Spatio-Temporal Relations between Rainfall and Evolution of Vegetation North East of Guinea

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Abstract:*This study focuses on the spatio-temporal relationships between rainfall and vegetation in the North-East of Guinea. It is part of the theme of vegetation monitoring through the use of data from remote sensing. Since the end of the 1960s, Upper Guinea has been affected by a rainfall deficit both in its intensity and in its duration. The objective of this work is to evaluate the correlation that exists between rainfall and vegetation in Upper Guinea during the period from 1998 to 2006. The approach adopted was successively the collection of data (rain and NDVI), their resampling and the calculation of the correlation coefficient between the two parameters. The correlation coefficients obtained at the threshold of 0.3044 make it possible to divide the study area into three: a strong significant correlation area with values reaching 0.873 (Siguiri and Dinguiraye), a transition area (Dabola and Kouroussa) where the correlation is moderately significant and a zone of low correlation with relatively low coefficients (Kérouané, Faranah, and Kankan).*

Keywords: Rainfall, NDVI vegetation index, correlation coefficient, Guinea

I. INTRODUCTION

The population explosion of recent decades has led to a whole procession of impacts on the environment, the most significant of which are inappropriate agricultural practices, overexploitation of soil and water resources, overgrazing [1, 2]. This results in a degradation of the environment which results in the reduction of crop yields and excessive deforestation [3, 4].

From the end of the 1970s, the degradation of ecosystems received considerable interest from scientists, politicians and the general public. Several authors have attempted to determine appropriate, simple and easily accessible indicators for monitoring the state of ecosystem degradation [5, 6].

From the 1960s to the present day, Upper Guinea has been affected by a rainfall deficit, both in its intensity and in its duration [7, 8]. Added to this climatic deterioration is a drastic increase in anthropogenic pressure on the environment. This is reflected in nature by an increase in flooding in the rainy season and the appearance of drier dry seasons, a disruption of the rainy regime, a significant reduction in plant cover, soil degradation causing a drop in crop yields and excessive and extensive deforestation [9, 10].

This work is part of the theme of the research of the link between precipitation and vegetation in the North-East of Guinea by the use of data from remote sensing. The qualitative assessment of this relationship will be based on the analysis of the decadal values of the NDVI in relation to the precipitation over the study period.

II. Method and material

2.1 Geographical location of the study area

The area of this present study corresponds to Upper Guinea or Upper Niger Basin. It is a vast region between 8° and 11°37 west longitude and between 8°45 and 12°35 north latitude. Its area is approximately 103.235 km² or 41% of Guineanterritory [11].

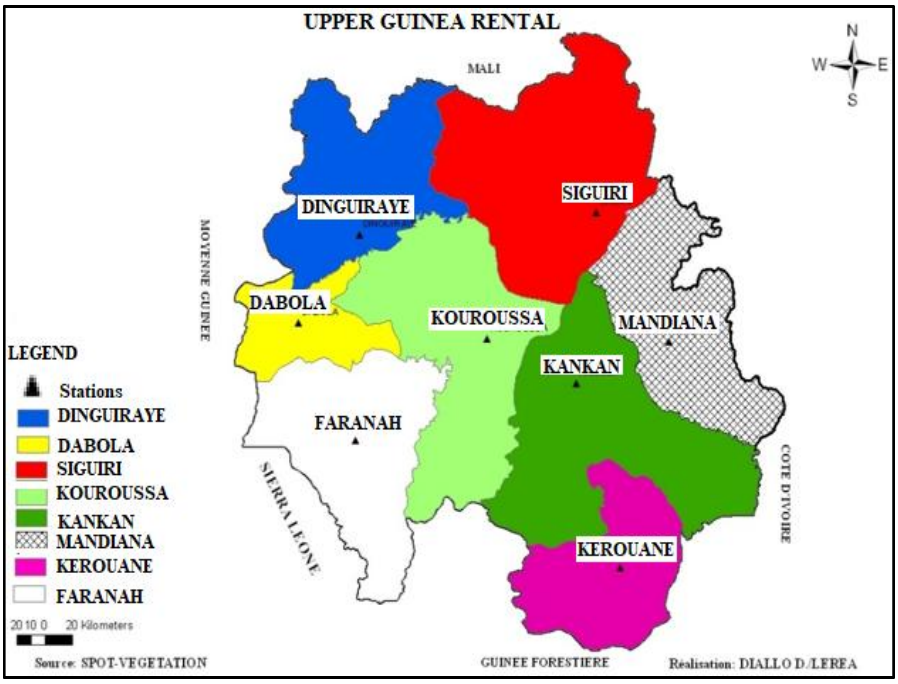

Fig. 1: Location of Upper Guinea

2.2 Data

The data used for this study are grouped in Table 1.

Table 1: Data Acquisition

Data Types	Source	Ladder	Period
Rainfall	DNMG	decadent	1998-2006
NDVI	SPOT-Vegetation	Daily	1998-2006
Vectormaps	LEREA	Sub prefectural	-

To establish the correspondence between the NDVI values and the vegetation, we used the interpretations made by the World Information and Early Warning Service (GIEWS) of the FAO [12].

Table 2: NDVI Classes (from Windisp 4.0 User Guide)

De	A	Legend
-0.1	-0.08	Cloud
-0.08	0.27	Bare ground
0.27	0.34	bare ground
0.34	0.37	bare ground
0.37	0.41	Sparse vegetation
0.54	0.57	Sparse vegetation
0.58	0.62	average vegetation
0.63	0.68	average vegetation
0.68	0.74	average vegetation
0.74	0.92	average vegetation
0.92	0.92	Water

II.3 Methodology

After the documentation stage, which made it possible to gather the existing documents on the domain and on Upper Guinea (reports, dissertations and theses), a sampling of the rain data was carried out. In this phase, the daily rainfall data were transformed into dekadal totals. Thus, 36 decadal values were obtained for each station.

The NDVI images obtained, at the scale of Africa, were cut out at the scale of Guinea and then at the scale of Upper Guinea using VGTExtract and ENVI software. And finally we calculated its values according to formula 1 [13, 14, 15].

$$NDVI = \frac{PIR - R}{PIR + R} \qquad (1)$$

Where - NIR : Near Infrared; A : Red

From the dekadal accumulations of rain and the NDVI values found, it was possible to determine the correlations between precipitation and NDVI on seven stations in the study area, taking into account two scales: the annual scale and the of the rainy season. The values thus calculated were grouped into four classes indicating non-significant, significant and strong, significant and moderate, significant and weak correlation coefficients in accordance with

Figure 2.

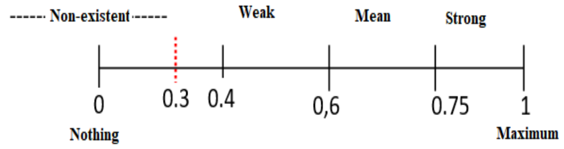

Fig. 2: Scale for interpreting the correlation coefficient

We compare the NDVI to the dekadal accumulations of precipitation recorded from April to October, corresponding to the period when more than 90% of the annual rainfall is recorded. Which ultimately makes nine (9) periods which correspond to the nine (9) years of study (1998-2006). The maximum value of the vegetation index is generally observed between the second dekad of June and the third dekad of October.

III. Results and Discussions

3.1 Average annual evolution of the NDVI in each prefecture of Upper Guinea

The observation of Figure 3 allows us to say that the prefecture of Kérouané records the strongest vegetation among the prefectures of Upper Guinea and that that of Siguiri has the least strong vegetation. For the entire study period, the curves representative of the prefectures of Kérouané, Faranah, Dabola, Kouroussa and Kankan are above 0.500, their vegetation is light. The Dinguiraye prefecture curve is below 0.500 from 1999 to 2003 and for the rest above its vegetation is sparse. However, for the prefectures of Siguiri and Mandiana the vegetation is sparse because their respective curves are below 0.500.

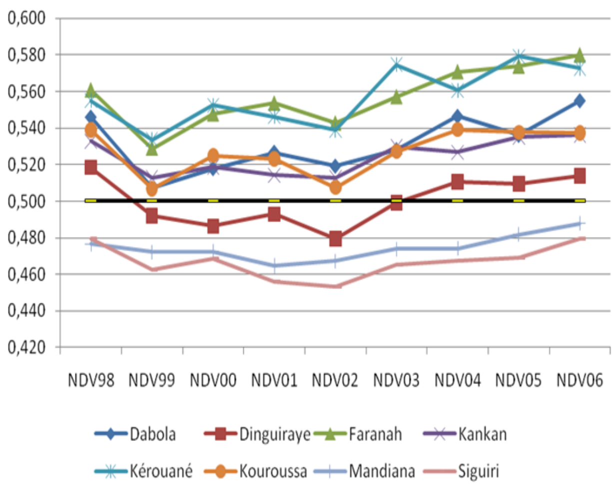

Fig 3: Average annual evolution of the NDVI of the Prefectures of Upper Guinea from 1998 to 2006.

3.2 Ten-day average evolution of the NDVI vegetation index in the prefectures of Upper Guinea

Figure 4 shows the dekadal average evolution of the NDVI from 1998 to 2006. We note that in the period going from the first dekad of January to the second dekad of April, low values of the NDVI (0.3000 approximately), which corresponds to almost bare ground for all the prefectures of Upper Guinea except in the prefectures of Kérouané and Faranah. Between the second decade of August and the third of November, these values are above 0.500, so the vegetation varies between light and medium as indicated in Table 2. From the first ten days of October to the third ten days of December, the curves tend to drop, which corresponds to a decrease in vegetation.

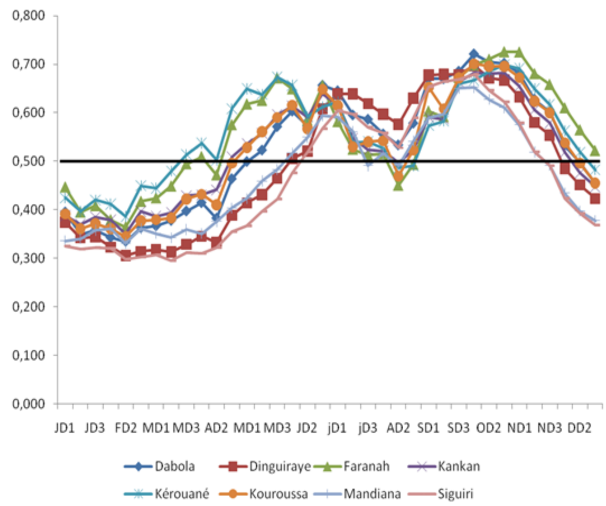

Fig. 4: Evolution of the dekadal average of the NDVI vegetation index of the prefectures of Upper Guinea from 1998 to 2006.

3.3 Evolution of rainfall in the stations of Upper Guinea

In Figure 5, we see an inter annual variation in rainfall intensity over the entire study period. The maximum precipitation was recorded in 2004 in the Kérouané station (2262.9 mm). However, the minimum is observed in Siguiri (979.4mm) in 2000. During this period, the year 2002 is the least humid and 1999 is the wettest year. We also notice that the prefecture of Siguiri receives less rain than all the others except in 2005 when the minimum is observed in Kankan and that Kérouané is the wettest prefecture.Fig. 5: Evolution of rainfall in the stations of Upper Guinea from 1998 to 2006

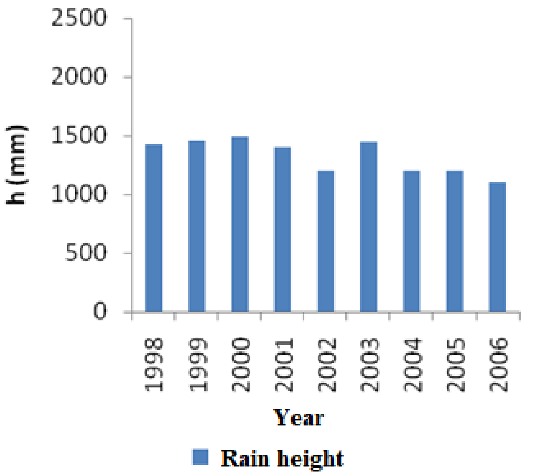

Fig. 5-a: Evolution of rainfall in Dabola from 1998 to 2006

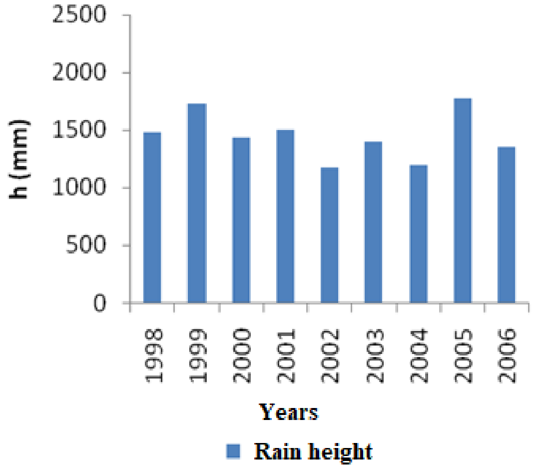

Fig. 5-b: Evolution of rainfall in Dinguiraye from 1998 to 2006

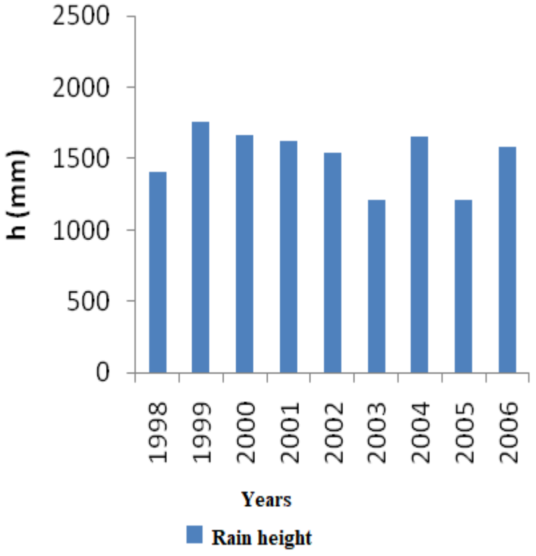

Fig. 5-c: Evolution of rainfall in Faranah from 1998 to 2006

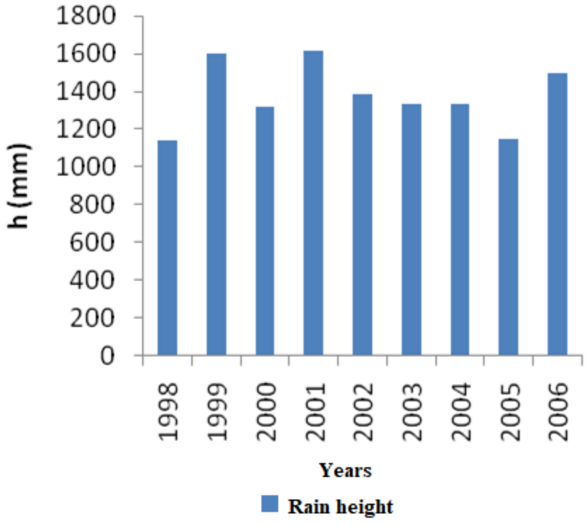

Fig. 5-d: Evolution of rainfall in Kankan from 1998 to 2006

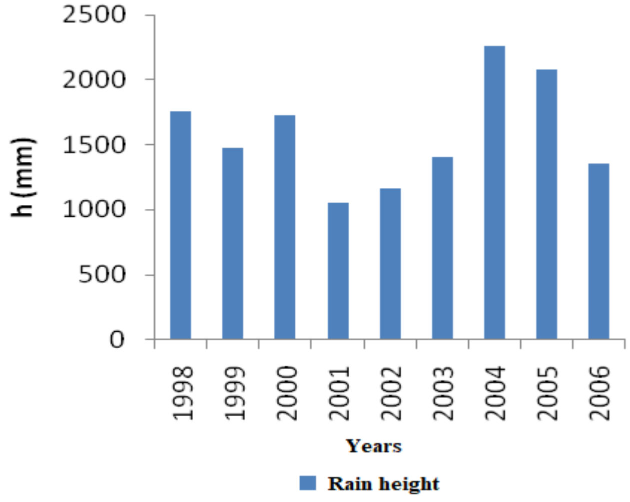

Fig. 5-e: Evolution of rainfall in Kérouané from 1998 to 2006

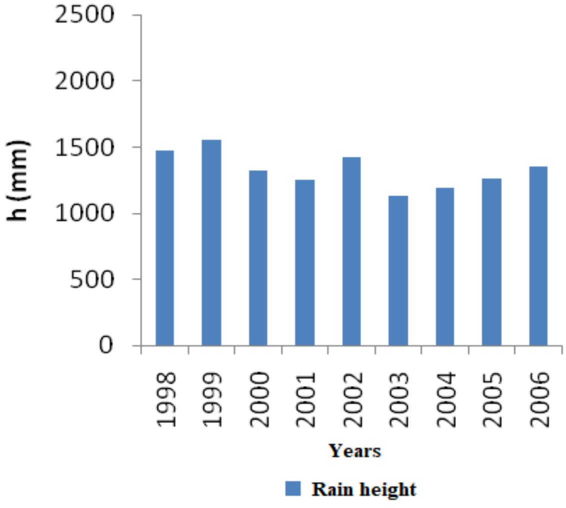

Fig. 5-f: Evolution of rainfall in Kouroussa from 1998 to 2006

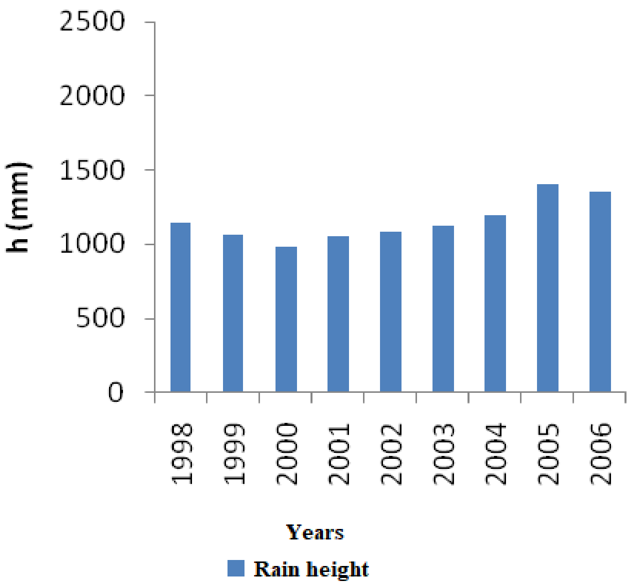

Fig. 5-g: Evolution of rainfall in Siguiri from 1998 to 2006

3.4 Analysis of the correlation between rainfall and vegetation (NDVI)

The analysis of correlations between precipitation and NDVI over the long term (1998-2006) was carried out on seven stations in the study area. When considering the rainy season, the correlation coefficient is noted CCSP (Correlation Coefficient of the Rainy Season) and all year round we have CCA (Annual Correlation Coefficient). These values of correlation coefficient, calculated at the threshold of significance of 0.3044, allowed us to carry out the analyzes below.

3.4.1 Dabola Station

For the Dabola station, it can be seen that on an annual scale, the correlation between rainfall and NDVI is significant and varies between low (0.5690) in 1998 and moderate (with values between 0.6133 and 0. 7195) for the other years (see A.I.1). However, when the scale is brought back to the rainy season, the coefficient is significant but this time varies between low in 1999 and 2000 (04938 and 0.5047 respectively), moderate for the years 1998, 2001 and 2003 (with values respectively of 0.7410, 0.7116 and 0.7043) and strong in 2002 and 2004 with respective values of 0.7768 and 0.8338. The link is stronger at the annual scale (Table 4).

3.4.2 Dinguiraye station

Table A.I.2 shows that at the scale of the year, the link between precipitation and NDVI is significant and strong with values of 0.7714 in 1999 and 0.7512 in 2002. For the other years, it is significant and moderate with values varying between 0.6029 and 0.7211. At the scale of the rainy season, apart from 2005 where the correlation is significant and moderate (0.6998), the link between the two parameters is significant and strong with values up to 0.8651 and coefficients of determination reaching 0.7484. We also note that the correlation coefficient is more significant on the scale of the rainy season than on the annual scale (Table 4).

3.4.3 Faranah Station

Low correlation coefficients were found for Faranah at the annual scale, except in 2002 and 2004 where significant and moderate correlation coefficients were found with respective values of 0.6662 and 0.6054 (Table 3). On an annual scale, however, we note that the correlation is not significant except in 2002 and 2004 where it is significant and respectively weak and moderate. For this station, the annual scale has the most significant coefficients (Table 4).

3.4.4 Kankan Station

We note that at the annual scale the correlation coefficient is significant and weak except in 2001, 2004, 2005 and 2006 where we found that the link is significant and moderate (Table 3). At the scale of the rainy season, it should be noted that with the exception of 2004 where the correlation is moderate, it is significant and weak. The annual correlation coefficient is more significant.

3.4.5 Kérouané station

Despite the high rainfall recorded in Kérouané, the correlation coefficients at the annual scale are significant and weak except in 1998 and 1999 when they are not significant (Table 4). On the scale of the rainy season, they are not significant except for that of 2004 which is significant and weak. It should be noted that the link between rain and NDVI is stronger on an annual scale.

3.4.6 Kouroussa station

At the annual scale, we find that the correlation coefficients vary between low and medium significance. At the scale of the rainy season, the correlations are generally weak except in the period from 2001 to 2004 when the link between rainfall and vegetation is average with coefficients varying between 0.6389 and 0.7338 (Table 4) . The correlation coefficients at the annual scale are more significant than those at the rainy season scale (Table 4).

3.4.7 Siguiri station

On an annual scale, the correlation between rainfall and NDVI is generally moderately significant except in 1999 when it is significant and strong (0.7975) and in 1998 and 2004 when the link is weak. At the scale of the rainy season, the correlation is highly significant (0.7883 to 0.8734) except in 2005 when it is medium significant (Table 5). The correlation is more significant at the scale of the rainy season.

This strong variation of the correlation coefficient would be the consequences of the combination of various factors, namely: certain artefacts on the satellite data, biophysical variations, rainfall variations and anthropogenic influences.

Table 3: Interpretation of the types of correlations

Table 3.a: Annual scale

Stations	**Types of correlation**
Siguiri	Significant and moderate
Dinguiraye	Significant and moderate
Dabola	Significant and moderate
Kouroussa	Significant and moderate
Kankan	Significant and low
Kerouane	Significant and low
Faranah	Significant and low

Table 3.b:Rainyseasonscale

Stations	Types of correlation
Siguiri	Meaningful and strong
Dinguiraye	Meaningful and strong
Dabola	Significant and moderate
Kouroussa	Significant and low
Kankan	Significant and low
Kerouane	Not significant
Faranah	Not significant

For information, we present tables 4 and 5 giving the summary of the correlation coefficients in Kérouané and Siguiri.

Table 4: Summary of correlation coefficients in Kérouané

Station	***Kerouane***									Threshold of meaning
Years	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	
h(mm)	1757.2	1472.8	1159.5	1050.2	1408.6	2079.3	1730.9	2262.9	1352.4	
CCA	0.0452	0.3016	0.3475	0.4407	0.3437	0.4487	0.5868	0.4254	0.3504	0.3044
R^2A	0.0020	0.0910	0.1208	0.1943	0.1182	0.2014	0.3443	0.1810	0.1228	
CCSP	-0.0005	-0.2185	-0.0973	0.0885	0.0362	0.0882	0.5570	0.1395	-0.0113	0.3044
R^2SP	3E-07	0.0477	0.0095	0.0078	0.0013	0.0069	0.3103	0.0195	0.0001	

h (mm): rainfall height in mm; CCA: Annual Correlation Coefficient ; R2A: Annual determination coefficient ; CCSP: Rainy Season Correlation Coefficient ; R2SP: Rainy Season Determination Coefficient

The interpretation of the summary tables of the correlation coefficients will be done in accordance with the following indications: Red: Significant and strong correlation coefficient, Light green: Average significant correlation coefficient, Green: Low significant correlation coefficient and Blue: Correlation coefficient not significant.

Table 5: Summary of correlation coefficients in Siguiri

Station	*Siguiri*									Threshold of meaning
Years	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	
h (mm)	1143.5	1067.5	1159.5	1050.0	1121.1	1405.2	979.4	1191.7	1352.4	
CCA	0.5285	0.7975	0.7133	0.6583	0.6673	0.7105	0.5617	0.6114	0.6541	0.3044
R^2A	0.2794	0.6360	0.5089	0.4334	0.4453	0.5048	0.3155	0.3738	0.4278	
CCSP	0.8382	0.8595	0.8599	0.8734	0.8590	0.8516	0.8156	0.7454	0.7883	0.3044
R^2SP	0.7025	0.7388	0.7395	0.7629	0.7378	0.7252	0.6652	0.5556	0.6214	

h (mm): rainfall height in mm ; CCA: Annual Correlation Coefficient ; R2A: Annual determination coefficientCCSP: Rainy Season Correlation Coefficient; R2SP: Rainy Season Determination Coefficient

3.5 Evolution of rainfall and NDVI vegetation index

In general, we note that the curves of evolution of rainfall and NDVI do not present the same pace everywhere. From the first decade of April to the first decade of July, the NDVI and rainfall curves vary in the same direction. From the second decade of July until the third decade of August we observe a drop in the NDVI while we notice an increase in the rainfall curve. This would be explained by the decrease in rainfall observed during the previous decades. From the first ten days of September to the third ten days of October we see a drop in rainfall. While the NDVI curve is on the rise. This would be due to the heavy rain recorded during the last decades of August.

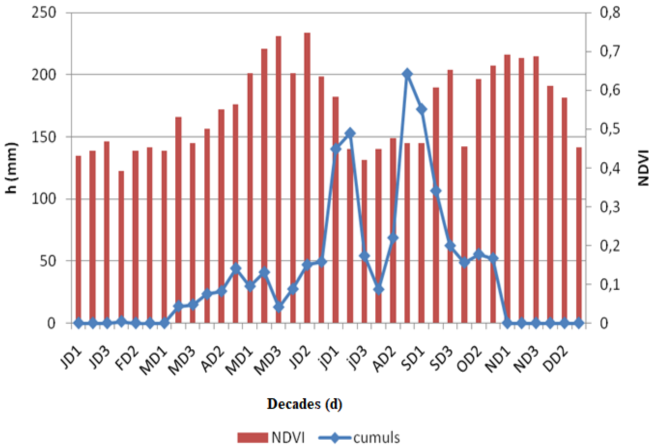

Fig. 6: Evolution of rainfall and NDVI

IV. Conclusion

This study has shown the interest of remote sensing tools in the analysis of the dynamics of natural resources. The analysis of the relationship between rainfall and NDVI in North-East Guinea was carried out for the period from April 1998 to December 2006. It emerges that the correlation coefficient is highly variable over time and in space. The correlation coefficients obtained made it possible to divide the study area into three: a significant and strong correlation area with values reaching 0.8734 (Siguiri and Dinguiraye), a Dabola and Kouroussa transition area where the correlation is significant and moderate and a significant and weak correlation zone (Faranah, Kankan and Kérouané). This study made it possible to describe the overall evolution of the vegetation and rainfall in Upper Guinea from 1998 to 2006. It emerges from this analysis that Siguiri is the prefecture of Upper Guinea with the least water and the least vegetation and that Kérouané is the wettest and most vegetative prefecture.

The lack of rainfall data for the Mandiana station prevented coverage of the entire study area. This work is not exhaustive, for its improvement and for its enrichment, our prospects would be to extend the study to the entire northern part of Guinea and taking into account the memory effect (autocorrelation) which would take into account the rain has a delayed effect on vegetation. One could use medium or high resolution images from SPOT, LANDSAT, MODI, etc.

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