

## Farmers' Perception and Response to Soil Erosion While Abiotic Factors Are the Driving Forces in Sudanian Zone of Benin

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**Abstract:** Sudanian drier zone is characterized by a natural phenomenon of soil collapse called "Donga". The main objective of this study is to contribute to a better understanding of the Donga process as perceived by the bordering population of the W National Park of Benin. Local people that belong to the main ethnic group were interviewed in surrounding villages in order to assess how far they pointed out causes and factors determining soil erosion and land degradation in the W National Park and in land use areas, using structured and semi-structured interviews. The results showed that the main causes of erosion and soil degradation according to the local population are deforestation (75% of respondents) and the farmers' settlement on farms (88.9% of respondents). The main factors they noticed were slope, run-off and gap in land cover and inadequate land use practices for agriculture. The perception of different ethnic group of erosion and soil degradation causes was in general the same. Concerning the erosion and soil degradation factors, we observed a well-structured perception according to the ethnic groups. Old Hausa and Adult Fulani often cited the soil type as the factors that determine soil degradation whereas Young Gourmantché and young Hausa pointed out the run-off and the slope. The main adaptation strategies developed by locals were orthogonal cultivation (73.5 %) crop rotation (62.5 %) and bottom slope cultivation (50.7 %).

**Key words:** Gully erosion % Donga % Land use area % Protected area % Causes % Benin

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### INTRODUCTION

In intertropical Africa, ecosystems have suffered since several decade, severe degradation due to the impairment of weather and the growing human impact. The natural and anthropogenic factors interact in the dynamics of plant communities. Paré [1] stated that natural and anthropogenic factors were the main responsible factors for changes in land use and result in declining vegetation cover, with associated decline in biological diversity and non-timber forest products according to local perception, so the combination of these natural and anthropogenic phenomena has consequences for deforestation, land degradation and desertification. Dry savannah zone has the same environmental problems where erosion and soil leaching seriously threat savannas productivity. The W National Park in Benin Republic is an important protected area established in dry sudanian zone. However, soil degradation in this reserve and its peripheral results mostly in erosion and natural soil collapse known as "dongas" [2]. Dongas induce serious threats to habitat and reduce the availability of fodder in

the W National Park. A better understanding of the causes of these various forms of erosion and land degradation and their mechanisms is essential for the development and implementation of rehabilitation strategies [2,3]. Several terms are used to name the process or forms described above. Among others, these include 'thalweg erosion', 'ephemeral gully erosion' and 'rills in valley bottoms'. Unfortunately, the terms applied are not synonymous, but reflect some important differences in the concepts involved [4]. Over the last decades, most research on soil erosion by water has concentrated on sheet (interrill) and rill erosion processes operating at the runoff plot scale. Relatively few studies have been conducted on gully erosion operating at larger spatial scales. Recent studies indicate that soil losses by gully erosion are far from negligible in a range of environments and that gullies are important and effective links for transferring water and sediment from uplands to valley bottoms and permanent channels. Chizana *et al.* [5] examine farmers' perceptions, understanding and interpretation of soil erosion factors and indicators and how they relate to land degradation and soil fertility



environmental dry conditions. Minimum temperature decreases by 17°C during the period of Harmattan in which the air dryness is the highest and the relative humidity is lower than 30 %. Relative irradiance average 2950 hours determining the environmental water balance. Rainy season occurred from May to September with average annual rainfall of 900 mm. Annual earlier rains provide soil humidification followed by humid period and establishment of the active herbaceous vegetation period. At the end of rainy season soil still remain relatively humid and some herbaceous species may still use available water for maximum growth. Landscape is a large peneplain holding granite and gneiss dominated by some hills. The geological substratum rock is composed by quartzite, basilar rock, micaschist, schist, granite, gneiss and sandstone [8]. Various soils such as mineral soils, little mature soils, tropical ferruginous soils and mineral soil with gley were found. The hydrographical network holds Mekrou River in 410 kilometres length, Alibori River with 338 kilometres and their tributaries. The main vegetation type encountered was shrubby savannah and dry forest [9]. The annual population growth rate was about 3.18 % giving a current estimation of 47,757 inhabitants. Four main ethnic groups were surveyed, i.e. Dendi and Djerma, Fulani, Gourmantché and Hausa. Recently, the natural soil subsidence and slumpflation “dongas” and their impact on grassland productivity were studied in the peripheral of W National Park. Dongas appear to be vast and abrupt depressions. Their depth ranges from 0.20 to 7.50 m and their size from 0.5 to 3.50 hectares. Their occurrence is accelerated by vegetation degradation and vulnerability of soils to erosion due to aggression by rains, weak soil structure, underground

drainage, wind, overgrazing and uncontrolled bush fires. The biomass produced in plant communities varies from 2.10 to 4.04 t DM haG<sup>1</sup>; productivity is higher on the plateau (3.33 to 4.04 t DM haG<sup>1</sup>) than those obtained in the donga (2.10 ± 1.3 t DM haG<sup>1</sup>) [8].

## MATERIAL AND METHODS

**Sampling and Data Collection:** Socio-economic and ethnobotanical surveys were carried out among local people around the W National Park from July to August 2007. Structured interviews using questionnaires were carried out with 136 persons among 4 ethnic groups randomly chosen in 14 surrounding villages in the Karimama district (Table 1). The choice of villages has been done according to socio ethnic group representativity in the study area. All the main 4 ethnic groups in Karimama (Dendi/Djerma, Gourmantché, Fulani, Hausa) were represented in the sample with respect to the age of the leader and a good representation of the old household leader who are supposed to be the best respondents to explain ecological changes in the study area. The sample is proportional to the ethnic group size. In each village, 6 to 17 farmers of different ethnic group including the chief of the village, traditional healers, other leader and Fulani’ chief were interviewed. Farmers were individually interviewed. Investigations focused on: i) farmer’s (respondents) status, their main and secondary activities, land tenure; ii) opinion of the respondents on erosion and soil degradation, various causes and factors of erosion and soil degradation in their farm and in the district of Karimama according to them; iii) assessment of different management practices and cropping techniques

Table 1: Number of farmers interviewed per ethnic group in the 14 villages of Karimama district

Villages	Dendi/Djerma	Fulani	Gourmantché	Hausa	Total	%
Banikani	6	-	-	-	6	4.41
Bimi-Lafia	9	-	-	-	9	6.62
Bogo-Bogo	4	1	-	1	6	4.41
Goroubéri	6	-	-	-	6	4.41
Kargui	5	-	-	3	8	5.88
Karimama	15	-	-	-	15	11.03
Mamassi-Peul (Karimama)	-	15	-	-	15	11.03
Kofounou	2	3	5	-	10	7.35
Kompa	2	2	-	2	6	4.41
Kompanti	2	2	4	-	8	5.88
Loumbou-Loumbou	1	-	6	-	7	5.15
Mamassi-Gourma	1	-	16	-	17	12.5
Monsey	5	1	-	2	8	5.88
Pétchinga	4	4	-	1	9	6.62
Torloh	4	2	-	-	6	4.41
Total	66	30	31	9	136	100
%	48.53	22.06	22.79	6.62	100	

and the reasons for selecting these techniques. Based on their way farmers use the land, a better ethnic group characterisation helps to show and explain differences between them: Dendi/Djerma are farmers and the largest ethnic groups in the study area while Gourmantché are hunters and farmers. Both groups used to practice fallow less than two years duration. Fulani are herdsmen while Hausa are traders selling sometimes fresh or braised meat to villagers. Both later groups become more and more farmers with land use limited, without fallow in the study area [10].

Group interview was also used to get additional information in some villages about potentialities, facilities, land use and cropping techniques.

**Data Analysis:** The interviewees were grouped according to ethnic group and age so that in each ethnic group, three subgroups were defined: young (Y) = 35 years, adult (A) about > 35 years old to 55 years, old (O) > 55 years. The key criterion to consider someone as adult is his responsibility, his capacity to feed himself and to be in charge of everything according to local perception. That is the reason why we considered people with more than 35 years of age as adult. Thus we constituted 12 subgroups (4 ethnic groups × 3 subgroups). Because the size of subgroups differed from one to another and an interviewee could know more than one uses, percentage of positive response for each modality of the variables related to the erosion and soil degradation was

determined for each of the 12 subgroups. These data were submitted to Principal Component Analysis (PCA). Moreover, descriptive statistics were also used to compute frequencies of causes and factors that explain “donga” phenomenon according to ethnic groups.

## RESULTS

### Overall Perception of Erosion and Soil Degradation:

About 90 % of locals have problems related to soil erosion and degradation in their farms. Farmers found donga phenomenon appear on their farm or have inherited it with the farm. The different ethnic groups attribute different name to this kind of soil erosion in the study area: “*Gorou goussou*” or “*Warambou*” for Dendi/Djerma (hole river), “*Koukpankpaagou*” for Gourmantché (where the water washes away the sand and dig a deep hole), “*Garouyé or Pogoodi*” for Fulani (small hole dug by water that become great) and “donga” for Zulu of South Africa. The percentage of positive responses of the respondents on the different variables relative to erosion and soil degradation and its local perception assessment was analysed. The table 2 showed the synthetic results of local perception combining all ethnic groups.

Globally, erosion and land degradation in land use area around the W National Park were evoked by 90 % of farmers in the study area (Table 2). Major causes of erosion cited were agricultural settlement and deforestation by more than 75 % of farmers, while slope

Table 2: Local people perception of erosion, soil degradation causes, factors, land use practices in the study area

Variables related to soil degradation	Modalities	Positive responses	
		Number	%
Causes	Erosion	122	89.7
	Agriculture settlement	121	88.9
	Deforestation	102	75.0
	Animal stamping	48	35.3
	Wildfire	42	30.9
Factors	Slope	113	83.1
	Run-off	112	82.4
	Cover bare soil	63	46.3
	Soil type	50	36.8
Land use practices (cultivation techniques)	Orthogonal cultivation	100	73.5
	Crop rotation	85	62.5
	Bottom slope cultivation	69	50.7
	Stony line	16	11.8
Problems	Tillage	132	97.1
	Poor organic matter	119	87.5
	Poor soil permeability	110	80.9
	Pruning	77	56.6
	Overgrazing	75	55.2
	Late wildfire	19	13.9

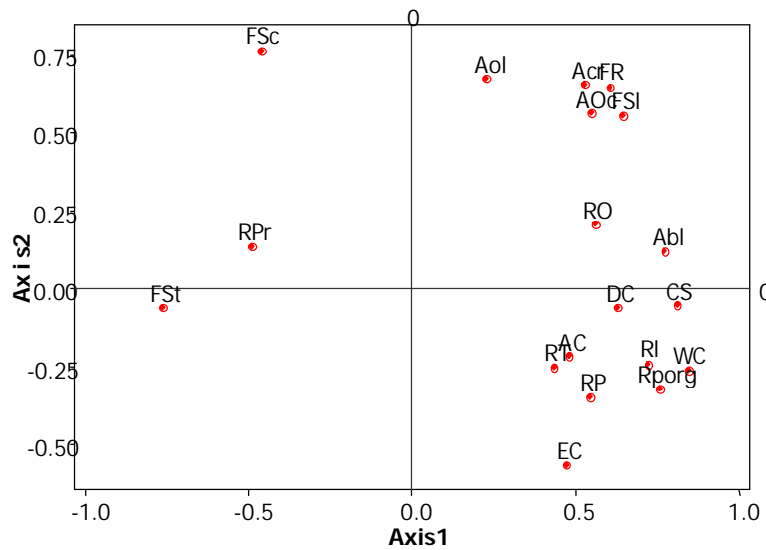


Fig. 2: Projection of modalities of the variables related to soil degradation in the system axis 1 and 2.  
 Legend: Causes: EC= erosion; DC= deforestation; CA= Agriculture settlement; WC= wildfire;  
 CS= animal stamping; Factors: Fr=run-off; FSt: Soiltype; FSI: slope; FSc=soil cover; Adaptation:  
 Aoc=orthogonal cultivation; Aol=stony line; Abl=bottom slope cultivation; Acr=crop rotation; Reason:  
 Rporg=poor organic matter; RP=permeable soil; RT= tillage; RO=over grazing; Rpr=pruning; RL=late wildfire.

and run-off were pointed as major factors by more than 80 % of farmers. Most of the farmers practiced ploughing orthogonally to the slope, crop rotation and cropping at the bottom of slope. According to local people, tillage (97 %), low soil fertility (87%) and poor soil permeability (81 %) are the major erosion and soil degradation problems.

Local response to soil degradation and adopted strategies according to ethnic groups.

Farmers consider that erosion and soil degradation due to deforestation, farmers' settlement for agricultural purposes, wildfire, pruning and animal stamping in dry season. However, these perceptions change according to ethnic groups. Results of principal component analysis (Figure 2) applied to percentage of positive response of modalities showed that the first two principal components explain 74.8 % and 79.1 % of the total variability of the causes and factors of soil degradation respectively, according to ethnic groups.

First axis of figure 2 presents wildfire, animal stamping and deforestation as causes of soil degradation and were often cited together with high slope as the main factors that determine soil degradation. Cultivation techniques like bottom slope cultivation, stony line and crop rotation are often used as adaptation. The erosion and soil degradation problems are, as reported, well adapted to poor soil for agriculture, to low permeability of soil and to late wildfire ignition. The potential for severe soil erosion exists after a wildfire because as a fire

burns it destroys plant material and the litter layer. Shrubs, forbs, grasses, trees and the litter layer break up the intensity of severe rainstorms [11]. However, on the other hand, some people considered soil cover (bare soil) and soil type as the main factors of soil degradation. On axis 2, local people considered soil cover, slope and run-off as main factors determining soil degradation and adaptation practices as orthogonal cultivation and crop rotation are opposed to erosion as the main cause of soil degradation. The projection of ethnic groups in the system axis 1 and 2 revealed that the axis 2 opposes young and adult Gourmantché with young and adult Fulani (Figure 3). In fact, the first group considered soil cover, slope and run-off as the main factors that determine soil degradation and adaptation practice as orthogonal cultivation and crop rotation whereas young and adult Fulani have another perception and considered in their majority the erosion as the main cause of soil degradation.

Combination of Figures 2 and 3 helps to analyze the relations between ethnic groups and local perceptions of soil degradation. Young and adult Hausa are opposed with old Hausa with regard to perceptions of soil degradation. Young and adult Hausa cited wildfire, animal stamping and deforestation as causes of soil degradation and maintained in their majority that a high slope is the main factor that determines soil degradation. Cultivation techniques used by them as adaptation are bottom slope cultivation, stony line and crop rotation.

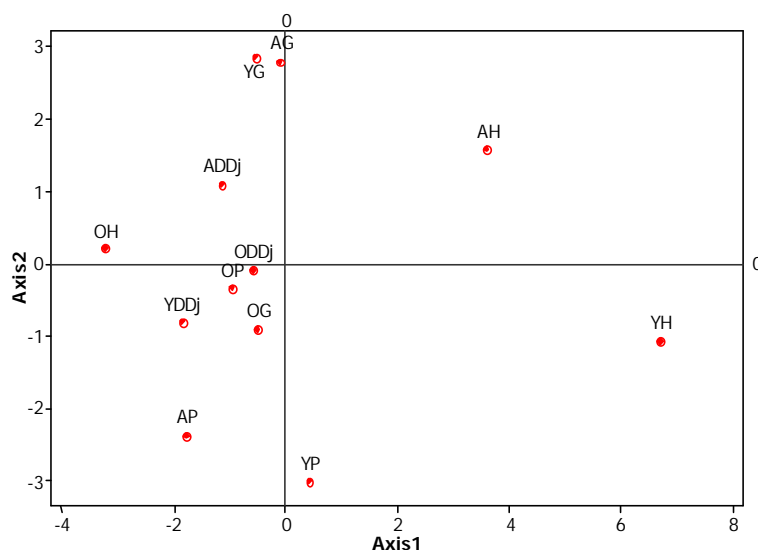


Fig. 3: Projection of ethnic groups in the system axis 1 and 2 defined by the local perceptions of soil degradation. Legend: YDDj: Young Dendi/Djerma; YG: Young Gourmantché; YP: Young Fulani; YH: Young Hausa ADDj: Adult Dendi/Djerma; AG: Adult Gourmantché; AP: Adult Fulani; AH: Adult Hausa ODDj: Old Dendi/Djerma; OG: Old Gourmantché; OP: Old Fulani; OH: Old Hausa

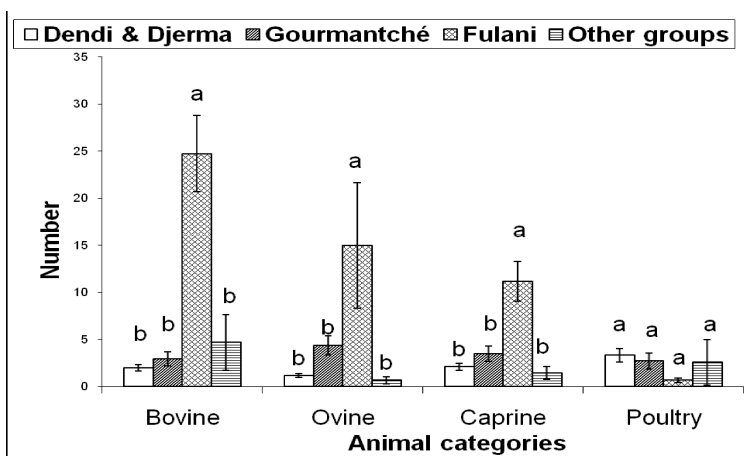


Fig. 4: Animal breeding system according to ethnic groups

Erosion and soil degradation problems, as reported by these people, are related to poor soil for agriculture, to low permeability of soil and to late wildfire ignition. Old Hausa have opposite opinion and considered soil cover (bare soil) and soil type as the main factor of soil degradation.

As adaptation strategies against erosion and soil degradation, local population have developed various techniques and behaviors. Fulani group developed bovine, ovine and caprine breeding as the main activity (Figure 4).

The other ethnic groups (Gourmantché, Dendi/Djerma and Hausa) used to practice fallow less than two years

duration (Figure 5). It is generally noticed a significant difference between ethnic groups considering the mean fallow duration (Figure 5).

As already reported, many cultivation techniques are used as adaptation. Adopted cultivation techniques are (i) the orthogonal cultivation (73.5 % of respondents), (ii) the bottom slope cultivation (50.7 % of respondents), (iii) the stony bunds or line (11.8 % of respondents) and (iv) crop rotation (62.5 % of respondents).

The table 3 showed the results of local perception and behaviour of each ethnic group categories on erosion and soil degradation causes, factors, land use practices in the study area.

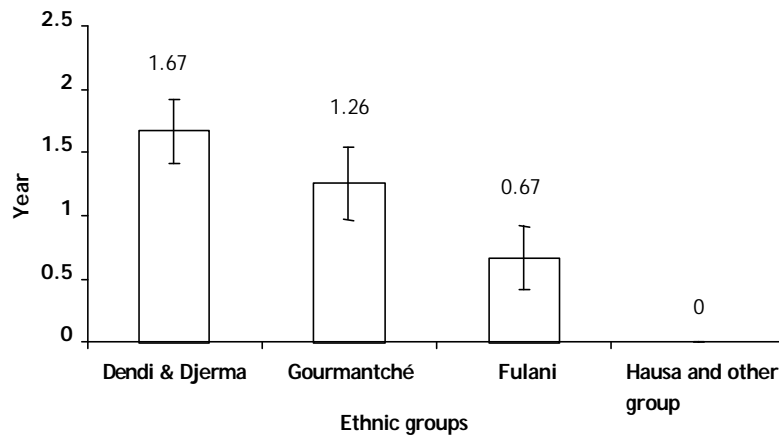


Fig. 5: Fallow duration according to ethnic groups.

Table 3: Local perception on erosion and soil degradation causes, factors, land use practices in Sudano-sahelian Benin

Ethnic groups	Categories	Causes	Factors	Land use practices (cultivation techniques)	Erosion and soil degradation problems
Dendi/Djerma	Young	Deforestation and farmers settlement for agricultural purpose	Slope and run-off	Farming system with 2 years fallow duration	Tillage
	Adult	-	Slope and run-off	Farming system with 2 years fallow duration	-
Gourmantché	Old	-	Slope and run-off	Farming system with 2 years fallow duration	Tillage
	Young	Animal stamping	Soil cover, slope and run-off	Orthogonal cultivation and crop rotation	Tillage
	Adult	-	Soil cover, slope and run-off	Orthogonal cultivation and crop rotation	Overgrazing
Fulani	Old	-	-	Animals breeding, crop rotation	Tillage
	Young	Erosion, deforestation, farmers' settlement, wildfire	-	Animals breeding	-
	Adult	Erosion	-	Animals breeding, farming system without fallow, crop rotation	-
Hausa	Old	-	-	Animals breeding, crop rotation	Overgrazing
	Young	Wildfire, animal stamping and deforestation	Erosion, high slope	Bottom slope cultivation, stony line and crop rotation	Poor soil for agriculture, low permeability of soil and late wildfire ignition
	Adult	Wildfire, animal stamping and deforestation	High slope	Bottom slope cultivation, stony line and crop rotation	Poor soil for agriculture, low permeability of soil, late wildfire ignition and tillage
	Old	-	Soil cover (bare soil) and soil type	-	Overgrazing

## DISCUSSION

**Overall Perception Analysis:** The fact that each of the investigated ethnic group has in its own vernacular language a word to explain “donga” suggests that this phenomenon has attained a high degree of cultural significance in the study areas. According to locals, the major causes of erosion were agricultural settlement and deforestation while slope and run-off were pointed as major factors. As adaptation strategy, most of farmers practiced ploughing orthogonally to the slope, crop rotation and cropping at the bottom of slope. Tillage, low fertility and poor permeability of soil are the major encountered problems by farmers [10]. Globally, the causes and factors evoked here were previously described in other regions [12-14]. Another cause may be the increasing agricultural lands intending to feed the

growing human population. In the study area, the increasing rate of the population is estimated at 3.58 % per year [15]. This is in accordance with previous findings in which increasing rural population led to a change in land use [16]. Population growth can cause land degradation in the short term, but it can also spur innovation and agricultural intensification as well as the adoption of conservation techniques [17,18]. According to the South African perceptions, the dongas might come from improper land use which would be linked to the practices of wildfires, grazing cropping management [19]. As reported in the results, the ethnic groups in the study area used to practice fallow less than two years duration. There is a decrease in the practice of fallow with breeders (Fulani) who improve by associating livestock to agriculture in contrast to previous study [20]. It is important to notice that Fulani who are mainly nomadic

herders and traders [21] become more and more farmers. The routes they established in western Africa provided extensive links throughout the region that fostered economic and political ties between otherwise isolated ethnic groups. Members of individual Fulani often settled down among their sedentary neighbors, intermarrying and establishing trading contacts for future business transactions. In the study area, farmers have no more land because of the presence of W National Park which is a protected area by law. They were obliged to use the same land each year and practice crop rotation for weed control against *Striga hermonthica*, a hemi parasite weed species and also an indicator species of poor soil fertility. Most of the farmers pointed the run-off and slope as inducing erosion and soil degradation and others added the type of soil as significantly contributing to soil erosion and land degradation. This is in accordance with previous findings that show soil conditions in dryland zones as key criteria in assessing the occurrence and severity of land degradation there and in particular climatic factors are of overriding importance [22]. The wildfire was already evoked by many farmers as causing land degradation conversely to agricultural settlement and deforestation. At the reverse, dongas might result from improper land use which would be linked to the practices of wildfires, grazing, etc. [19]. Whether wildfire was a minor land degradation factor in the study area, or it is possible that a complex of factors lead to these degradations. Furthermore, human-caused environmental changes are creating regional combinations of environmental conditions [23]. These environmental modifications might become a greater cause of global species extinction than direct habitat destruction [24]. There is therefore a need to search at the scale of the study area, the quantitative contribution of each factor especially the wildfire and climate change in erosion and dongas processes [25].

**Ethnic Group Perception Analysis:** In the current study, young and adult Gourmantché considered soil cover, slope and run-off as the main factors that determine soil degradation and adaptation practice as orthogonal cultivation and crop rotation whereas young and adult Fulani have another perception and considered in their majority the erosion as the main cause of soil degradation. Traditionally, Gourmantché are hunters and farmers [26] whereas Fulani are well known in Africa as nomadic herders and traders. Gourmantché and Fulani perception could be explained by their activities. The Gourmantché ethnic group members are farmers and they provided more details on causes and factors of erosion and soil

degradation and highlighted the used adaptation actions. Their perception is similar to Dendi and Djerma who are also farmers in the study area. The Fulani group gives less detail in their perception. Young and adult Hausa cited wildfire, animal stamping and deforestation as causes of soil degradation and maintained that a high slope is the main factor which causes soil degradation. The adaptation actions used by them are bottom slope cultivation, stony line and crop rotation. Such practices should be, as reported by these people, well adapted to poor soil for agriculture, low permeability of soil and late wildfire ignition. Old Hausa have opposite opinion and considered soil cover (bare soil) and soil type as the main factor of soil degradation. It is important to notice that Hausa are traders. Hausa ethnic group has a large geographical mobility in western Africa like Fulani group. Old Hausa opposite opinion to young and adult Hausa' perception could be explained by old man experiences on nature understanding. During their walking or journey, many natural phenomena has been observed or appeared to reinforce their environmental knowledge. Because they are many years old and according to their experiences they perceived bare soil and soil type as the main factors of erosion and soil degradation. Old Hausa perception is in accordance with the previous findings that bare soil increases the erosion potential [27]. Local knowledge has been described as experiential, rooted in place, empirical and dynamic [28]. Also, old Hausa have the same adaptation practices to soil erosion (overgrazing) with old Fulani and adult Gourmantché while young and old Djerma, young and old Gourmantché and adult Hausa consider tillage as the main practice for the adaptation to soil degradation. The Fulani have mainly animal breeding or sometime farming as activities while Gourmantché are farmers in their majority. The adopted adaptation strategies by each of the locals in the study area depend on their perception about the erosion and soil degradation causes. The adaptation strategies developed by locals depend on their activities or their ecological knowledge. The most relevant of such strategies in terms of yield of crops are the orthogonal cultivation, crop rotation and the bottom slope cultivation. Local peoples are knowledgeable about their soils, lands, plants and environment and well qualified to define their own problems [29]. Farmers' perception and description of their environment are often linked to land management experience and land use history [30]. Research has already shown the usefulness of using farmers' knowledge [31] to assess soil fertility [32]. Among others, Habarurema and Steiner [33] and Murage *et al.* [32] documented extensive

knowledge of farmers on landscape processes and relations between soil productivity and relief position. Positive experiences have also been reported in the use of indigenous knowledge for erosion assessment [34]. As farmers' and scientists' perceptions sometimes mismatch [35,36], Van Dissel and de Graaff [37] suggested that the adoption and adaptation of farmers' knowledge into a scientific framework could only be achieved by thorough assessment of farmers' perceptions of ecological degradation. The importance of the contribution of local knowledge to ecological sciences has been acknowledged [38], but difficulties remain in how to integrate effectively local and scientific knowledge systems. Methodological studies that focus on integrating local and scientific knowledge are few [30]. Niemeijer and Mazzucato [39] argued that the potential of farmers' knowledge has only been partially exploited and they pleaded for a move from the recognition of farmers' knowledge as a source of information to a more effective use of such knowledge for sustainable development. In order to understand local soil and land knowledge systems research items would include local management and conservation and local perceptions and beliefs about soil and land spatial heterogeneity, natural dynamics and processes and interrelationships with other biophysical factors [40]. Various approaches were set up to restore degraded environments using phylogenetic resources [41-45]. The integrated approach identifies and mobilizes the relationship between local knowledge and scientific data in order to elaborate natural resource management schemes according to local social, cultural, economic and ecological contexts. Together with off community agents (e.g. soil scientists, agronomists, social scientists, planners, among others), farmers could participate in validating and integrating information into the local decision-making and planning procedures. Designing sustainable natural resource management models could aim at linking soil and land wisdom and knowledge in order to promote feasible and sustained local endogenous development in an interdisciplinary perspective [29].

### **CONCLUSION**

Globally, farmer settlement for agricultural purposes and deforestation were pointed out by all local population as the main erosion and soil degradation causes. Concerning the erosion and soil degradation factors, a well structured perception was noticed according to the ethnic groups. Old Hausa and Adult Fulani often cited the

soil type as the factors that determine the erosion and soil degradation whereas young Gourmantché and young Hausa pointed out the run-off and the slope. Local farmers' perception showed a gradient in responses which suggest an existing impact of multidimensional environmental changes. Series of relatively small changes may be as important as a single major change. The restoration strategies should combine causes and factors (farmers' settlement, deforestation, animal breeding, pruning, over grazing and animal stamping with slope, run-off and soil type) and the target group will be priority Dendi/Djerma, Gourmantché and Fulani. More investigations on land use and land cover practices and soil composition are needed to well understand the erosion processes in the study area.

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