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Dieumerci Eluo, Hervé Parmentier. Evaluation of the hydro-pedological and hydrological peatlands functioning by topographical and geological positioning Peat forest from Congo basin, Lokolama (DRC). Congo Basin Science Initiative (CBSI) and CongoPeat, University of Leeds, Sep 2024, Leeds (Angleterre), United Kingdom. hal-04728080

HAL Id: hal-04728080

<https://hal.science/hal-04728080v1>

Submitted on 9 Oct 2024

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Evaluation of the hydro-pedological and hydrological peatlands functioning by topographical and geological positioning Peat forest from Congo basin, Lokolama (DRC)

Dieu Merci ELUO et Hervé PARMENTIER



SUMMARY

- **INTRODUCTION**
- **DATA AND METHODS.**
- **EVALUATION OF THE HYDROLOGICAL FUNCTIONING OF A PEAT BOG BY TOPOGRAPHICAL POSITION AND HYDROLOGICAL ENVIRONMENT.**
- **EVALUATION OF THE FUNCTIONING OF THE PEAT BOG WITHIN ITS GEOLOGICAL ENVIRONMENT AND ITS GROUNDWATER.**
- **WHAT PARAMETERS OF THE WATER BALANCE OF A FOREST PEAT BOG.**
- **PERSPECTIVES**

Introduction

Peatlands are environments with variable drainage where the processes of accumulation of organic matter prevail over the mechanisms of decomposition and humification. The deposits resulting from this accumulation have an architecture comprising two layers:

- **Acrotelm,**
- **Catotelm,**

Each are distinct in terms of their hydraulic properties. The water table fluctuates near the surface, within the permeable layer formed by the acrotelm, while the lower layer (catotelm), less permeable, remains saturated almost permanently due to an excess water balance. These conditions are conducive to the transient storage of water and, depending on their position within the hydrogeological environment, peat bogs modulate the dynamics of groundwater flow and the water regime of lakes and rivers.

Our study aims to evaluate the hydro-pedological functioning of the Congolese forest peat bog of Lokolama based on the hypothesis of **a hydro-pedological functioning of the peat bog depending on its geological environment and dependent on its hydrographic and topographic network.**

Context / Study area

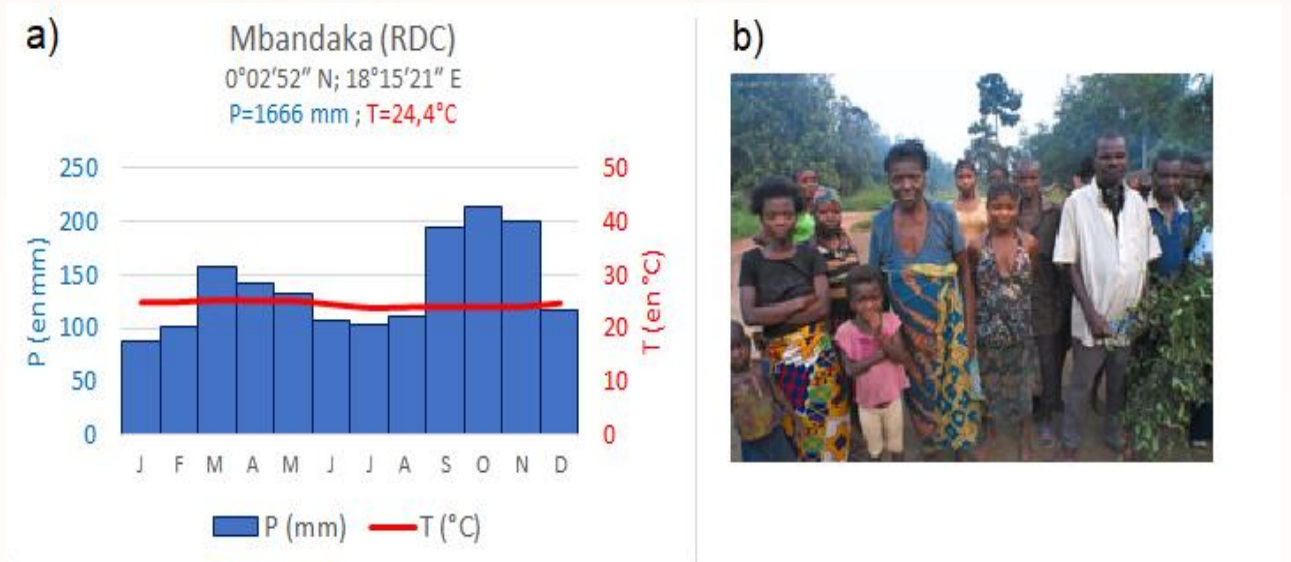
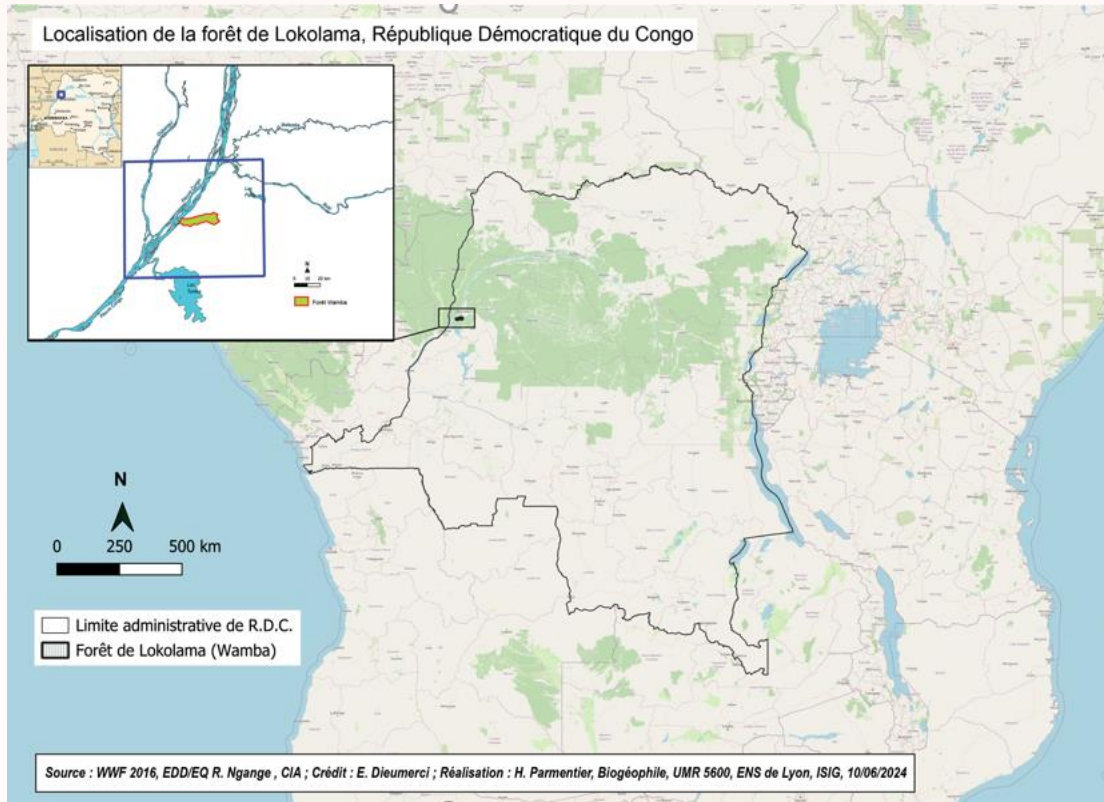


Figure.1 Contexte du lieu étudié : a) Diagramme ombrothermique de Mbandaka (1981 et 2018), b) Population pygmée de Lokolama (cliché : Eluo, 2021).

Two relatively “dry” periods (DJF = 305 mm and JJA = 321 mm of water) and two humid periods (SON = 608 mm and MAM = 432 mm) punctuate this equatorial climate, associated with the double passage of the Intertropical Convergence Zone (ZCIT); wet season precipitation is very important for maintaining the peat forest in particular and for the survival of local populations.

MATERIALS :

➤ *The datasets of geographic informations :*

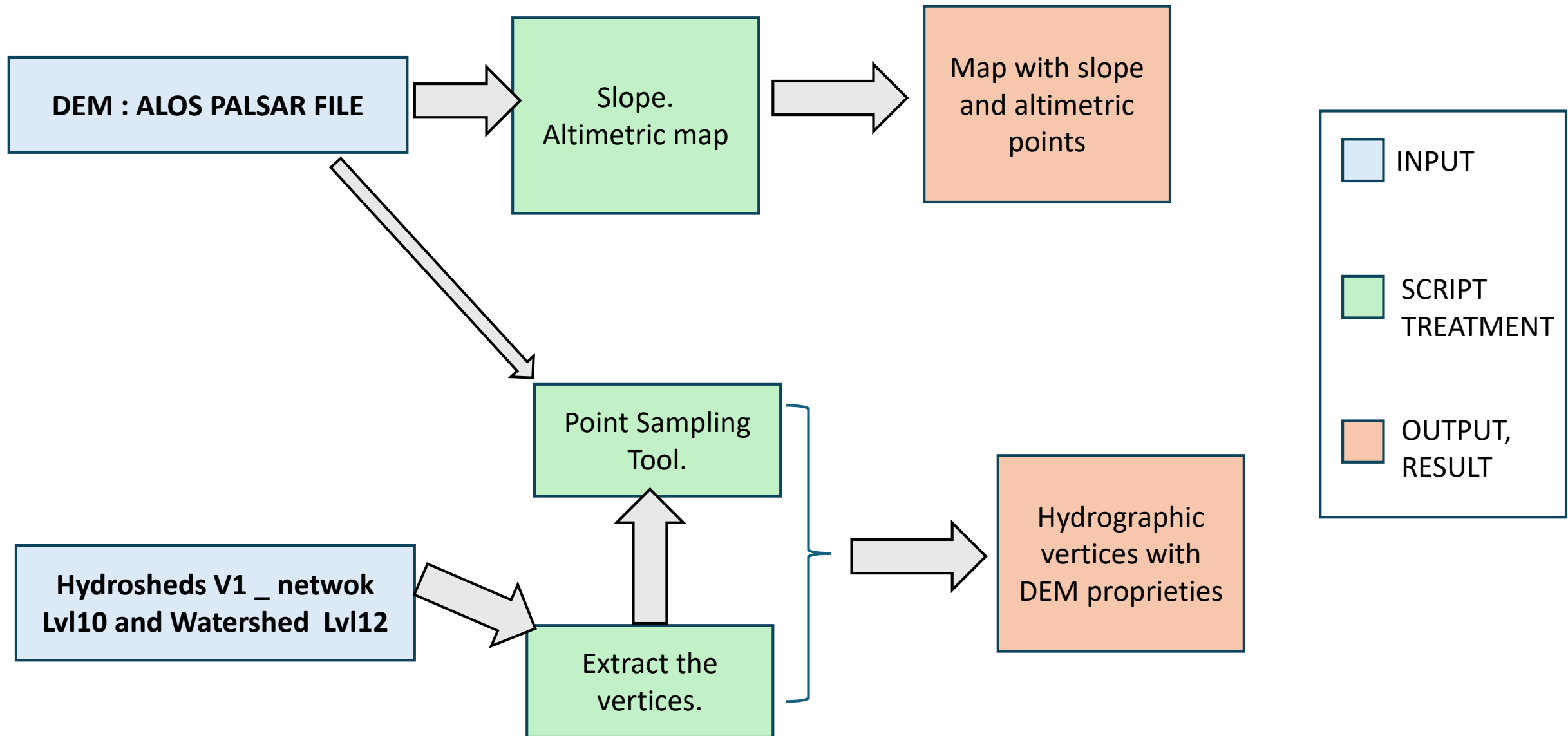
- Alos Palsar 26/04/2023 images (1 pixel = 25 m accuracy):
N00E017_2022_linci_F02DAR and N00E018_2022_linci_F02DAR.
- Hydrosheds V1 network Africa, clipped for DRC.
- Geological shape : British Geological Survey. 2019/2021. Africa
Groundwater Atlas Country Hydrogeology
<https://www2.bgs.ac.uk/africagroundwateratlas/index.cfm>
- Maps. Africa Groundwater Atlas. - Shape polygon of Lokolama forest,
create by digitalization, coming from litterature.

➤ *The software :* Saga Gis and finally Qgis

Technical referens and bibliography :

- Lehner, B., Grill G. (2013). Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. *Hydrological Processes*, 27(15): 2171–2186. <https://doi.org/10.1002/hyp.9740>
- [Scott Arko](#).(2013) QGIS Plugins – Point Sampling Tool, Digital Geography : blog about GIS, geodata, webtechnology.
- Masayuki Takada, Yoshio Mishima, Shosuke Natsume.(2009) Estimation of surface soil properties in peatland using ALOS/PALSAR. *Landscape Ecol Eng* (2009) 5:45–58 [Doi 10.1007/s11355-008-0061-4](https://doi.org/10.1007/s11355-008-0061-4)

« Conceptual model » of data use and gis treatments :



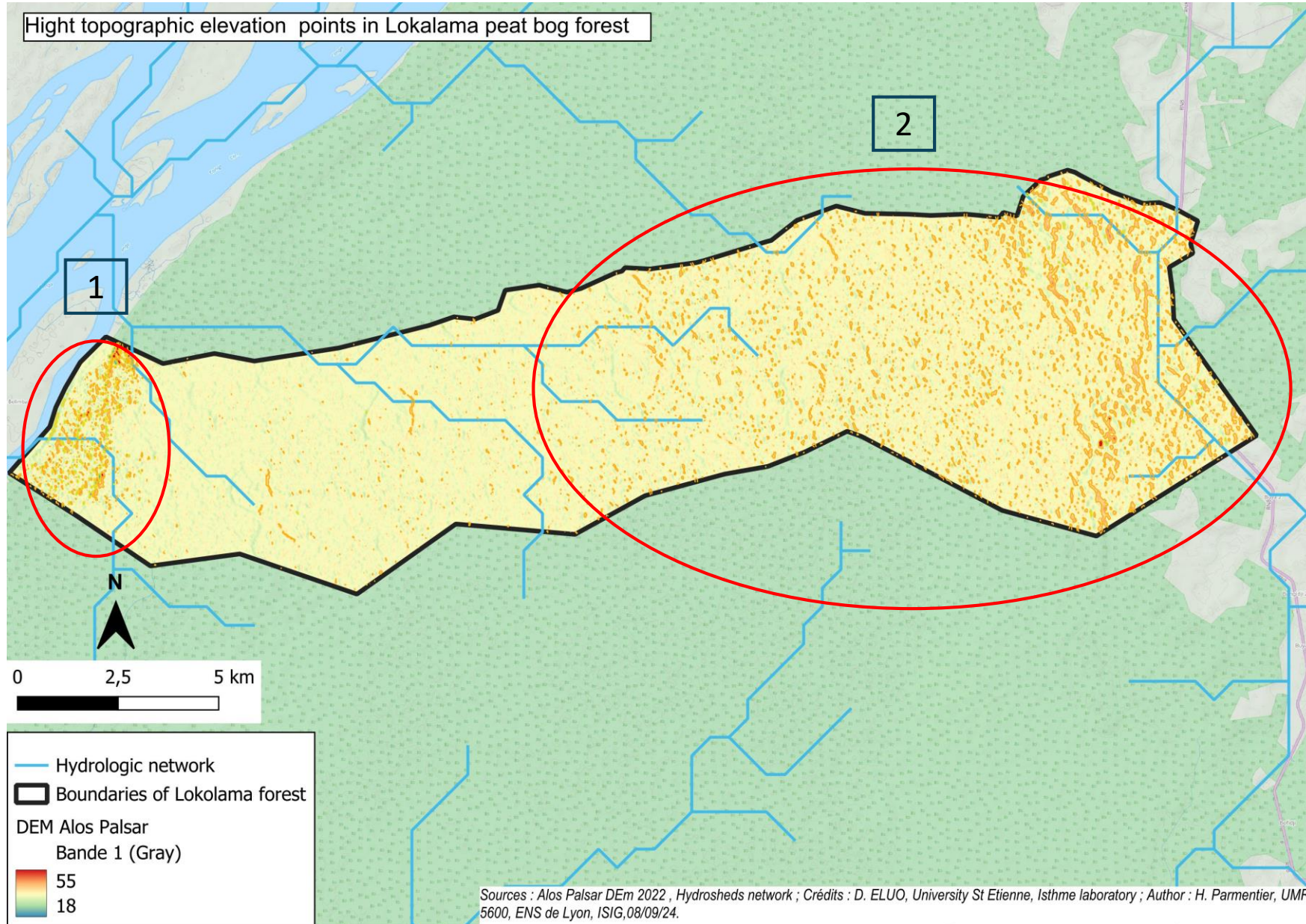
GENERAL STEPS METHOD : (few simple steps have been used to proceed)

- **First test** was trying to use Saga Gis, especially hydrologics modules to create using DEM Alos Palsar a flow accumulation (Top-Down) and direction , but the result with the Alos Palsar resolution was not so convincing.
- Than we used Qgis. **First step extract the vertices of the vector hydrographic network** from the HydroSHEDS database area study.
- **Second step**, I have charged the “**Point sampling tool “ plugin into Qgis.** This plugin give the altimetric value for each point of the hydrologic extracting vertices, coming from DEM. This operation is necessary to show the slope altimetric points direction of each part of Lokolama hydrologic network.
- Than, I ‘ve made the **topographic map of the DEM**, to confirm the topographic hypothesis.
- To complete this analyze, we made some simple view maps of hydrogeologic situation, just to have a idea of the situation. But this data give a global indication, we don't have the pedologic situation, this part of study must be improved as the hydrolic modelisation.

METHODOLOGY :
THE HYDROTOPOGRAPHIC
APPROACH

High topographic elevation points in Lokalama peat bog forest

RESULT- 1

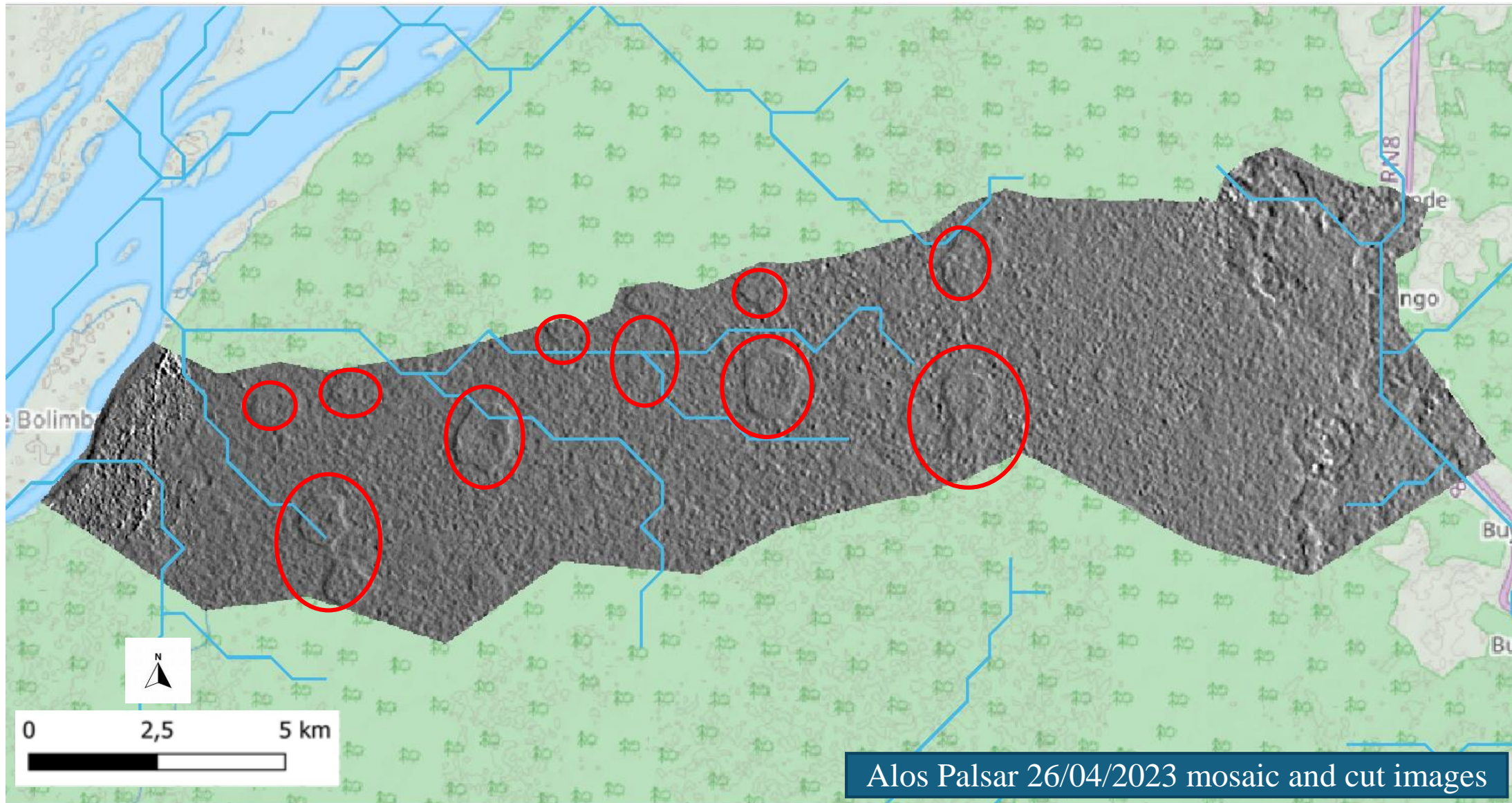


○ Most high positions

1 Flat area of stepped alluvial terrace

2 Other geomorphological models

Morphologic anomalies in the topography ??



In addition to these altimetric observations, there are “**small rainwater natural retention basins**” on raised edges facing west and located under forest cover. Some field observations can confirm this hypothesis.

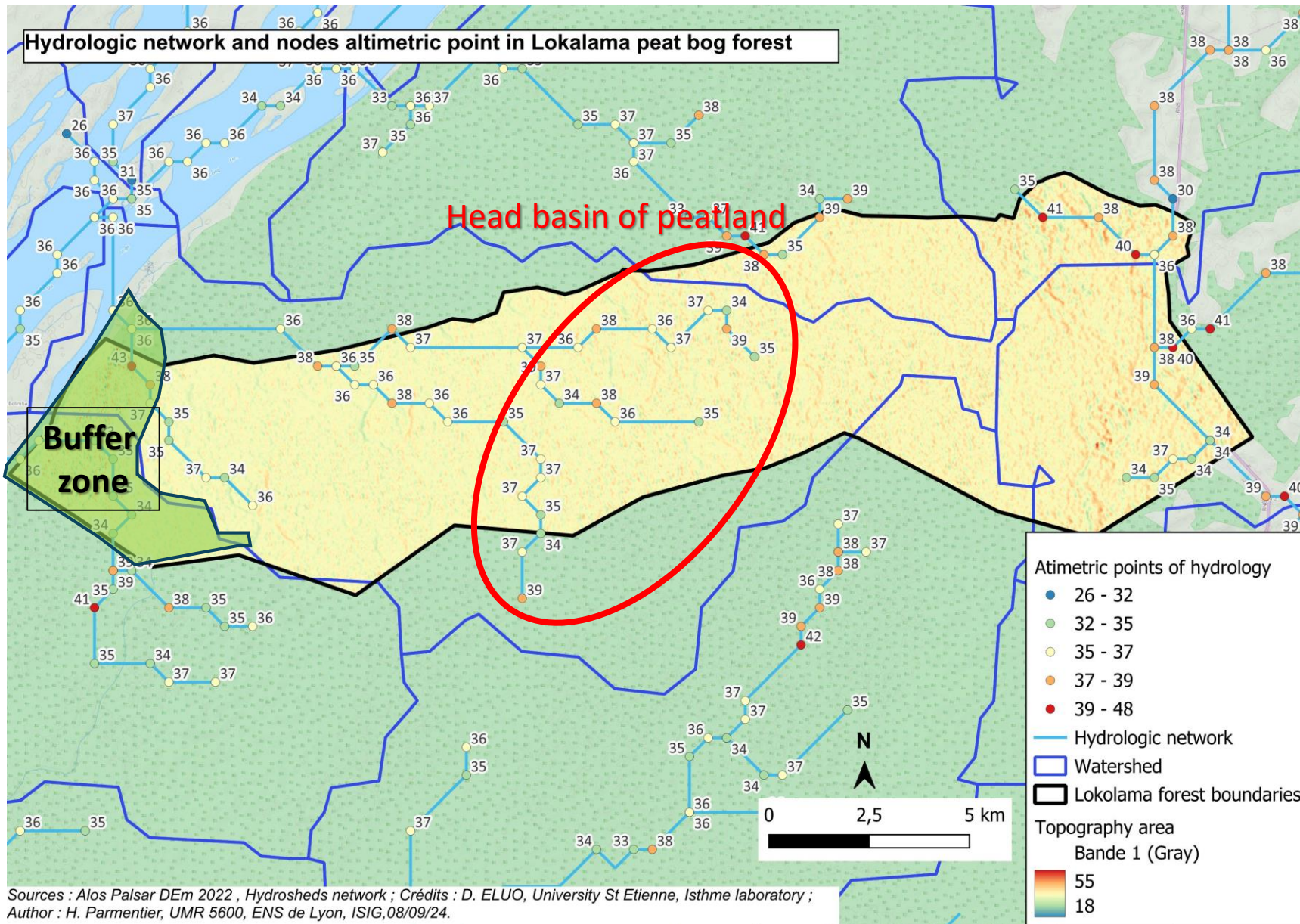
The simple topographic view

This map shows a part of the flow direction Lokolama forest the hydrologic network.

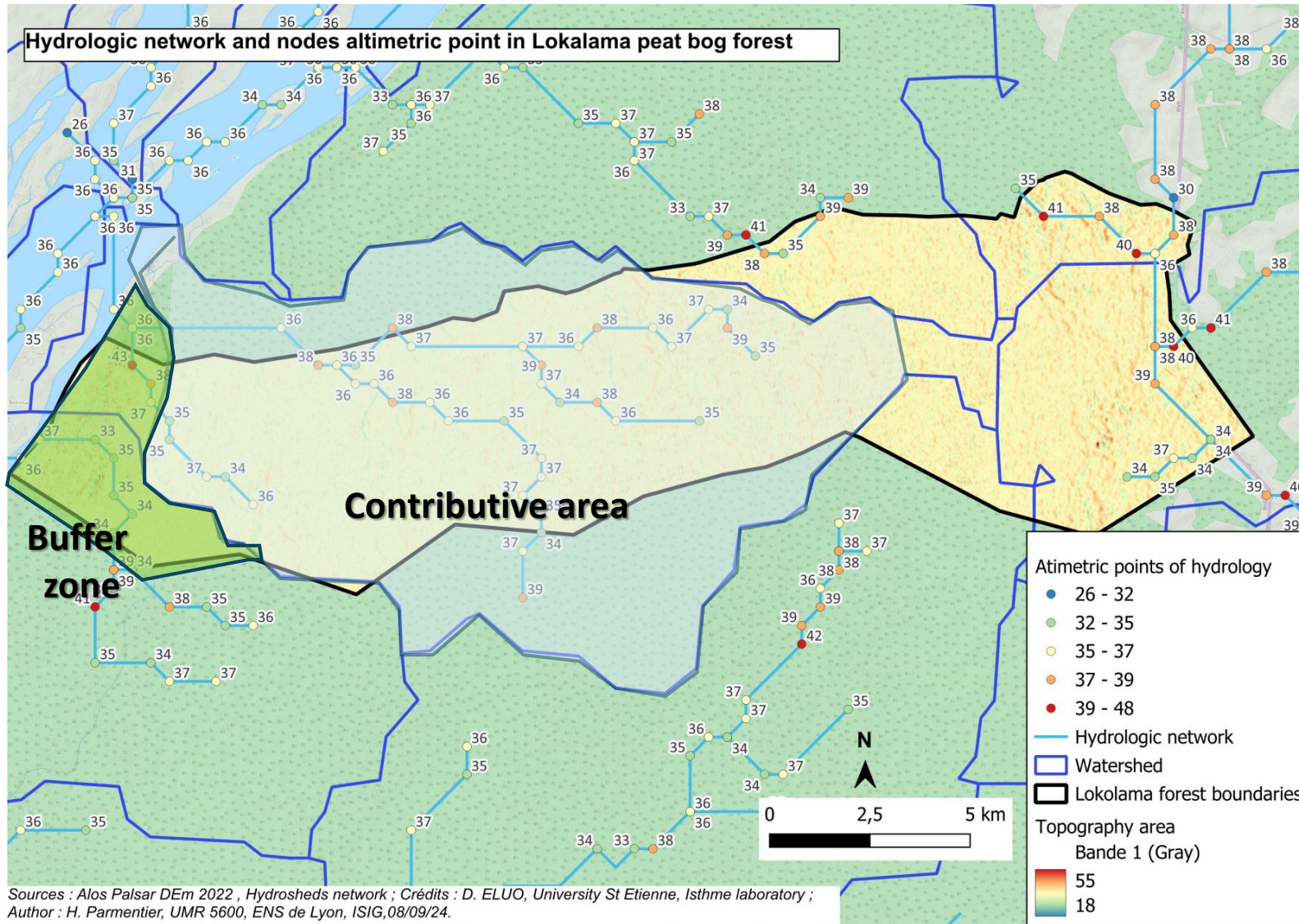
The **altimetric points** give some information's about the **topographic situation**, but not with enough precision. Note the presence of high points of **fluvial terrace uplift** on the western part of the Lokolama peat forest, close to the **Congo River**.

The minimum **distance of the braiding arm** (width of about 500 meters)of the **Congo river** from Lokolama hydrographic network on the right bank is estimated from 0 m to 650 meters. It contributes in a certain way by submersion to the water feeding of the peat bog of Lokolama.

In fact **the water feeding come from flooding water from Congo** and other Lokolama's hydrologic network from one part , but also from second part, from **by rising damp coming from the phreatic groundwater**.



The simple topographic view



Hypothesis :

Contributive are : The flows converge towards the river and are the origin of hydrosedimentary flows which also induce biogeochemical and biological flows.

Buffer zone : Inside the contributing zone, the area immediately adjacent to the river has a buffering effect on flows coming from the contributing zone. This is the buffer zone. This zone can act as a filter between the contributing zone and the river and affect hydro-sedimentary and biogeochemical flows.

The watercourse: The hydrological functioning of alluvial sites is generally affected by the hydro-sedimentary dynamics of the watercourse.

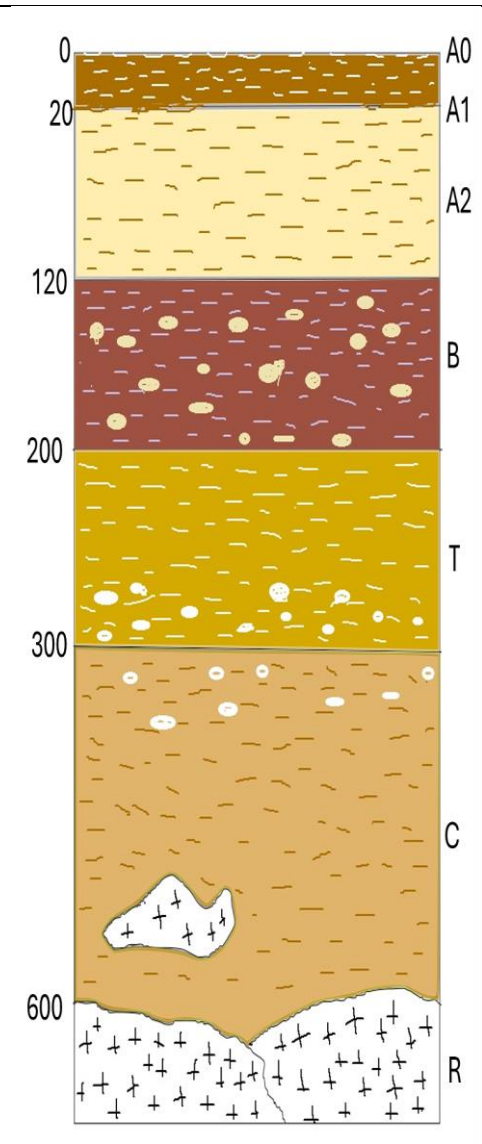
METHODOLOGY :
THE HYDROGEOGEOLOGIC
APPROACH

EVALUATION OF PEAT LAND FUNCTIONING ACCORDING TO THE GEOLOGICAL ENVIRONMENT AND LINK WITH WATER TABLES:

Under the peatlands of the tropical forest of the Congolese basin, the soil formation is of the ferralitic type. The formation process is conditioned by water according to the following mechanisms:

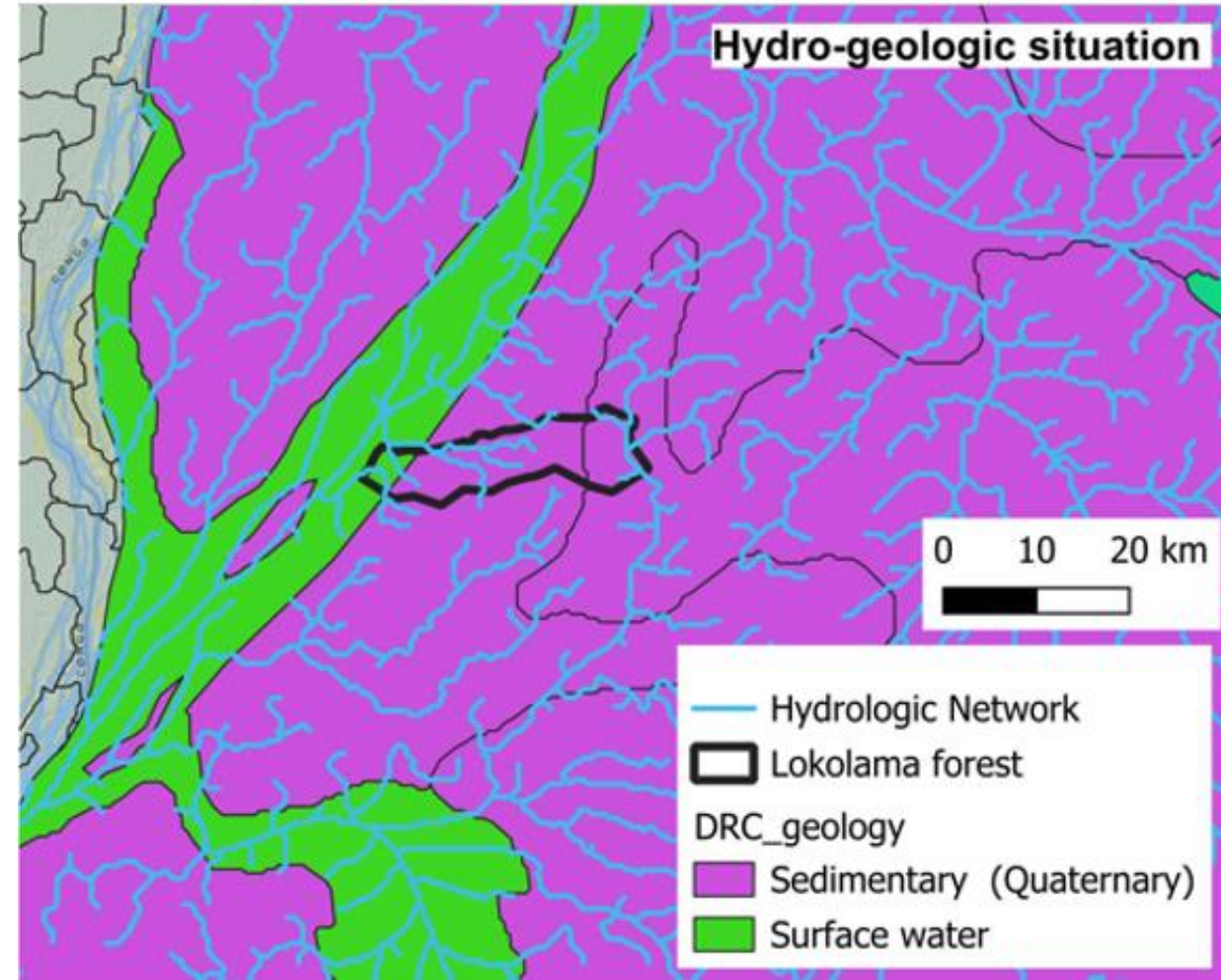
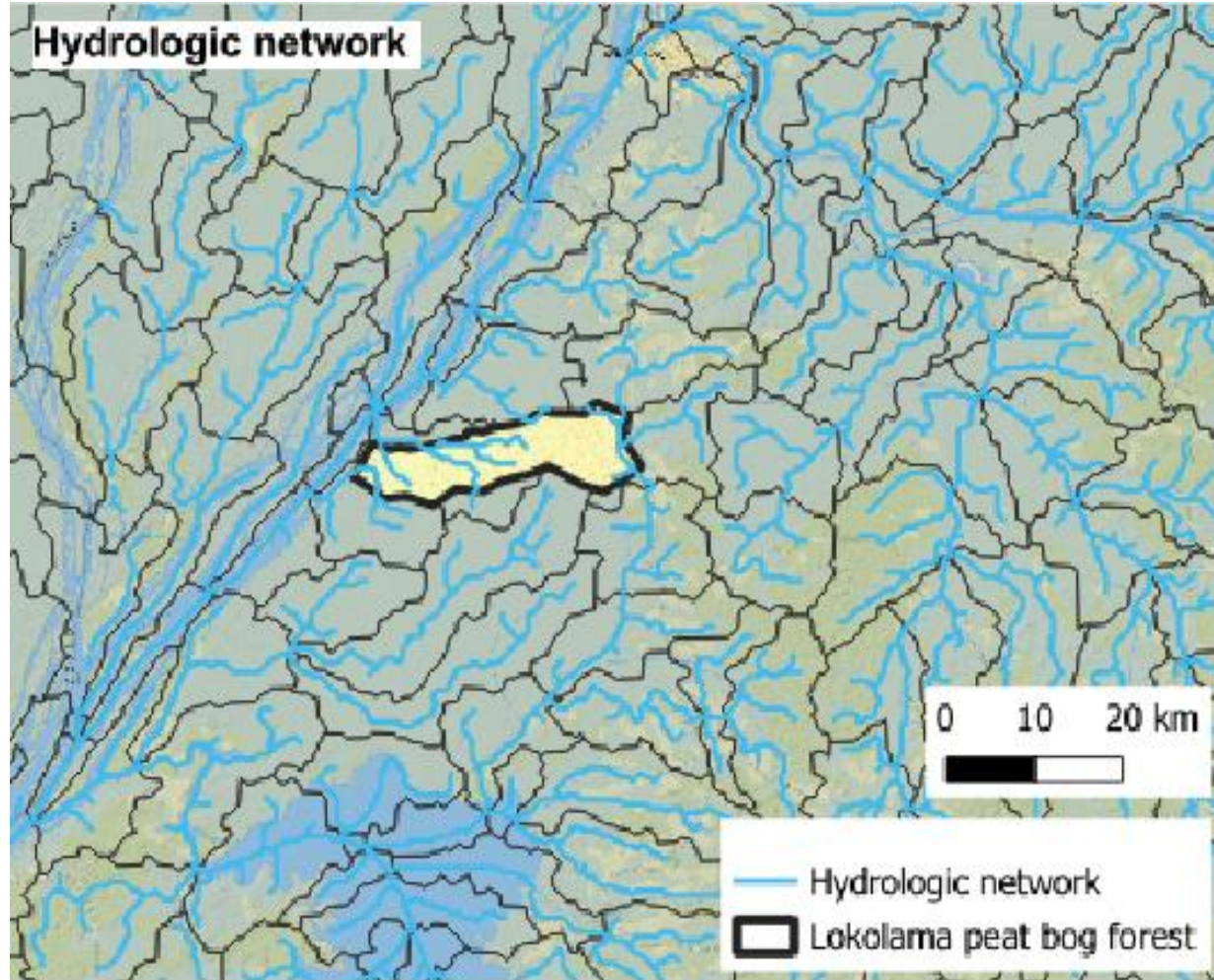
- A complete alteration of primary minerals other than quartz and some heavy minerals (zircon, anatase, rutile, etc.)
- The elimination of a large part of the silica and the majority of the bases solubilized during this hydrolysis,
- The neoformation of kaolinite-type clay, poor in silica, and iron and aluminum oxyhydroxides: gibbsite, goethite, hematite,
- High matter content (carbon/nitrogen (C/N) ratio of organic matter is close to 12).

SUPERFICIAL HORIZONS	FEATURES	
Horizon A0 thin	Made up of litter quickly mineralized by soil fauna and microorganisms	0-20 cm
Horizon A1 from 0 to – 20 cm	humous, lumpy, porous, acidic (pH = 5), dark brown, with many roots and intense biological activity	20-120 cm
Horizon A2, from – 20 to 120 cm	Eluvial, silty, depleted in clay, with gravel and quartz grains, subject to the action of water and organic compounds formed on the surface, ocher-beige in color;	120-200 cm
Horizon B, from – 120 to 200 cm	Clayey, compact, impregnated with water, brick red in color with ocher spots, more or less hardened with ferruginous concretions; it is the illuvial horizon of clay accumulation	200-300 cm
Horizon T between 2 and 3 m	dappled, clayey, slightly acidic horizon, which corresponds to the water table beating zone	300-600 cm
Horizon C from 3 to 6 m sometimes more	alteration horizon in which ferralitic alteration releases SiO ₂ and alkaline cations: Ca, K, Mg, Na	600 cm
Horizon R, beyond 6 m	Unaltered parent rock	



*Evolution de la matière organique du sol en milieu tropical humide/source : Duchaufour, 1988/
Auteur : D. ELUO, 2024*

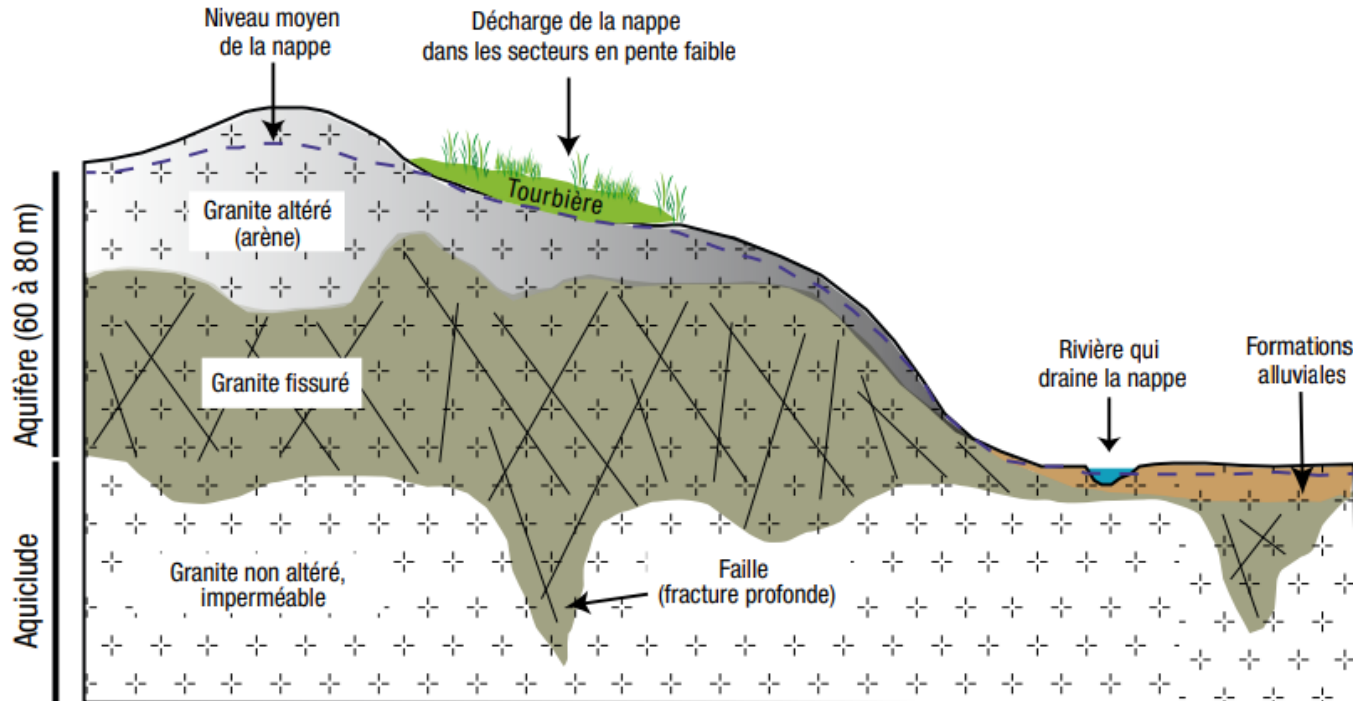
A simple hydrogeologic view



The other hypothesis is that **water feeding is of pedagogical origin** (substrate of the fluvial deposit coming from cretaceous quaternary origin) by a type of **soil very permeable** (the main bed of the Congo River and unconsolidated soil for the rest under forest cover). These **mineral sedimentary deposits are filled by contributions of organic matter from the banks cover vegetation (leaves, barks, branches and dead trees in the process of decomposing).**

A simple hydrogeologic view.

Primary link with the water table: general principle



Multilayer hydrogeological model of granite (d'après Lachassagne et Wyns, 2006)

By progressing from the surface we can therefore distinguish:

- The ground a few decimeters thick;
- Surface formations whose accumulations can reach 4 m;
- The granite arena, generally predominantly sandy-gravelly, produces physico-chemical alteration, its thickness can reach around twenty meters;
- The cracked granite, several tens of meters thick;
- The solid, hard, unweathered, uncracked granite that forms the waterproof base of the model.

FOREST WATER BALANCE PARAMETERS

The water balance can be summarized by the following general equation: :

$$P - i - ET - D + \Delta S = 0$$

P = precipitation during the period considered,

i = quantity of rainwater intercepted by the woody stand and reevaporated directly into the atmosphere,

ET = quantity of water corresponding to the evapotranspiration of the stand during the same period,

D = water loss in the soil through drainage; there are two components to this value: deep vertical drainage D_v and lateral drainage D_e ,

ΔS = value corresponding to the variation in the stock of water stored in the soil. During the wet phase, ΔS is linked to the Δh variation in the thickness of the perched water table between the beginning and the end of the period: **$\Delta S = k \cdot \Delta h$**

Where k is an expression of the macro porosity of the slice of soil in which the sheet has moved.

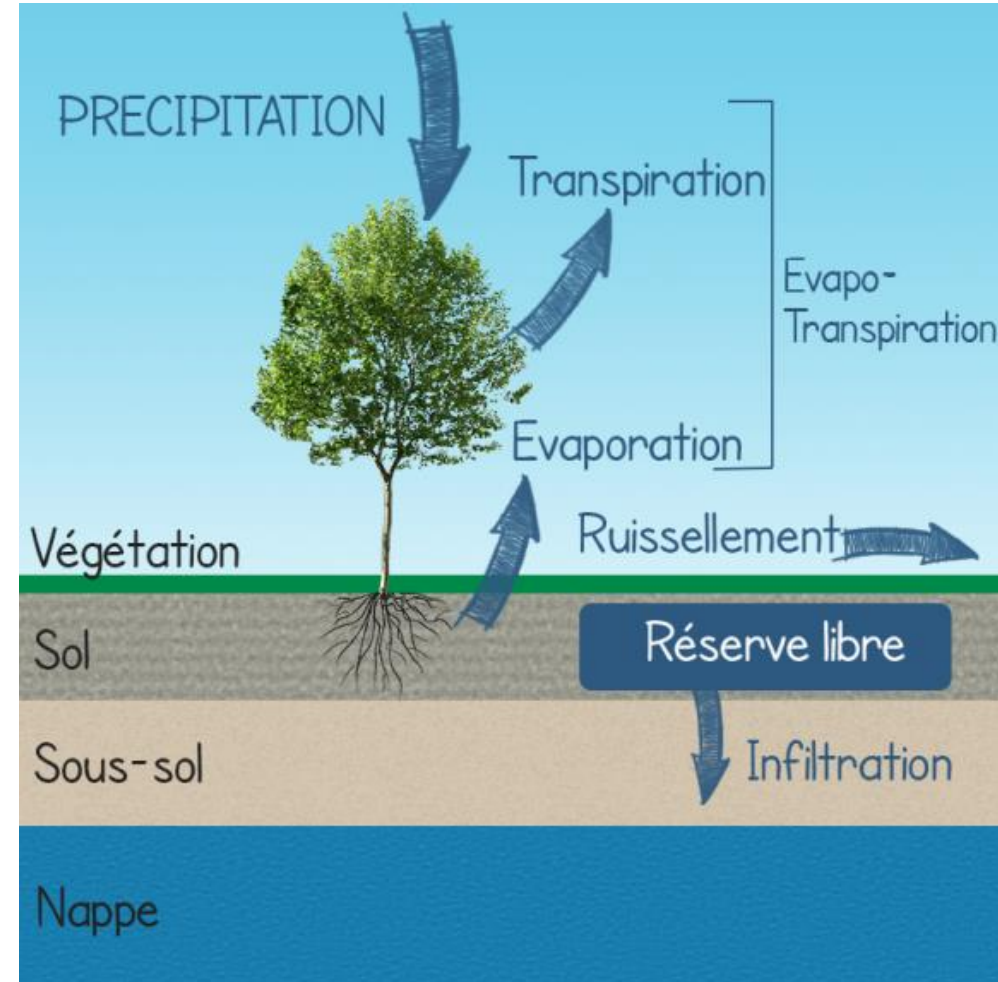
In this case : **$P - i - ET - D + k \cdot \Delta h = 0$**

CIRCULATION PARAMETERS AND WATER CYCLE OF THE LOKOLAMA FOREST PEAT LAND

The transfer of water in the soil-vegetation-atmosphere system is characterized macroscopically by two components :

THE TREE STRATE : it is characterized by a **distribution of underground root surfaces** and its **aerial leaf surfaces**. Water transport from the root surface to the entire tree is strongly dependent on **the distribution of leaf surfaces and their stomatal regulation**.

INFILTRATION, RUNOFF AND DRAINAGE : The **canopy of the tree layer largely intercepts the rain** and promotes preferred **flow and temporarily sifts the high intensities of rain, facilitating infiltration**.



**WHICH PERSPECTIVE ?
WHAT ' S NEW ?**

METHODOLOGICAL & TECHNICAL RECOMMENDATIONS FOR THE FUTUR :

***To study the water contribution and the hydrodynamic phenomena in the Lokolama peatland, there are several problems.**

***The field is not easy to progress by feet, and to carry heavies scientific materials. Cloud cover makes it difficult to use optical imaging and the forest cover is very dense. Radar imaging is preferable, but so precise for little streams.**

***To adding, using free geographic information datas is not very precise, and there is reduced quantity of data. Large scale data are most used in this study.**

***With this approach, we just have a global view of the hypothesis, but in the future will use the evolution of WaterSHEDS dataset products can improved this study Tandem X Data Elevation Model. Waiting to this data free access, TDX-Hydro: Global High-Resolution Hydrography Derived from TanDEM-X can be use with very caution for river under 3 strahler order.**

Conclusion

Topographical and geological factors can explain the hydro-pedological and hydrological functioning of the Lokaloma's peatland.

Two main water feedings coming can explain the hydrodynamic ; in one part by the underground waterground circulation and rainfall regime (for example "rainwater natural retention basins"). In second part from the flood of the Congo River, by overflow and groundwater phreatic upwelling.

Better comprehension is the future goal to validate these theoretic views, than we expect more collaboration with other researchers for regular collection and analysis of data coming from Lokaloma field.

THANK YOU FOR YOUR ATTENTION !

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