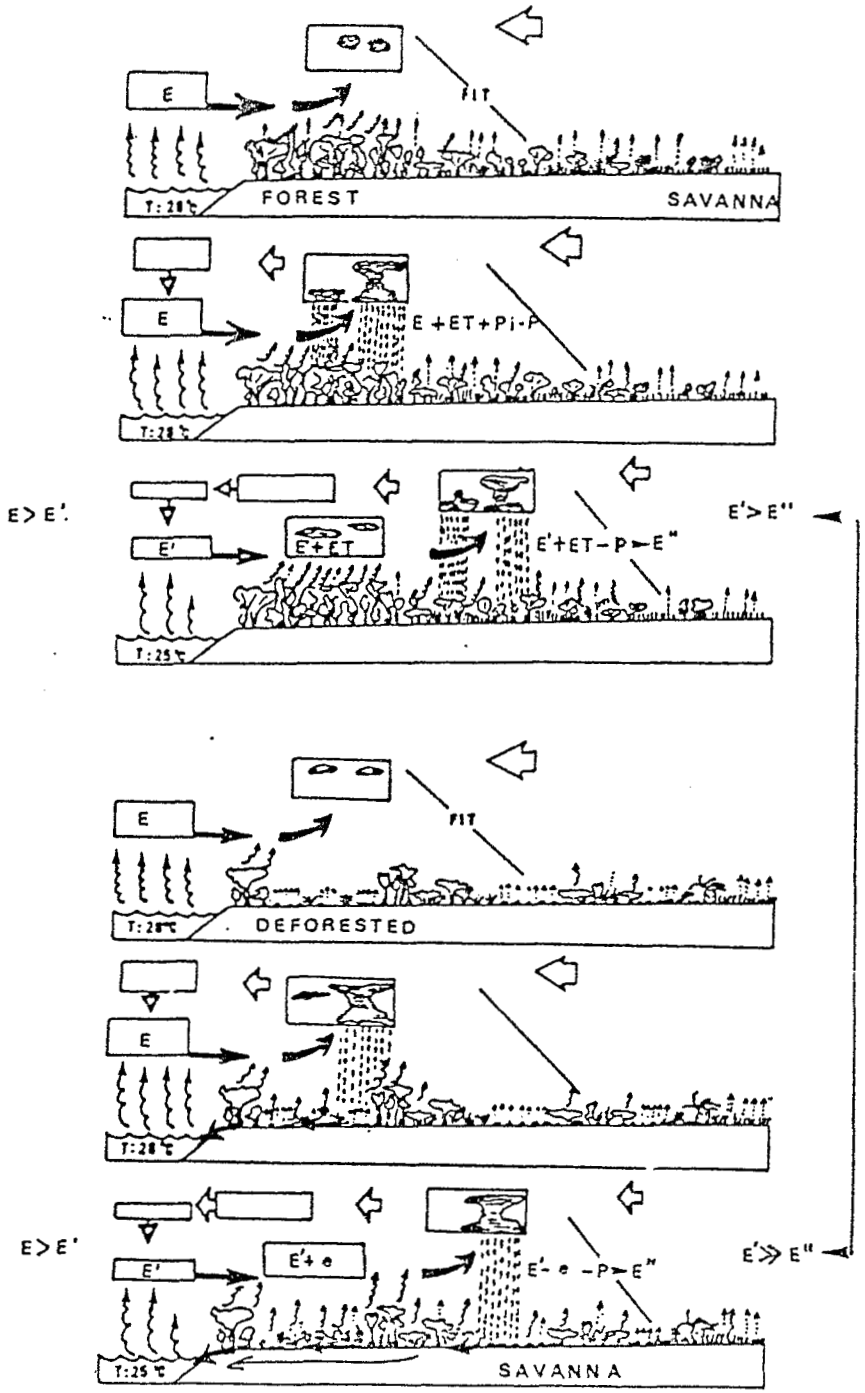
For short period, the results of the simulation emphasise some limitations of the catchment flow model, due to the high frequency of moderate-heavy rainfall in this rain forest environment. Over longer time (10 days) the hydrological budget simulation results agree well with experimental work.

Catchments cleared of native forest vegetation and used as agriculture land, are disturbed mainly by :

1. **the vegetation characteristics :**
   The available net radiation is reduced compared to forest radiation budget ;
   Total soil water avaibility decreased in relation with the depth of the root system ;
2. **modern deep tillage practices :**
   The physical and hydraulic conductivity of forest soils are partially destroyed ;
3. **soil surface horizon exposed to climatic agression :**
   Raindrops impact creates a driving crust on the soil surface ;
   Exposed to solar energy, it dries and reduces the infiltration capacity of the soil.

Simulation of the catchment hydrological balance shows that land use changes in forest areas will have some consequences on physical air parameters as temperature and water vapour concentration.

The tropical forest injects the equivalent of 63 to 74 % of the annual precipitation as water vapour into the atmosphere. The same conclusion has been found for the amazonian forest. The driving force of the global water cycling is the water vapour advection from the nearby ocean. This advected vapour precipitates over land. The regional recycling of this precipitated water depends on the vegetated land surface wich acts as a water source for the atmosphere.



Owing to this important forest evapotranspiration rates over large area, the depletion of the atmospheric water vapour content by precipitation above land is quite low. This moisture contributes to the formation of clouds which will precipitate mostly in the northern region in relation to the general atmospheric circulation.

Surface changes (annual crops) as simulated by the hydrological model will transfer only the equivalent of 40 to 55% of the annual rainfall. The reduction in the evapotranspiration rates is linked to the rapid soil water depletion in the root zone and to the reduction of the vegetative activities. The decrease of water vapour exchange by annual crops is compensated by an increase of sensible heat transfer which affects the air temperature.

Deforestation on a large scale in the humid zone as it is the case now will affect the regional water budget : a decrease in the surface - atmosphere water vapour transfer contributes to the reduction of the atmospheric water vapour content. This process associated with some ocean-atmospheric perturbations will increase the disturbance of the rain distribution over West Africa.

One of the most important decision in humid tropical regions is the choice of an appropriate land use practice in relation with soil-climate conditions. Significant improvement can be achieved with mixed cropping systems (perenial plants associated with annual fooding crops) which maintain the fauna activity in the soil and protect the surface from impacting raindrops. (*VALENTIN* ,1987)

A decrease in water vapour transfer from the surface to the atmosphere will reduce the probability of cloud formation and rain, affecting the regional climatic characteristics in relation to the air mass movements.