Rainfall and ecosystem re-greening in Burkina Faso

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Abstract

In the Sahel part of Burkina Faso, ecosystems have been exposed to drought and land degradation since the 1970 years. This contributes to environmental degradation and biodiversity loss. Regarding Sahel ecosystems future, two main point of view have opposed the scientists: the first one is pursuing of ecosystems degradation, while others think that despite the climate change, Sahel ecosystems are recovering. This study was conducted in Sahel to understand rainfall change and its implication on vegetation dynamic. To achieve this goal, we considered two contrasted zones: The first shows re-greening trend and the second a degradation trend. Rainfall data over three decades (1980 - 2010) and images of the regions were analyzed. We found that the first decade (1980-1990) was dried. However, the rainfall has been improved since the 1990 years with net improvement from 2002 (third decade) and especially in the re-greening zone, what contributed to the greening in the field which was increased in area. Contrary, in the same time, degraded zone, rainfall has dropped and bare soil was increased. In the Sahel, with the climate change, we can find some area that was improved because community arrived to adapt to the disturbance.

Key-words: Dry spell; wet spell; satellite image; improvement; Sahel, Burkina Faso

Pluviométrie et reverdissement des écosystèmes au Burkina Faso

Résumé

Dans la zone sahélienne du Burkina Faso, les écosystèmes sont influencés par la sècheresse et la dégradation des terres. Ce phénomène contribue à la dégradation environnementale et à la perte de la biodiversité. Concernant le futur des écosystèmes du sahel, deux principaux points de vue ont opposé les scientifiques. Bien que certains scientifiques soutiennent que les écosystèmes sont en dégradation, d'autres pensent qu'en dépit des changements climatiques, les écosystèmes du sahel se restaurent. Cette étude a été conduite dans la zone sahélienne du Burkina Faso pour comprendre les variabilités de la pluviométrie et son implication sur la dynamique de la végétation. Pour atteindre cet objectif, nous avons considéré deux différentes régions contrastées ; la première montre une tendance au reverdissement et la seconde une tendance à la dégradation. Les données pluviométriques sur trois décades (1980- 2010) et les images satellitales des zones ont été analysées. Nous avons trouvé que la première décade (1980-1990) a été sèche. Cependant, la pluviométrie a été améliorée depuis les années 1990 avec une nette amélioration en 2002 (troisième décade). Particulièrement dans la zone en reverdissement ce qui a contribué au reverdissement dans les champs lesquels ont augmenté dans cette zone. Contrairement, au même moment, dans la zone dégradée, la pluviométrie a baissé et les sols nus ont augmenté. Dans le sahel, avec les changements climatiques, nous

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pouvons trouver des zones qui ont été revégétalisées parce que les communautés ont été capables de s'adapter aux perturbations.

Mots clés : période sèche, période humide ; image satellitale ; amélioration ; Sahel, Burkina Faso

INTRODUCTION

The sub-Sahelian zone of Africa has been suffered successive droughts since the 1970s and 1980s (DIOUF *et al.*, 2000) and is still affected by climate change. The ecological disturbances, which are among other things, land degradation, declining soil productivity, and loss of biodiversity (N'DAD *et al.*, 2008) were accompanied by the development of a number of technologies which helped to reduce its effects in this area.

In Sahel, climate change and its consequences still do not allow the blossoming of the population and the development of the region. Indeed, the disappearance of trees and herbaceous flora that drastically reduce the biological activity of soils and increase runoff and erosion, have led to ecosystems degradation (CONEDERA *et al.*, 2010).

But for some years, using satellite imagery based on the study of the values of normalized difference vegetation index (NDVI) and field works (HERRMANN *et al.*, 2013; DARDEL *et al*., 2014; SAVADOGO *et al*., 2015; SAVADOGO *et al*., 2016), found an increasing of these values so an improvement of the vegetation cover in the Sahelian zone, especially in the cropland (OUÉDRAOGO *et al*., 2014; SAVADOGO *et al*., 2016). This ecosystem recovery is not only linked to the return of rainfall according to some authors who showed that other factors such as changes and improved land management, the soil type, the success of projects on the technologies of soil and water conservation, socio-economic factors and some decisions taken at the political level have contributed much there (HUTCHINSON *et al*., 2005; REIJ *et al*., 2005; GIANNINI *et al.*, 2008; SENDZIMIR *et al.*, 2011; OUÉDRAOGO *et al*., 2014, KUSSEROW, 2017).

Indeed, the vegetation plays an important role in rainfed agriculture in west Africa because as it influences many phenomena (HARTEMINK *et al.*, 2008) and its degradation creates disturbances in the ecosystems. What are the actual trends of rainfall and vegetation index in the Sahel? What have improved compartments of ecosystem according satellite image?

Thus, with the observed vegetation dynamics in the Sahel at broad scale using satellite data, very few studies have focused in details on the context of re-greening processes at local scale. This present study was conducted at the Sahelian zone of Burkina Faso. The objective of the study was to compare re-greening intensity based on NDVI and rainfall improvement index at two contrasted zones in the Sahel.

This study was focused on the assessment of the evolution of landscape and rainfall. More specifically, the research explores the improvement of land use and land cover in the Sahel.

1. MATERIALS AND METHODS

1.1. Sites of the study

The study was conducted in two locations namely, the North and Central-North Regions of Burkina Faso (figure 1). Oula and Boursouma are located in Ouahigouya district and fall within the re-greening zone while Lebda and Koalma in Kaya district belong to the degrading zones according to previous studies (ANYAMBA *et* TUCKER, 2005; HICKLER *et al*., 2005; FENSHOLT *et al*., 2012; DARDEL *et al.*, 2014). All the sites belong to the semi-arid climate zone that has been severely damaged by the different drought's episode of 1972-73 and 1983-84. The prevailing vegetation on the sites is shrub savannah, and the mean annual rainfall varies between 500 and 600 mm. Monthly, minimum and maximum temperatures average range respectively from 16 to 29 ^{o}C and from 32 to 42 ^{o}C. The main soils are: (i) tropical ferruginous types, poorly to fully leached (ii) degraded holomorphic soils comprising solonetz (iii) tropical eutrophic brown soils overlying high clay parent material and poorly evolved erosional soil overlying gravelly material (CILSS et OMM, 2001).

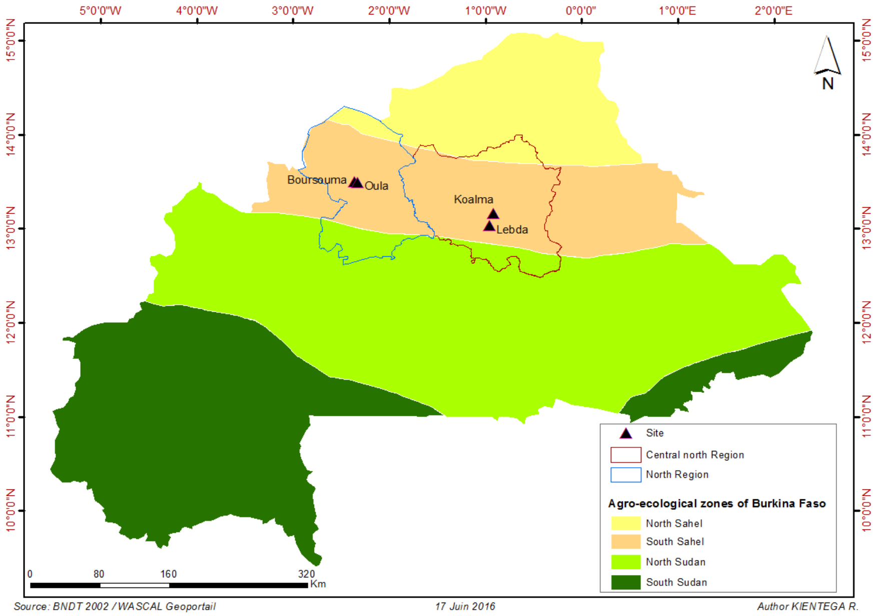


Figure 1: Burkina Faso Agro-ecological zones and Site location map

Sites were chosen using the Burkina Faso map with trends in NDVI and residual NDVI from 1982 to 2008 from HERRMANN *et al.* (2005). The sites have roughly the same population density and are located in the same agro-ecological zone where soil water conservation technologies are intensively implemented. According to EKLUNDH (2003); HICKLER *et al.* (2005), the areas surrounding Ouahigouya are experiencing a vegetation re-greening trend while areas around Kaya are in continuous degradation.

1.2. Rainfall data analysis

The rainfall data analyzed in this work are from the National Meteorological Office of Burkina Faso and they cover almost three (03) decades (1980-2010). Annual rainfall index (RI) and mean deviation index (DI), (STOUR *et* AGOUMI, 2009) were determined to identify wet and dry years. The sequences threshold of dry and wet were estimated based on the computed standardized precipitations index (SPI) (BERGAOUI *et* ALOUINI, 2001).
Rainfall index (RI), is a ratio of annual rainfall (Ra) to mean rainfall (Rm):
$\boldsymbol{R}\mathbf{I} = \mathbf{Ra/Rm}$ **; (RI > 1: wet year, RI < 1: dry year).**
The mean deviation index (DI) is the difference between annual rainfall (Ra) and annual mean rainfall (Rm):
$\boldsymbol{DI}\ (\%) = (\mathbf{Ra} - \mathbf{Rm})/\mathbf{Rm\ x100}$; (a year is said dry when index is negative and wet when it is positive).
Standardized precipitations index (SPI) is used for the determination of rainfall deficits on 1980 to 2010 period in the two zones (Oula and Pissila):
$\mathbf{SPI} = (\mathbf{Ra} - \mathbf{Rm})/\boldsymbol{\sigma}$; (Ra: i year rainfall; Rm: mean rainfall; σ: standard deviation).
Intervals values of SPI to identify anomalies of rainfall are the following: **ISP > 2: extreme wet; 1 < SPI < 2: strong wet; 0 < SPI < 1: moderate wet; -1 < SPI < 0: moderate dry; -2 < SPI < -1: strong dry; SPI < -2: extreme dry.**

1.3. Images analyze

The satellite images of 1999 and 2016 were used in the research to analyze the evolution of land use (Table I).

Table I: Characteristic of satellite images used for land use detection of Oula and Pissila

Images	Path/row	Projection	Resolution	Period
Landsat 7	195/051	UTM Zone 30 Nord	30 m	October 1999
	196/051			
Landsat 8	195/051		30 m	October 2016
	196/051			

Source: Landsat data base

The images were downloaded from the web site of United State Geological Survey (USGS). Both images were obtained in the same season (end of the rainy season) and are both at the same resolution of 30 meters. The two dates have the same vegetation conditions reflecting the climate of the area. Images are already projected in the WGS 84 UTM Northen Zone 30 system by a provider. Colored composition with bands 543 (landsat 8) and 432 (landsat 7) allowed to identify 4 types of land use in the area.
Classification was made according to the algorithm maximum Likelihood supervised classification. Validation of classification was made using field verification and high-resolution image (google earth).

2. RESULTS

2.1. Evolution of rainfall in both zones during the three last decades

The trend of this development is somewhat stable in the degradation zone (Kaya) and there is a significant revival in the re-greening zone (Ouahigouya). The coefficients of determination (r^2) in both zones are low ($r^2 < 50\%$) but more important in the re-greening zone (25.41%) than degraded zone (Figure 2).

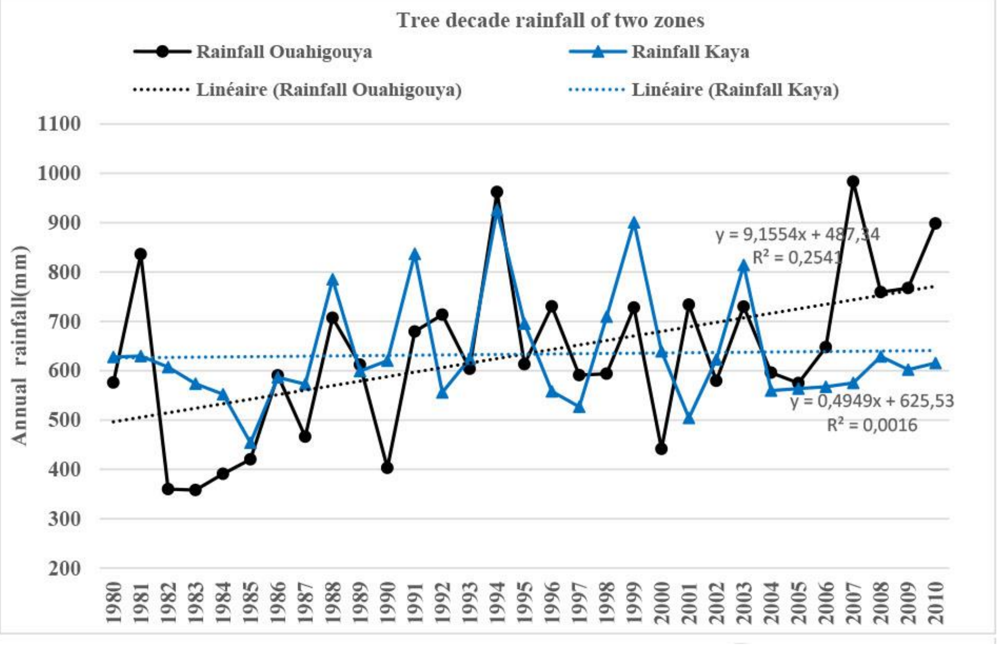
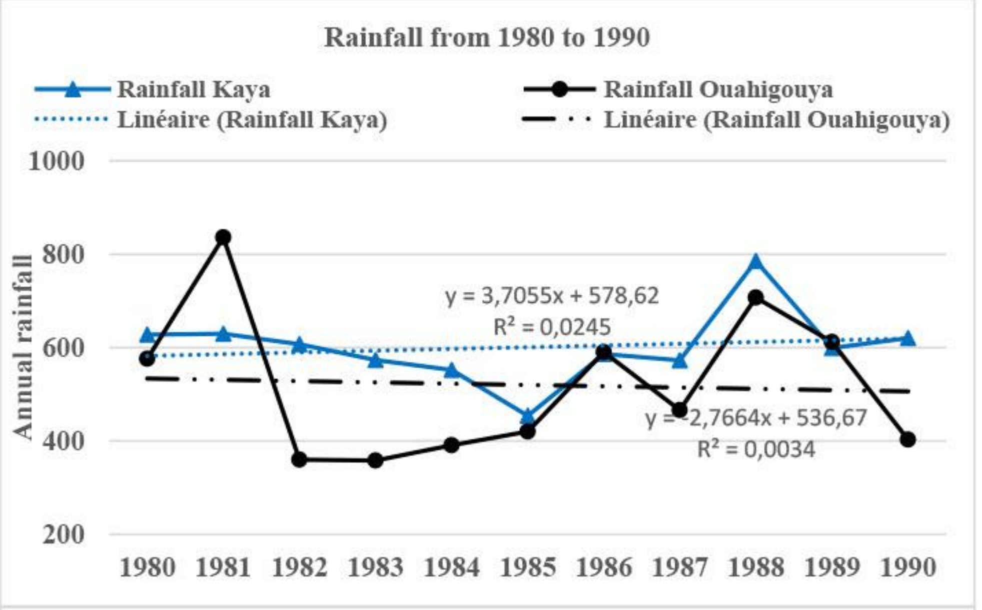
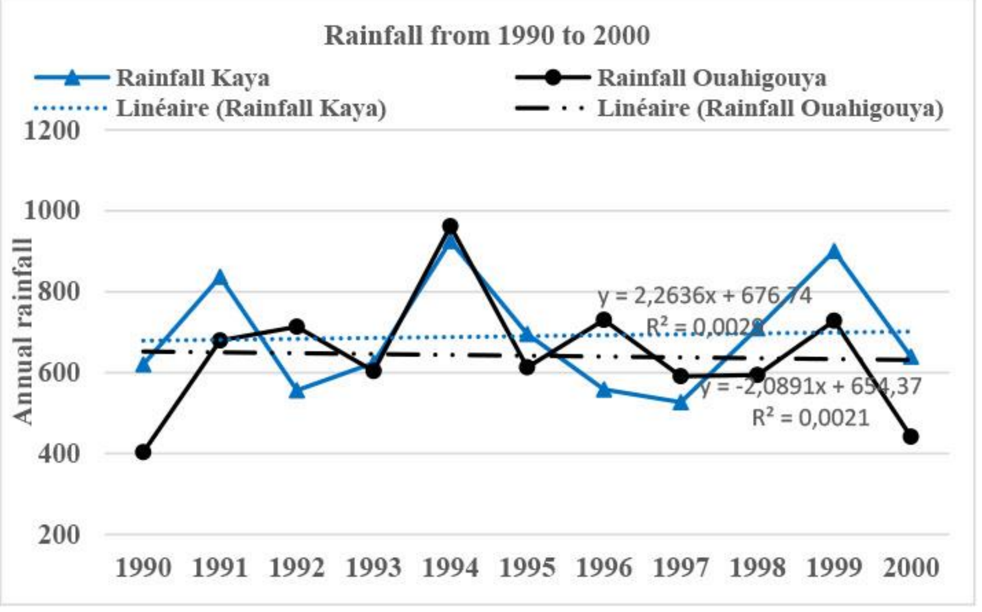


Figure 2: annual rainfall dynamic from 1980 to 2010

If we use the 10 years' evolution, we show that in the re-greening zone, the significant evolution begins in the second decade from 2000 to 2010 period (figure 3). And to 2004, we see a net evolution.


Rainfall from 1980 to 1990
Rainfall Kaya
Rainfall Ouahigouya
Linéaire (Rainfall Kaya)
Linéaire (Rainfall Ouahigouya)
Annual rainfall
y = 3,7055x + 578,62
R² = 0,0245
y = -2,7664x + 536,67
R² = 0,0034
1000
800
600
400
200
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990


Rainfall from 1990 to 2000
Rainfall Kaya
Rainfall Ouahigouya
Linéaire (Rainfall Kaya)
Linéaire (Rainfall Ouahigouya)
Annual rainfall
y = -2,0891x + 654,37
R² = 0,0021
1200
1000
800
600
400
200
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000

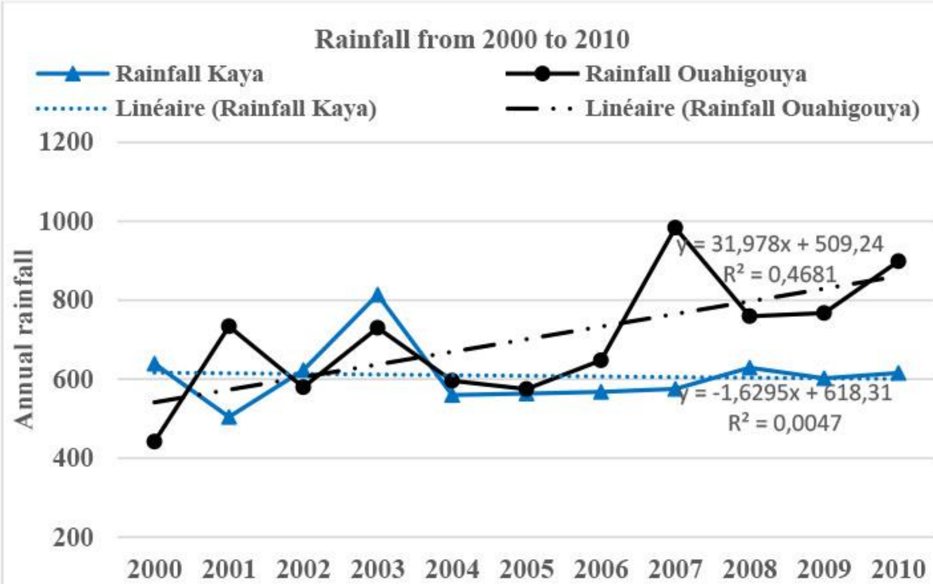


Figure 3: Trends of rainfall each 10 years

2.2. Dry and wet spell to Ouahigouya and Kaya from 1980 to 2010

The years 1980 to 1990 have been a dry spell and starting from the years 1990 to 2000 have been alternate in dry and wet period. But, the years 2000 to 2010, have been wettest especially to Ouahigouya (Figure 4).

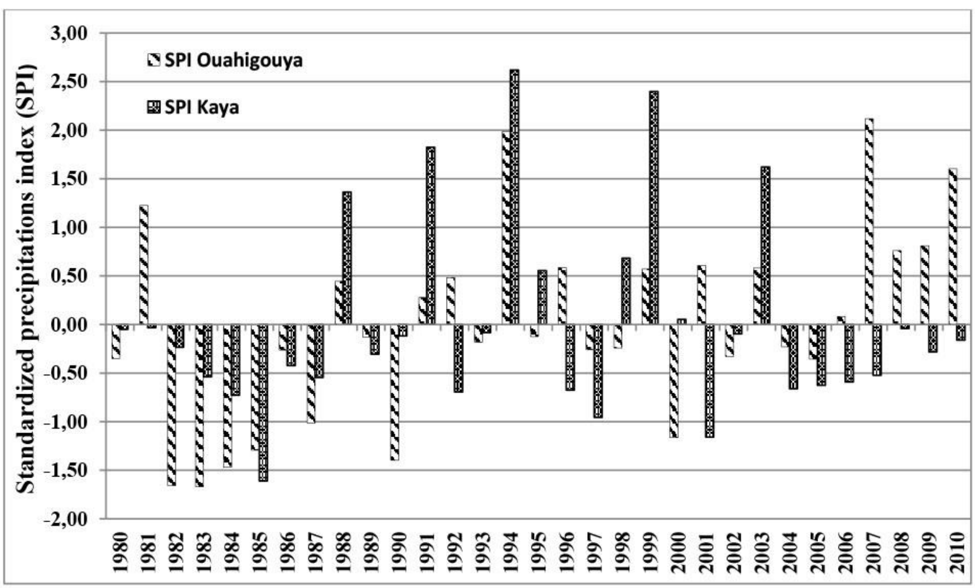


Figure 4: Standardized Precipitation Index dynamic in Ouahigouya and Kaya District

2.3. Changes in landscape

In Oula, bare soils decreased in 2016, farms are increased and some farms are becoming savannah (figure 5) and the change of land use type is reflected in the transition table of occupancy units for the period 1999 and 2016. The farm/fallow and savanna units have increased between these 17 years and in the same time, we observed a decreasing of bare soil (table II). For the degrading area, bare soils are increased in 2016, farms are also increased but savannas are in decreasing (figure 6) and the analysis of the transition table of land use units in Pissila shows a progression of farm/fallow, water body and bare soil, and a decrease in savanna. All the 1999 units are still present in 2016 (table II).

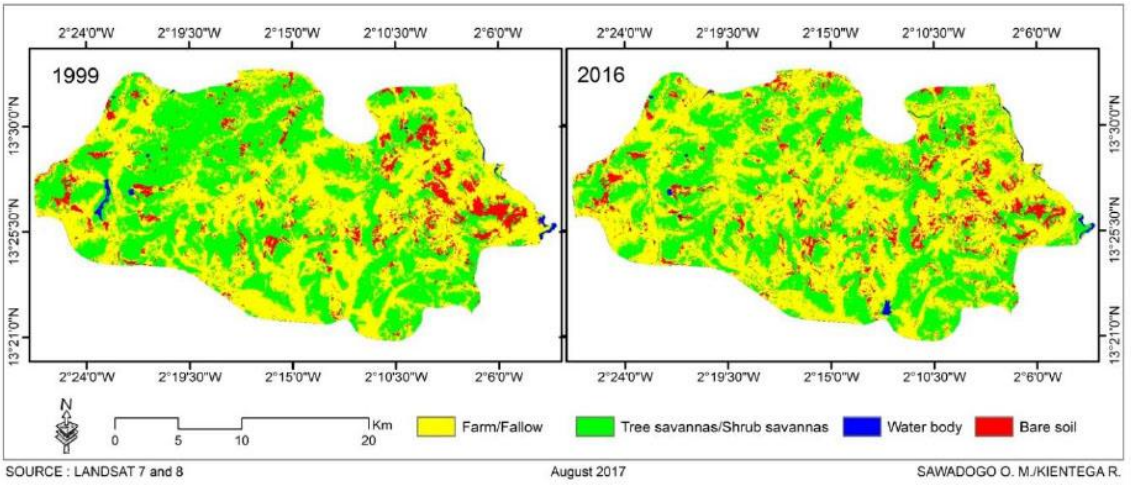


Figure 5: Land use dynamic in re-greening area between 1999 and 2016 (Oula)

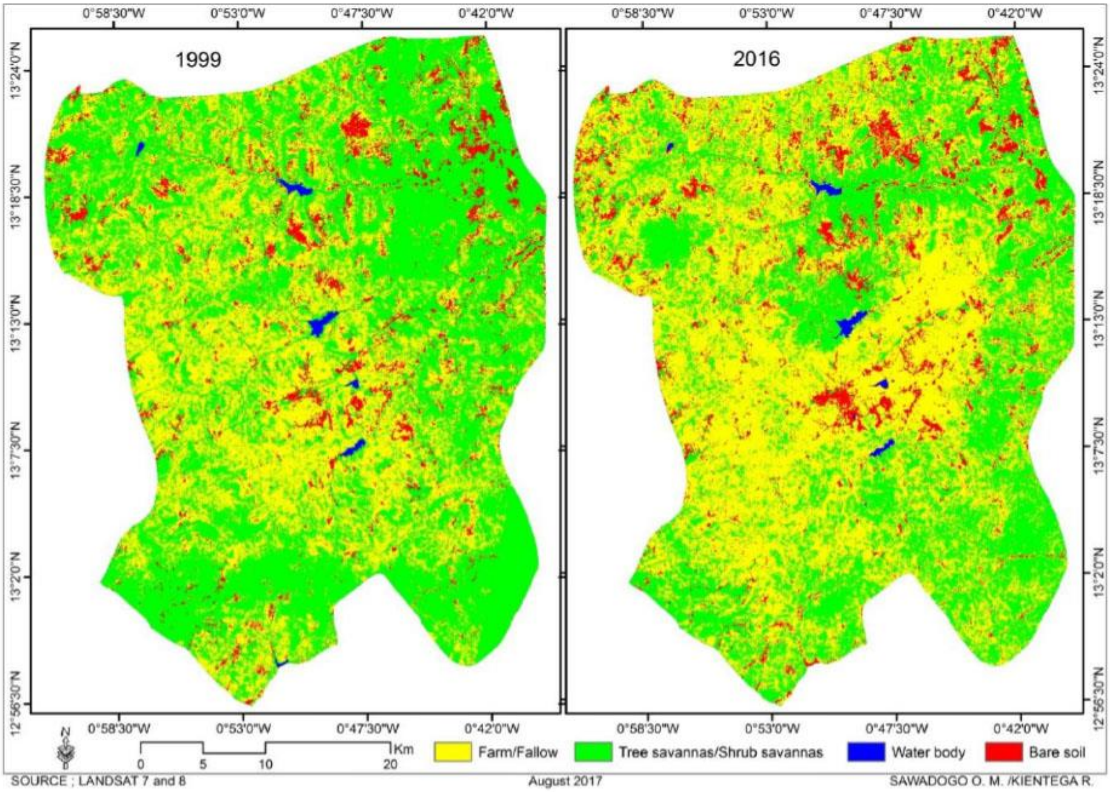


Figure 6: Land use dynamic in degrading area between 1999 and 2016 (Pissila)

Table II: Land use types and changes from 1999 to 2016 (unit: %)

		Farm/Fallow	Savanna	Bare soil	Water body
Oula	**1999**	49.66	42.56	7.29	0.49
	2016	55.19	37.18	7.30	0.34
Pissila	**1999**	39.53	53.63	0.36	6.48
	2016	54.60	37.21	7.83	0.36

3. DISCUSSION

The coefficients of determination (r^2) in both zones are low ($r^2 < 50\%$) which means that the probability that the trends continue is low (25.41%) at the re-greening zone where we has been renewed rainfall in recent decades rainfall could know declines in the coming years, this corroborates the results of (BARRON *et al*., 2010) who found that using scenarios of future climate change will be with a great variability of precipitation although some zone will be known increasing. For the degraded zone, the trend is even lower (0.16%) and stability in rainfall in this zone could record deficits in the future.

Indeed, in the Sahelian zone of Burkina Faso, we cannot deny that there has been restoration of rainfall (MAHÉ *et* PATUREL, 2009; FENSHOLT *et* RASMUSSEN, 2011; MERTZ *et al*., 2011) and this was a factor that has contributed significantly to the re-greening (HEUMANN *et al*., 2007; GIANNINI *et al*., 2008).

Rainfall recovery and the wet period began since the 1990 years (NOUACER, 2020; OZER *et al*., 2009). SARR (2008) found the same results when he worked in the Ferlo basin on the climate variability in West Africa and the dynamic of woody species. This changes contribute to improved vegetation in the 2000 years (ANYAMBA *et* TUCKER, 2005).

People in the Sahel, with a climate change found and used news technologies for water and soil conservation technologies on and off farm (stone line, planting pits (zaï), half-moon, earth bund and RNA). These technologies in the farm improved soil physical, chemical and biological quality (BAGGNIAN *et al.* 2014; ZOUGMORÉ *et al*., 2002). That gives to the soil the elements necessary for its restoration and conductive environment for the plant's growth. Therefore, these are the fields where technologies are practiced that have regenerated. That's why, greening was observed in the field rather than the other units of the landscape.

Since the 1960s, NGOs and national partners began soils restoration with Soil and Water Conservation technologies. But, it is at 1980s year that these technologies for the soil restoration got a successful (KABORE-SAWADOGO *et al*., 2014). That allows to reduce degraded land area and increase field area and technologies permit to change field landscape.

We can say that, even with the climate change, rainfall and water and soil conservation technologies contribute to the re-greening of Sahel.

Conclusion

The purpose of this study was to examine rainfall trends from 1980 to 2010, and land use trends from 1999 to 2016 in two contrasted ecosystem zones in the Sahel of Burkina Faso. We can say that, rainfall recover in the re-greening area in Sahel in recent decades and water and soil conservations technologies have greatly contributed to the greening and particularly the field greening of the Sahel. In the degrading area, increasing of bare soils has shown that ecosystem goes on to deteriorate. Degraded soil of site in degradation increases superficial water running and exposed to erosion. Rehabilitate soil and improve land cover are a key step to fight to ecosystems degradation. However, it is necessary to bring amendments to soil and amenities as adapted water and soil conservation technologies to enable it to reverse if the desertification process will extend the Sahel.

There is still uncertainty about rainfall trend and soil quality in the Sahel. It is important to train farmers, that will go to bring local knowledge and know-how and technologies to adapt themselves to a new environment and manage to sustain it for the improvement of livelihood.

COMPETING INTERESTS

The authors declare that they don’t have any competing interest.

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