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Research Article

Technical Studies of Treatment Basins and Ravines of Area of Sanghe (Senegal)

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Abstract: The Sustainable Management Project (RSM) of Sanghe area, Rural Community (RC) of Notto Diobass, region of Thies in Senegal, is the implementation of control technologies against water erosion that is the main soil degradation in the rural community region. It affects about 80% of the area and, to address this degradation, extensive diagnostic recommendations made by the Senegalese Institute of Agricultural Research (ISRA) focus on comprehensive care of this deterioration through actions in trays, basins and crop areas. To do this, several meetings and site visits were conducted. They led to the concerted following decision: the first action will be used to apply treatment technologies to trays and secondly to slope sand areas of crops recovered. The present study aims mainly the second action that is to say, the technical study for the treatment of slopes and ravines of the Sanghe area.

Keywords: Bottom, catchment basin, dam filter, hypsometric curve, slopes, water erosion

INTRODUCTION

The soil erosion by water is one of the forms of degradation of the most recurrent, especially in developing countries environment. It represents a serious threat to agricultural production and rural infrastructure. It reached alarming proportions, especially in poor and densely populated areas. Each year, about three million hectares of arable land is lost due to water erosion in the world (Benmansour *et al*., 2006).

In Senegal, there have not been many studies that have been done on water erosion (Thierno and Planchon, 1999). This study is part of an already dynamic triggered by various studies (Brahant *et al*., 1996). It aims not only to study this phenomenon in an area called Sanghe, but also to consider development scenarios that could reduce its scope.

To fight against the erosion that is currently causing a lot of damage in the Sanghe area including villages threatened (Cisse *et al*., 2012), the loss of agricultural land (Gordon *et al*., 2007) (following the progressive gully (Lamachere, 1986; Serpantie, 1988; Brochot and Meunier, 1996) and aggregate deposits in the plains from trays), works have been made in the plates which corresponds to a first level of processing. Existing structures are bunds, half-moons and Zai technique (Zougmoré and Zacharia, 2000). In fact, these preventive solutions are not enough. We present in this study curative solutions that is to say, consisting essentially of hydraulic filter dikes. A method of study of a water development is first presented and topographical and hydrological studies carried out for studying the design of a dam filter work as a barrier to the flow of runoff in low land and to obtain a better water infiltration into the dam.

PRESENTATION OF THE SCOPE OF THE STUDY

Location: The study area is located in the rural community of Notto Djobass. It is located 12 km from the city of Thies (70 km from Dakar) and houses the capital of the district of the same name (Fig. 1a and b). Indeed, it is located in the center of the region of Thies and is bounded on the north-east by the rural community of Fandène at North-west by Thiénaba, to the south by rural community of Tassette and Mbour department and finally to the West by rural community of Keur Moussa. The rural community includes 67 villages and covers an area of 252.1 km^2. Its population is estimated at 49614 people.

Presentation of the community rural NOTTO DJOBASS: The rural community has been divided into (5) zones:

- Zone1: Baback
- Zone 2: Pout Diack
- Zone 3: Hanène
- Zone 4: Sanghé
- Zone 5: Notto Diobass and this project is the Zone 4, that is to say Sangué (Fig. 1)

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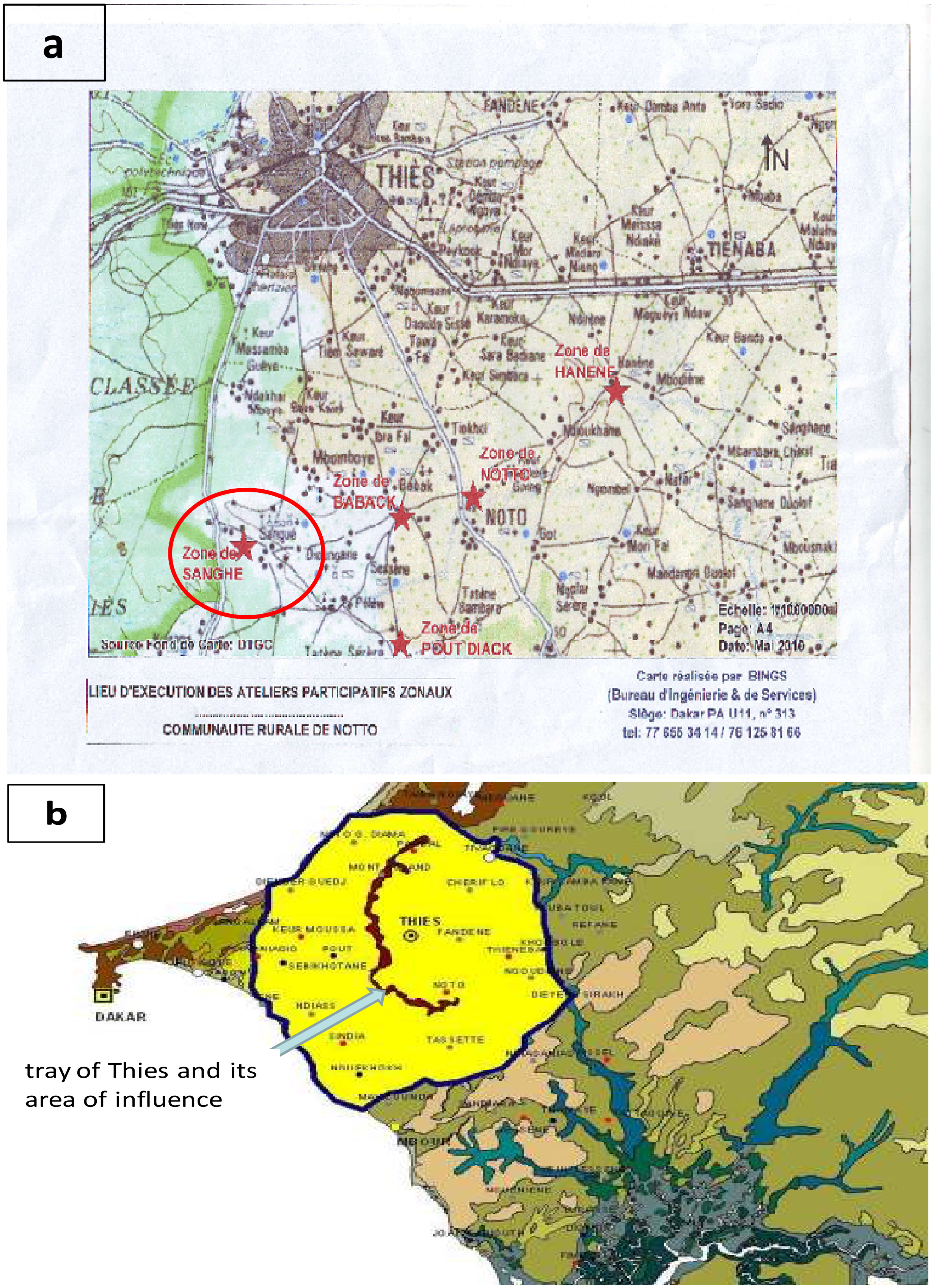


Fig. 1: Location map of the study area

Located on the tray of Thies, Rural Community Notto has a flat terrain dotted with places of hills and dunes interconnected by low-pressure areas enhance runoff of rainwater into the valley that degrades (silting) of the year. This valley through the whole Community territory has its source in the tray of Thies and extends from west to east through the center.

MATERIALS AND METHODS

The digital terrain model produced with the Surfer software is the result of the combination of geographic Google Earth and Embankments using a handheld GPS.

In situations of extreme rainfall, agronomic measures are not always enough and a complementary means of hydraulic is required.

Working method to study water management: The approach for estimating runoff volumes and flows is based on a precise knowledge of the field and a closest adaptation of possible risks to each catchment basin. These methods are often used to design the structures necessary to contain successively along a catchment basin runoff (Brochot and Meunier, 1996) and thus limit erosion. They are based on analyzes of rain, climatic and topographic conditions for estimates of flow rates and runoff volumes.

The facilities offered are generally expected to fight against chronic phenomena (Kolawole *et al.*, 2012; Jajarmizadeh *et al.*, 2013). They are not designed to cope with events frequency rare, but at best, ten-year frequency (rain occurring statistically every ten years). This explains the fact that we have chosen the ten-year frequency for estimating runoff at different catchment basin. A higher level of protection works requires greater structures capacity and therefore larger area.

Topographic studies: Available topographic maps at 1/50 000 scale for the area did not permit to delimit catchment basin in the selected sites for this study. So topographic surveys were conducted in different sites. These surveys have enabled us to delimit the different catchment basin and determine the topography and water necessary for the evaluation of runoff for the design of hydraulic structures.

RESULTS

Topographic results: Figure 2 to 5 below show the appearance of different topographic sites.332-

Results for hydrological studies: The objectives are to estimate flows for designing hydraulic structure.

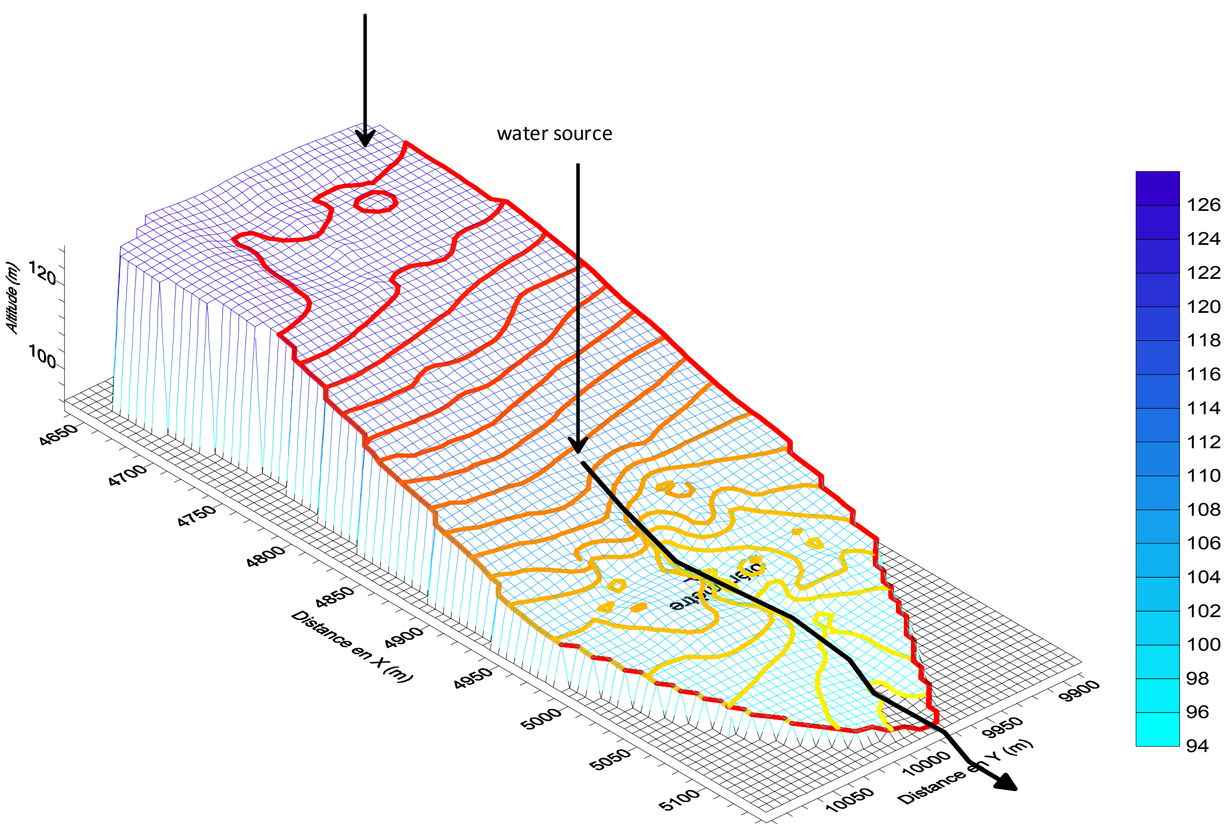


Fig. 2: Catchment basin of Kissane

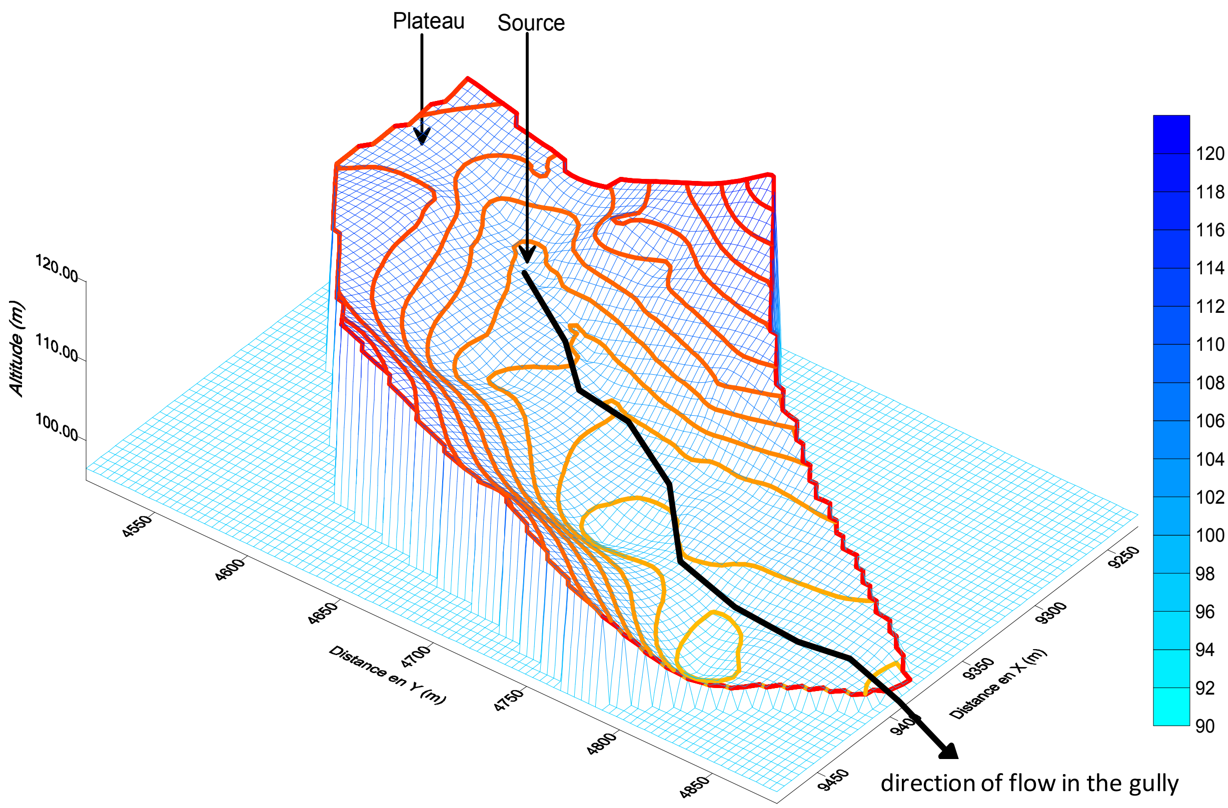


Fig. 3: Catchment basin of Birbirane

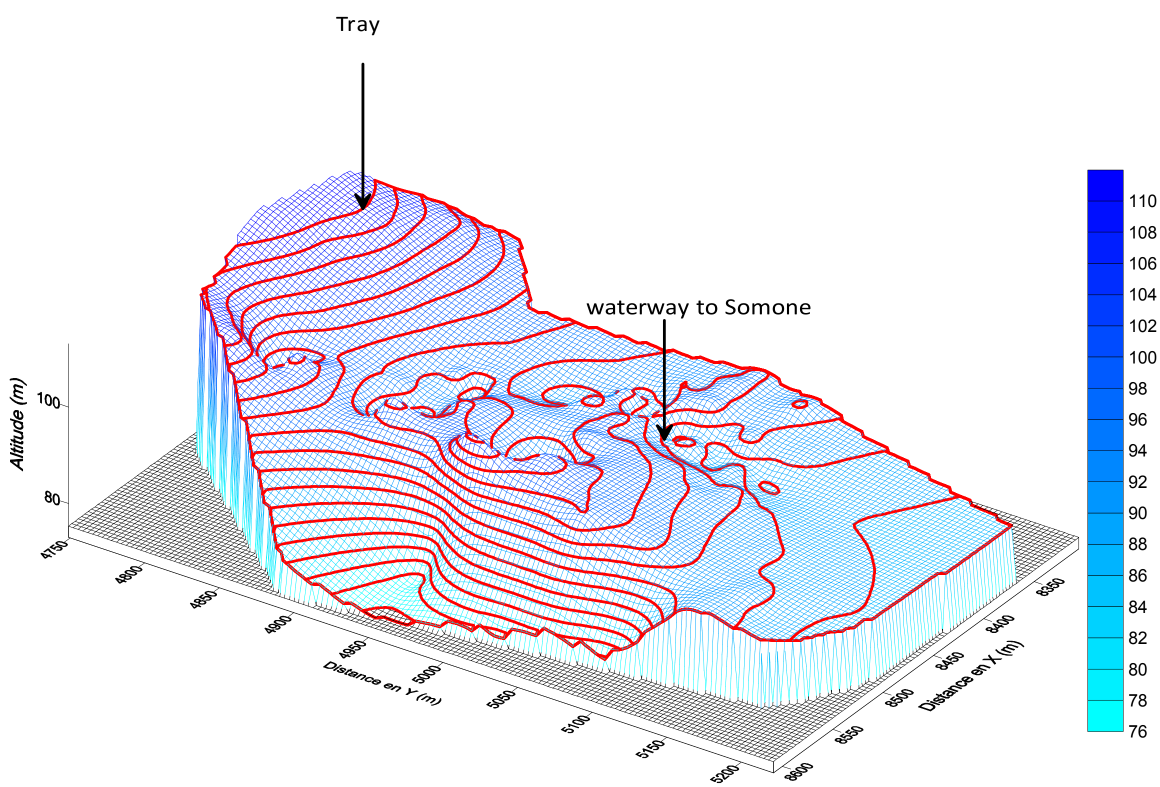


Fig. 4: Catchment basin of Diass

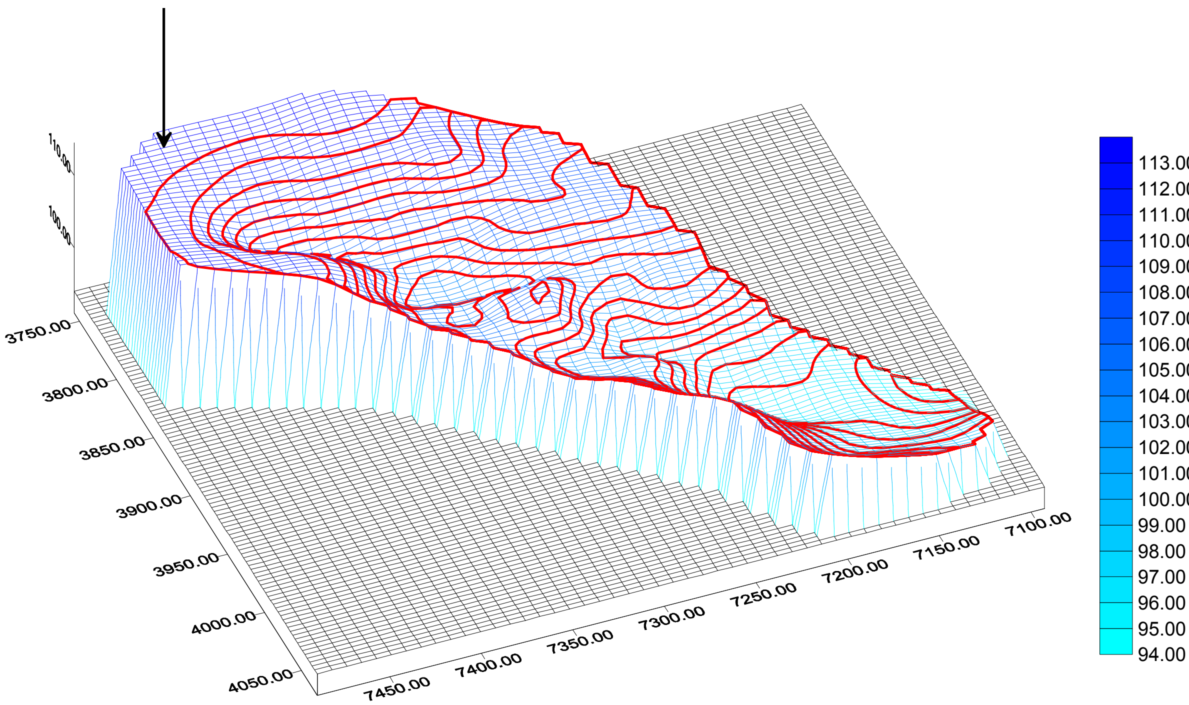


Fig. 5: Catchment basin of Palam

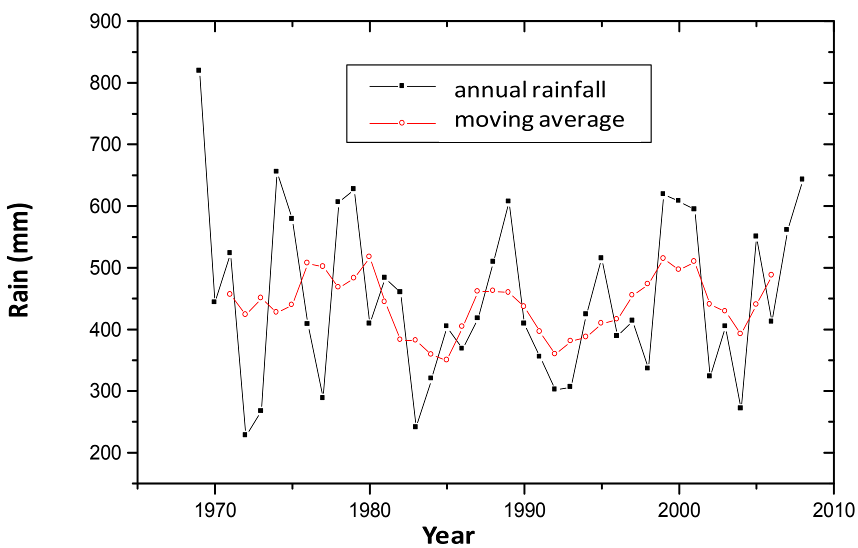


Fig. 6: Annual rain in thies and moving average over 5 years

- **Calculation of average rainfall:** Enough rainfall data for the study area are not available and so we considered the Thies city rainfall data. Figure 6 shows the evolution of annual rainfall in Thies and intrinsic control data by moving average over five years. The intrinsic control shows that the station is regular without any increasing or decreasing trend.
- **Daily rainfall frequency uncommon:** The study of daily rainfall amount sun common frequency (return period equal to 5, 10, 20, 50 or 100 years) is useful for the understanding of flooding, especially for small watersheds (Brunet Moret, 1968). For "n" years of observation, the sample consists of "n" values. Each year, we retain the maximum height of daily rainfall observed (Fig. 7 and 8).

The adjustment of the Gumbel distribution to maximum daily rainfall of the city of Thies was done by calculation and the results are shown in Table 1.

The frequency study on maximum daily rain fall has allowed us to determine the decadal we train which is estimated at 127 mm based on a confidence interval

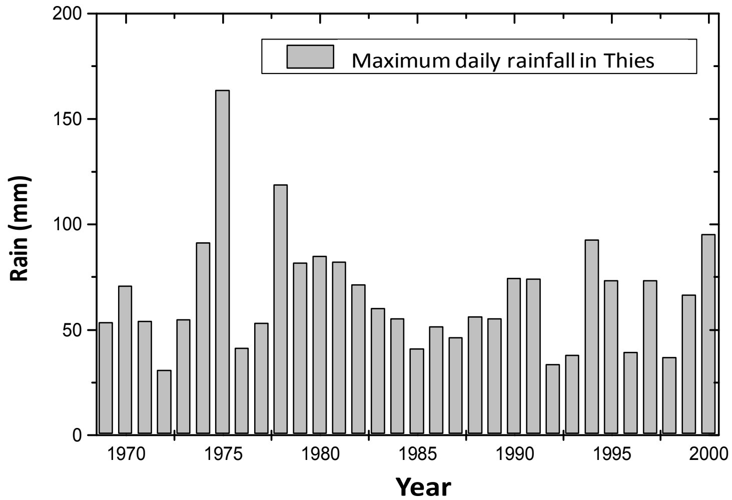


Fig. 7: Evolution of the maximum daily rain in Thies

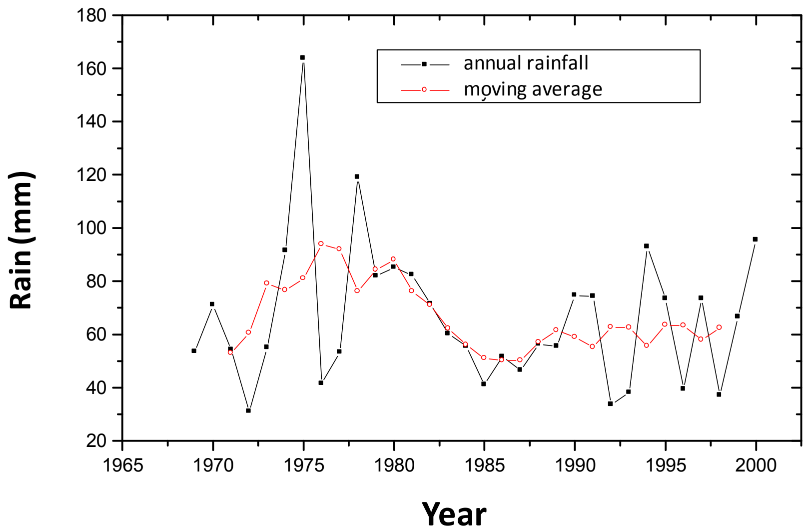


Fig. 8: Rain in Thies and maximum daily moving average over 5 years

Table 1: Results of the frequency analysis

Average annual rainfall (mm)	Avg DR-(mm)	S.D.	Parameters of the Gumbel law		Daily rainfall decadal (mm)	Confidence interval at 90%	
			x_0	S		Infterminal CI	Supterminal CI
452.4	66.3	26.9	53.3	24.2	107.8	88.4	127.2

of 90%. Note that we have chosen the upper bound of the confidence interval due to people and property safety.

- **Estimation often-year flood:** Determination of year flood flow was made by the method of Inter-African Committee of Hydraulic Research (CIEH). We used the following three parameters in relation to the area of West Africa (AO) which corresponds to the geography used by Puech and Chabi Goni (1984):

$$Q_{10} = aS^{b} I_g^{c} P_{an}^{d} \tag{1}$$

S = Catchment area in km^2
I_g = Overall index slope in m/km
P_{an} = Average annual rainfall in mm

The coefficients a, b, c and d are given in Table 2.

To determine the overall index gradient needed for the estimation of year flood, we realized hypsometric curves for different watersheds, which allow us to access the height difference for each basin (Fig. 9 to 12).

Estimates of flood flows for ten different watersheds are presented in Table 3.

Table 2: CIEH coefficient for AO zone

A	B	C	D	Correlation coefficient
197	0.633	0.35	-0.643	0.928

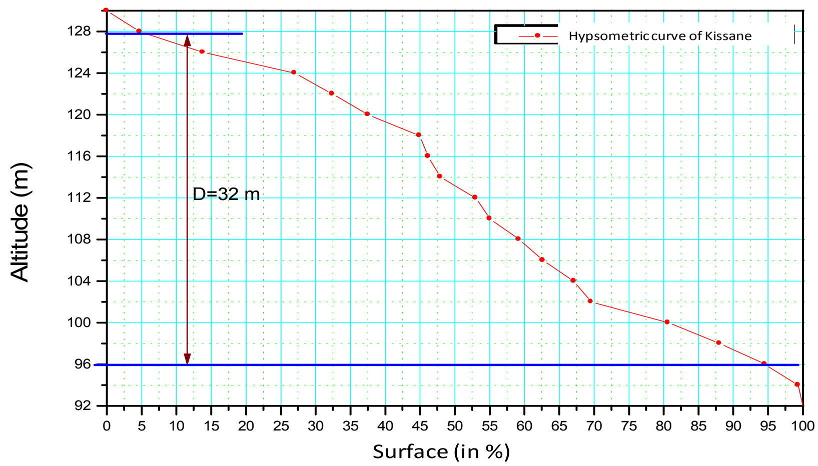


Fig. 9: Hypsometric curve of Kissane

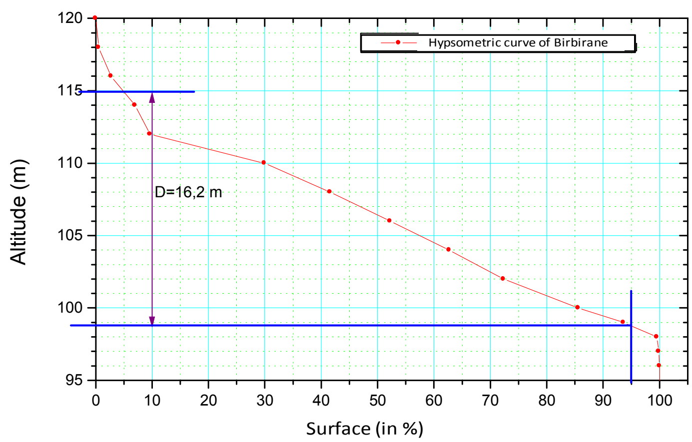


Fig. 10: Hypsometric curve of Birbirane

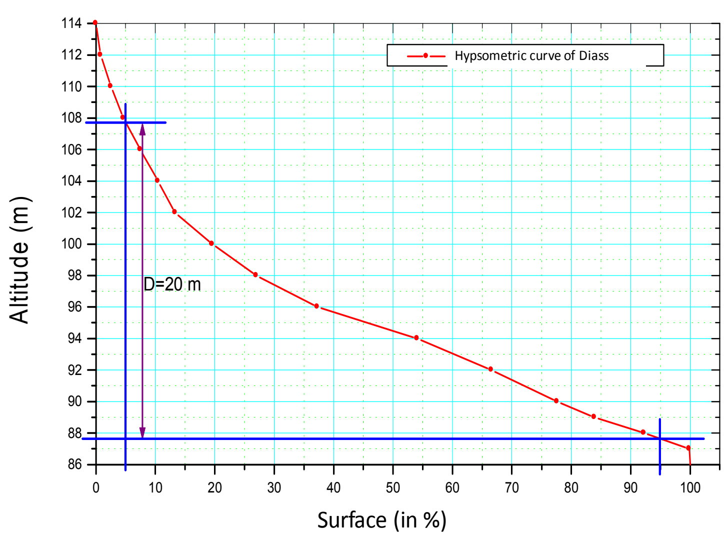


Fig. 11: Hypsometric curve of Diass

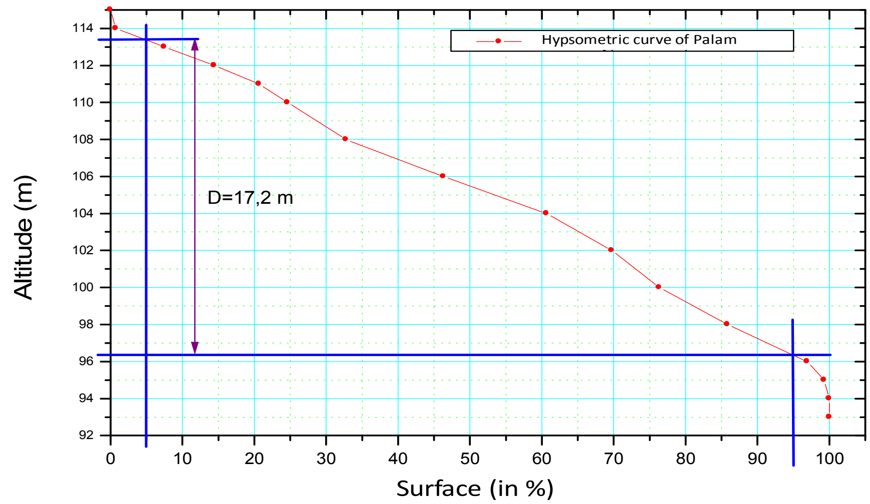


Fig. 12: Hypsometric curve of Palam

Table 3: Estimate Q_{10}

Watershed	S (km^2)	I_g (m/km)	P_{an} (mm)	Q_{10} (m^3/s)
Kissane	0.076	68.62	452.4	3.32
Birbirane	0.054	52.63	452.4	2.45
Diass	0.085	40.85	452.4	2.974
Palam	0.058	41.07	452.4	2.343

Table 4: Characteristics of the works

Site	Dam height (m)	Crest length (m) TOPO	Crest length (m) CALCUL
Kissane	2	68	101
Birbirane	2,5	78	75
Diass	1	106	91

Table 5: Estimate Q_p

Watershed	Q_{10} (m^3/s)	Coefficient peak	Q_{mr} (m^3/s)	Safety factor	Qp (m^3/s)
Kissane	3.32	2.6	8.632	2.5	21.58
Birbirane	2.45	2.6	6.37	2.5	15.925
Diass	2.974	2.6	7.7324	2.5	19.331
Palam	2.343	2.6	6.0918	2.5	15.2295

Rates presented in Table 4 represent flows year flood (Q10). To determine the maximum runoff (Qmr) it will multiply year flood and found a peak coefficient (Cp) which depends on the studied watershed, generally Cp = 2.6 for small watersheds. At the four sites we have small watersheds and we have:

$$Q_{mr} = 2{,}6.Q_{10} \tag{2}$$

In determining the design flow rate (Qp), the maximum runoff must be multiplied by a safety factor (Cs) which varies often from 1.45 to 3.We choose to study a safety factor estimated at 2.5 (low risk) given the types of rain in Senegal; heavy rains and short that generate runoff almost instantaneously causing flow very fast even torrential. Thus, different rates are presented through Table 5.

DISCUSSION

Studies show that we are in the presence of small watershed sizes and hypsometric curves show significant changes in elevation including Kissane where it is 32 m for a total slope index of 68.62 m/km. If we refer to the ORSTOM classification (Rodier and Auvrey, 1965), we are in the presence of watersheds Class R5 (high relief) to Kissane and Birbiane and R4 (relief strong enough) to Palam and Diass. This results in relatively large slopes which as a consequence of relatively high rates of runoff. The vegetation is practically almost nonexistent, the rate of rise of flood is very important that explain the enormous consequences of various kinds, found in the plains.

PROPOSALS FOR SOLUTIONS

Following the field visits and technical studies in this section we propose solutions to fight against water erosion in the study area and treat ravines and slopes of this locality. And will require:

- Reduce the slope slopes for all four sites and the technique used is the densification of the vegetation, the least expensive solution compared to terraces stairs are another form of treatment slopes.

- For sites Kissane and Birbirane where we have a source of water that flows through the ravines, we propose a realization of:
  - A series of minidams gabion cascade the ravines to slow the speed of the water by a dissipation of energy, with a riprap bank protection by Gordon and Reeves (2007)
  - A dam filter gabions downstream that will increase groundwater recharge and let filter to downstream low flow which will prevent damage caused by the current erosion. Table 6 summarizes all the solutions proposed for each site.

Type of development choice: In the four sites we have small catchment basin area (less than 1 km^2) and we chose to fight against water erosion, implement of filtering gabion dams (Fig. 13). They are permeable dams, gabion low height whom main aim is to stop the flood water and spread on farm land of lowland and let a low flow downstream.

Like an obstacle to the flow of runoff in the lower back (cause major damage observed), a barrier filter provides:

- Improved infiltration of the water upstream of the weir which leads to a charging of the soil useful reserve for a good supply of water to crops but also an increase of the refill of the groundwater
- Retention of sediment transported by runoff and erosion from the slopes, this second part fills the ravines and avoid degradation plots downstream as is already the case in the area study.

Such a choice is justified by:

- Ease of implementation affordable for populations
- Availability of materials needed for the realization of development (riprap and gabions making)
- A lower cost alternative to the embodiment of a retainer. The purpose of a filter dam is not to retain water but the restoration or protection of fertile lowlands for more efficient pluvial agriculture.

Design facilities: Dikes filter can be made either with free riprap or gabions as appropriate.

- **Height of dam:** It varies depending on the site and is usually between 0.5 and 2 m maximum for riprap dams. Beyond 2 m in height, the load on the upstream causes high pressure on the bankment, which induces a percolation rate of water in the body of the work inconsistent with riprap stability. At gullies crossing, this height is easily reached and free technical riprap may be replaced by the use of gabions.
- **Length of the ridge:** Filter dikes are horizontal crest works whom length depends onside slopes and ridge height. These are transverse structures and do not exceed a few hundred meters in length (100 to 200 m).

Table 6: Summary of selected solutions

Site	Types of structures	Author	Observations
Kissane	Reforestation; mini gabions dams; By riprap bank protection; Gabion dam filter	Population	Reduce the slope of the slopes by a densification of vegetation
Birbirane	Reforestation; mini dams gabions; By riprap bank protection; Gabion dam filter	Population	Reduce the slope of the slopes by a densification of vegetation
Diass	Reforestation; Bunds, half-moons and Zaï tray; Gabions threshold against the bottom	Population	Reduce the slope of the slopes by a densification of vegetation
Palam	Reforestation; Recess of Stone bunds; Gabions threshold against the bottom	Population	Reduce the slope of the slopes by a densification of vegetation

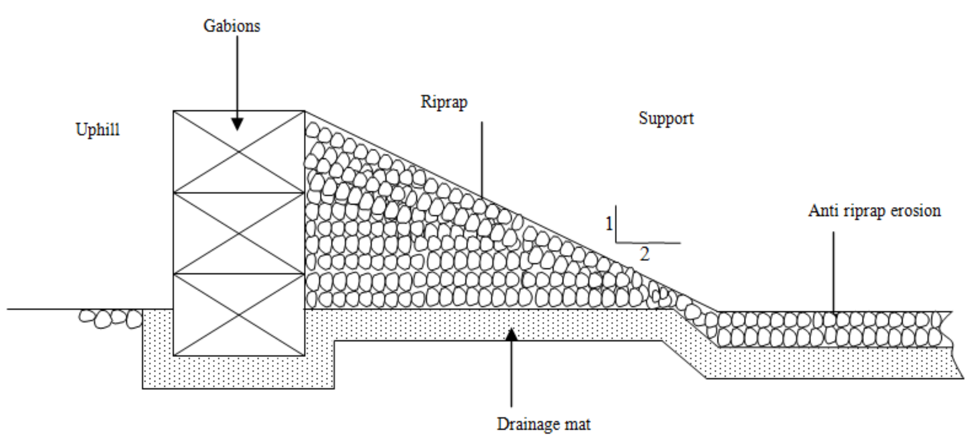
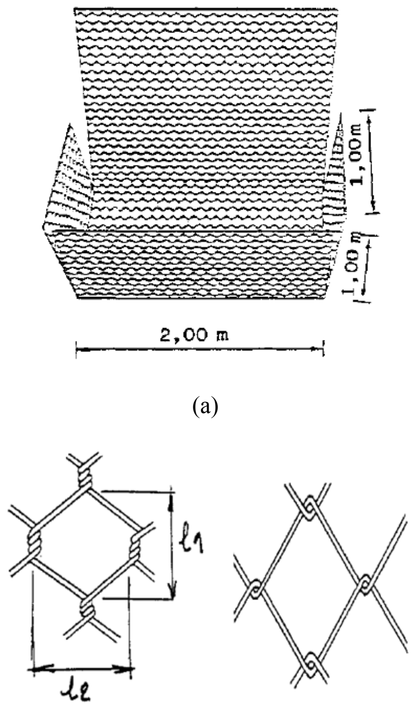


Fig. 13: Cutting across the dam type filter



(a) (b) (c)

Fig. 14: Gabion (a: standard gabion cage, b: double twisted wire c: simple twisted square trellis)

- **Technical:** Dikes filter proposed in the project will be conducted in gabions and riprap. A gabion (Fig. 14) is a rectangular parallelepiped shape cage made of galvanized wire which is filled with pebbles. The durability of gabion depends on the quality of the trellis. Galvanized wire of 2.5 mm is used for the manufacture of gabions soles sized 1 m×2 m×0.5 m with a volume of 1 m^3 with 100 mm double twisted trellis. Rock fill materials consist of lateritic gravel to be deposed in the downstream part of the dam.
- **Protection against erosion:** To prevent scour below the filtering demand renard effect, it is necessary to implement a drainage mat in after scouring of the ground surface layer. This drainage mat is composed of sand, gravel and stones. Each layer must be at least 10 cm thick.

By diverting part of the filtering flow, then it plays a dual role

- It allows a slower emptying of the residual water
- Limiting the speed, it also decreases the renard effect risk dam downstream to avoid dam downstream erosion, it should make riprap rockfill on the drainage mat. The riprap length will be equal to twice the sum of the heights of the structure and overflowing water layer.

The crest width is equal to gabion's (1 m) and let's note that the filter dikes discharge along the entire length.

And to calculate the length we consider that our dam behaves like a single large step or thick crest overflow. We consider the maximum flow conditions. Thus the flow is given by the following expression:

$$Q = 0{,}385 LH\sqrt{2gH} \qquad (3)$$

Which then drives to the following expression for the length:

$$L = \frac{Q}{0{,}385 H\sqrt{2gH}} \qquad (4)$$

Q = Flow rate in m^3/s
H = Overflowing water layer height (m)
L = Length of the weir (m)

In our case, the overflowing water layer height equal 25 cm

We present through Table 4 characteristics (height and crest length) works for different sites.

CONCLUSION

This technical study allowed a more precise characterization of the different development sites. The data and all studies (topographical and hydrological studies) led to proposals for treatment on the slopes and ravines of the study area.

Preventive solutions existing at the purl area source (stone cordons, half-moon, Zai and reforestation) will be combined with curative solutions consisting essentially on hydraulic filtering dikes.

Thus, we will realize a filtering dam in each site. This type of structure is a barrier to the outflow in lowland and provides better water infiltration at dam upstream which increases the groundwater recharge and sediment retention that will help to fill up the ravines and avoid degradation plots downstream.

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