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Variations of Rainfall and Air Temperature affecting Rainfed Rice Growth and Yield in a Guinea Savanna Zone

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Abstract

To strengthen rain fed rice adaptation to climatic adverse events, relevant parameters need to be characterized along with their relations with agronomic performances of rice. The rainfall and temperature in a guinea savanna zone of Côte d'Ivoire were analyzed for the respective periods of 1961 – 1990 and 2000 – 2014 coupled with three years rice cropping (2012 – 2014). Popular inter specific upland rice named NERICA 5 was sown per hill and spaced by 20 cm a part. It was revealed a pronouncing bimodal character of rainfall pattern with more intensive and longer drought period of mid-season (June – September) while, highest annual rainfall characterized by more irregularity was observed recently. Moreover, it was observed an increase of the average air temperature (20 - 30°C) of about 2°C. Reductions of physiological cycle and the grain number per panicle were likely the consequences of drought and heat stress (2013) while, highest rainfall was mitigating the effect of heat (2014) which may have negatively affected the agronomic performances even when occurring during the vegetative growth stage. March was recommended for sowing date and the revalorization of *Oryza glabberima* potentially tolerant to heat effect was suggested for reinforcing the adaptation ability of rice to the current climatic conditions.

Keywords: Rainfall, heat, drought, and rain fed rice, guinea savanna

1. Introduction

Rain fed agriculture is characterized by low yield especially, for upland rice cropping producing a grain yield between 0.5 tha^{-1} to 1.5 tha^{-1} in Africa (Hari, 1997). However, there is limited perspective of increasing crop yield in rain fed agriculture because of the high seasonal and inter annual variations of rainfall affecting adversely more than 50% of agricultural lands in West Africa (FAO, 1997), hence, constituting a serious threat for food supplying (Ainsworth and Orth, 2010).

Yet, the gap between rice production and requirement is about 1 300 000 tones in Côte d'Ivoire (FAOSTAT, 2008) while, 93% of rice fields (600 000 ha) are accounting for rain fed upland condition (Hari, 1997) with an average yield of 1.5 tha^{-1} (MINAGRI and PNR, 2009).

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The Global Environment Changes occurring worldwide (De Datta and Vergara, 1975; Maccracken *et al.*, 1985) may further pronounce this situation regarding to rainfall reduction observed in West Africa during the last fifty years (Servat *et al.*, 1997; Sircoulou, 1990) mainly characterized by more severe drought (Koné *et al*., 2008) with potential variation of annual average temperature. This context may have negative effect on rice physiological cycle and grain yield (Garrity and O'toole, 1995; Lafitte, 2000).

In fact, beside a low grain filling in limited soil moisture condition (Audebert *et al.*, 1999; Fofana *et al.*, 2010), the variation of the degree-days (Yoshida, 1981) and/or night time air temperature (Pentidol *et al.*, 2014) likewise the extreme values (maximu and minimum) may affect the sustainability of rice agrosystems (Eyshi Rezaei *et al.*, 2014) except for most adapted genotypes. Therefore, it is compulsory to characterize the agro-climatic zones, especially, where the agriculture is already weakened by a mid-season drought occurrence under bimodal rainfall pattern. Though, there are comprehensive analyses of climate changes in West Africa (Jalloh *et al.*, 2013) and adaptation strategy planning (van de Gisen *et al.*, 2008), the ecological and agrosystemic particularities are under explored.

Therefore, the current study was initiated for exploring the effects of rainfall and temperature variations on rice physiological and phenological parameters (flowering, grain filling and grain maturity) as well as the yields (grain and straw). The aims were, i) to characterize climate variability from a past long period up to date, ii) to point out quantitative and qualitative differences between recent and historic data of rainfall and temperature and, iii) to underline the effect of recent period climate variation on rain fed upland rice growth and yield. Overall, the study should point out some strategies for improving rice adaptation to adverse effect of the current climate.

2. Material and Methods

2.1. Studied site description

The study was conducted around the locality of Bouaké city at M'be (07°52N, 05°14W, 261 m asl) in the centre of Côte d'Ivoire, a forest-savanna transition zone. It is characterized by transitional equatorial climate as Guinea savanna with a bimodal rainfall pattern ranging annually between 900 mm to 1300 mm in amount. The annual averages temperature and air humidity are 27°C and 70% respectively. A long period (>10 years) fallow mainly composed of grass was characterizing the studied site with dominance of *Imperata cylindrica* and the rice fields were laid out at foot slope position of a plateau landscape on colluvium hydromorphe soil as Arenosol (FAO, ISSS and ISCRIC, 1998) characterized by the occurrence of seasonal perched ground water within 70 cm depth.

2.2. Rice variety

The studied cultivar named NERICA 5 was released by Africa Rice Center for upland cropping. It is an inter specific obtained by crossing *Oryza sativa* L. as Asiatic rice and that originated from Africa (*Oryza glabberima* L.). It is an early matured variety with a short cycle of 95 – 100 days for a potential grain yield of 5 tha^{-1} (ADRAO, 1995). With robust teams and high tillering potential, NERICA 5 has tolerance of biotic and abiotic stress including drought stress tolerance.

2.3. Field trial

A rice field was conducted during successive three years (2012, 2013, and 2014). After manual clearing, vegetation residues were cleaned out and 700 m^2 was tilled using hoe. Eight micro plots of 5m × 3m in individual dimension were considered for each of the four replications. Basal fertilizer (N(40 $kgha^{-1}$), P (100 $kgha^{-1}$), K (100 $kgha^{-1}$), Ca (50 $kgha^{-1}$), Mg (50 $kgha^{-1}$) and Zn (10 $kgha^{-1}$)) were applied before sowing rice per hill of 2-3 grains spaced by 20 cm × 20 cm a part. Sowing was done on 1rst June 2012, 27th May 2013 and 17th June 2014 for the different cropping respectively. Two weeks after emergence, the rice hill was thinned to 2 plants when necessary and additional N-fertilizer (30 $kgha^{-1}$) was applied twice at maximum tillering and panicle initiation stages after manual weeding. No irrigation was applied.

2.4. Data collection

Historic climatic data (rainfall and temperature) of the period extending from 1961 to 1990 were collected from nation agency of meteorology (SODEXAM) and the recent period (2000 – 2014) data were collected at the main experimental station of Africa Rice Center. Standardized Precipitation index (SPI) as defined by McKee *et al.* (1993) was used for determination of drought intensity:

$$SIR = \frac{(R_i - R_m)}{SE} \quad [1]$$

R_i : Rain fall amount of year i; R_m : Average rainfall of a given period ; SE : Standard deviation of rainfall in a given period.

The scale of interpretation of SRI values is given in table 1:

Table 1: Drought classification according to the values of SPI

Value of SIR	Drought sequence
≥ 2	Extremly humid
1.5 – 1.99	Highly humid
1.0 – 1.49	Moderatly humid
-0,99 – 0.99	Likely normal
-1.00 – -1.49	Moderatly dry
-1.50 – -1.99	Highly dry
≤ -2.00	Extremly dry

The duration from germination to 50% of flowering was considerate as physiological maturity occurrence and collected as number of day as well as for the grain maturity. At the maturity, rice was harvested in $8m^2$ leaving two lines in border. Grain yield (RGY) was determined for standard moisture content of 14% considering measured moisture content of the grains. The weight of 1000 grains was further determined while the straw yield (SY) was calculated directly for a given weight and the harvested surface ($8m^2$). Rice harvest index (HI) was calculated as a ratio of RGY and Total dry matter (RGY + SY).

2.5. Statistical analysis

The mean values of monthly rainfall and temperature as well as their minimum and maximum values were determined by descriptive statistic respectively. So was done for the SPI values. By analyze of variance (ANOVA) monthly average of both parameters were also determined according to rice growing stages and Student-Newmann-Keul (SNK) test was applied for mean comparison according to years 2012, 2013 and 2014. In the same manner, the mean values of rice physiological cycle, grain yield, straw yield, total dry matter, harvest index and the weight of 1000 grains were determined for 2012, 2013 and 2014. Pearson correlation analysis were performed in order to underline the influence of rainfall and temperature effects on the studied agronomic parameters according to the occurrence during rice growing (vegetative stage and maturity) and the cumulative effect. SAS (version 10) was used for the analysis and α was fixed at 0.05.

3. Results

3.1. Historic and recent rainfalls and temperatures

Figure 1 is presenting the monthly average of historic rainfall data for 30 years (1961 – 1990) compared to that of the last 15 years (2000 – 2014) associated to the temperatures respectively. There is highest rainfall amount for the recent period except for the months of August, September and December along a bimodal rainfall pattern. Two peaks of 179 mm and 190 mm are observed in April and September respectively for the recent period of 2000 – 2014 while occurring previously (1960 – 1990) in June (146 mm) and September (268 mm) successively. Thus, a time difference of two months is resulting between the rainfall peaks of both periods during the first rainy season while, no similar change is observed for the second peak. The beginning of the first rainy season is also the same whatever the studied period however. Although the mid-season drought is always occurring, there is change in its intensity: more severity is observed in August for the recent period contrasting with the historic data characterized by lowest rainfall in July.

Except for the months of January and December characterized by similar values of temperature, the monthly mean values observed during the recent period are highest with about 2°C over that of the historic period. September is likely the moistest month during both recent and historic periods.

3.2. Monthly historic rainfall and that of rice cropping period

Figure 2 is showing the monthly average of rainfall during the historic long period of 30 years in the manner to be compared with the recorded similar data during the three years (2012, 2013 and 2014) of rice growing. Bimodal pattern of rainfall is observed during both periods with two rainy seasons: The first is occurring during 4 months as the main rainy season from March to June while, the second shortest is occurring during two months. Alternatively, a mid-season drought is observed between both rainy seasons before the main dry season from December to February (4 months duration). Furthermore, the recent period is characterized by longer mid-season drought period from June to September except for the year 2014 with contrasting highest rainfall amounts in June and September.

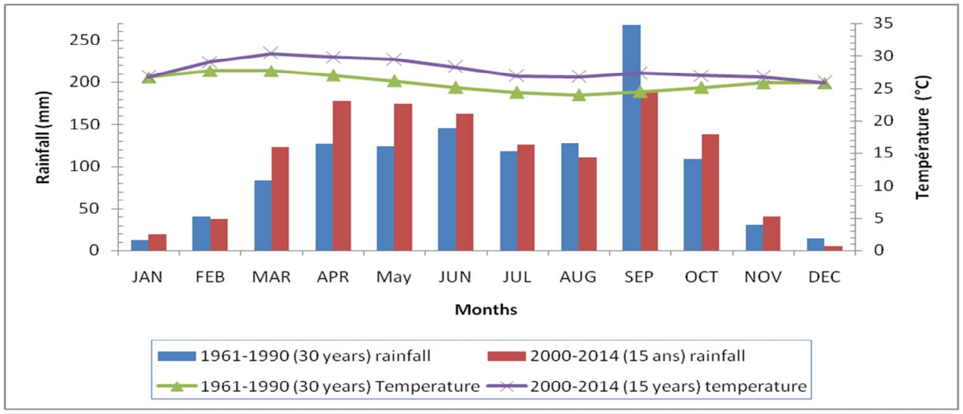

Figure 1: Monthly rainfall and temperature as recorded during the periods of 1961 – 1990 (30 years) and 2000 – 2014 (15 years)

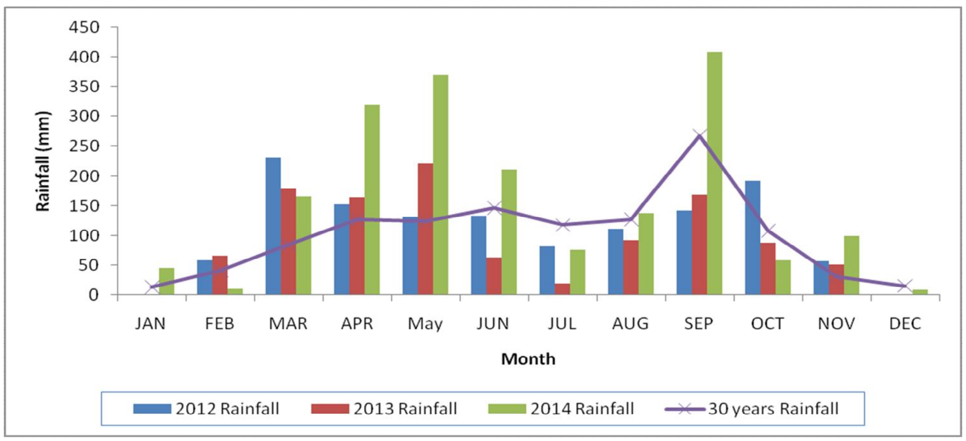

Figure 2: Average monthly rainfall as recorded during the period of 1961 – 1990 (30 years) and during rice growing (2012, 2013 and 2014)

Mean values of monthly rainfall amounts are presented in table 2 for 12 years (2000 – 2012) period and during rice growing period from 2012 to 2014. There are variances of rainfall amounts during both periods especially for the minimum amounts in December (4.6 mm and 3.2 mm) and the maximum values in September (164.4 mm and 239.5 mm). No significant difference is observed between the mean values except for the months of March and May significantly ($P<0.05$) referring to highest rainfall amounts during the recent period. Roughly, highest variability (CV > 100%) of rainfall amount is accounting for the months of January, February and December. Details of these results are presented in table 3 showing distinctly the average, maximum and minimum values of monthly rainfall amounts during 12 years (2000 – 2012) and during the period of rice growing (2012 – 2014). There are temporal and quantitative variations of rainfall extreme values between both periods: maximum values are observed as 297.2 mm in June and 408.5 mm in September for the past 12 years and for the rice growing period respectively. But, January and December are the driest months during both periods with 0 mm as average rainfall record. In turn, February and November are drier for the past (12 years period) when observing 10.5 mm and 50.5 mm during rice growing respectively.

Table 2: Monthly average rainfall amount for the past period of 12 years (2000-2011) and during the trial (2012-2014)

	Rainfall (mm)											
Period	JAN	FEB	MAR	APR	MAY	JUN	JUL.	AUG	SEP	OCT	NOV	DEC
12 years	14.2a	32.4a	91.7b	157.2a	144.4b	139.4a	117.1a	103.3a	164.4a	127.1a	30.9a	4.6a
Trial	15.2a	45a	191.8a	212.3a	241.5a	136.1a	58.9a	113.8a	239.5a	112.7a	68.8a	3.2a
CV (%)	171.2	102.1	44.2	27.9	42.1	49.9	62.9	47.0	39.9	52.8	79.3	283.0
P > F	0.95	0.59	0.01	0.09	0.05	0.94	0.2	0.75	0.13	0.74	0.08	0.86

Letters a and b are indicating the mean values with significant difference for α = 0.05

JAN = January; FEB= February; APR = April; MAY= May; JUN = June; JUL= July; AUG= August; SEP= September; OCT= October; NOV= November; DEC= December

Table 3: Monthly variation of rainfall during the past 12 years (2000-2011) and the trial period (2012-2014)

		Rainfall (mm)											
Period		JAN	FEB	MAR	APR	MAY	JUN	JUL.	AUG	SEP	OCT	NOV	DEC
	Minimum	0.0	0.0	37.4	93.3	50.4	61.5	33.5	9.5	98.0	40.5	0.0	0.0
12 years	*Mean*	14.2	32.4	91.7	157.2	144.4	139.3	117.1	103.3	167.4	127.1	30.9	4.6
	Maximun	73.3	99.0	223.5	222.5	245.0	297.2	228.9	191.5	246.8	231.5	98.0	46.3
	Minimum	0.0	10.5	165.4	153.0	132.5	63.0	19.2	92.0	142.1	58.1	50.5	0.0
Cropping	*Mean*	15.2	45.0	191.8	212.3	241.5	136.1	58.9	113.8	239.5	112.7	68.8	3.2
	Maximum	45.5	66.0	231.5	320.0	370.5	211.3	82.0	138.3	408.5	192.0	99.0	8.5

JAN = January; FEB= February; APR = April; MAY= May; JUN = June; JUL= July; AUG= August; SEP= September; OCT= October; NOV= November; DEC= December

3.3. Climatic conditions during the growth stages of rice

The rainfall occurrence and air temperature levels are presented in figure 3 for monthly decades in 2012 (a), 2013 (b) and 2014 (c) during the different physiological cycles of the rice NERICA 5. There is a variability of decade rainfall amounts during the rice growing indifferently to the years when the extreme values of temperature (maximum and minimum) are almost constant about 30°C and 20°C for a giving year and across the years respectively. The vegetative growth stage of rice is moistest in 2012 (Figure 3a) as compared to that of the other years while, the beginning of the reproductive stage is similarly dried as that of the rice growing in 2013 (Figure 3b) even moistest at the end of this period in 2012. Although the similar rainfall occurrences during the vegetative stage of rice growing in 2014 (Figure 3c) and 2012, this period is preceded by heaviest rainfall (>100 mm) in 2014 with further increasing trend during the reproductive stage of rice. The maturity stage of rice is also moistest in term of rainfall amount during 2014 also characterized by highest variation of the air temperatures. Average rainfall amounts and temperatures as recorded during each of the development stage of rice and cumulative values as well as mean values are presented in Table 4 for the three cropping seasons (2012, 2013 and 2014). Significant difference of rainfall and temperature are observed (P<0.05) for a given development stage and for the cumulative values of rainfall as well as the mean values of temperature. Overall, there is limited condition of water availability characterized intermittent lowest rainfall amount except for last cropping season (2014).

Table 4: Average values of rainfall and temperature during the growth stages of rice in 2012, 2013 and 2014

	Rainfall (mm)				Temperature (°C)			
Years	Vegetative stage	Reprod. stage	Maturity stage	Cumulative value	Vegetative stage	Reprod. stage	Maturity Stage	Mean value
2012	160.0b	130.0b	37.0c	327.0b	25.5c	25.4c	25.7b	26.1c
2013	108.2c	15.0c	41.0b	164.2c	27.5a	25.7a	25.2c	26.6b
2014	193.3a	219.8a	223.5a	636.6a	27.1b	25.5b	26.7a	26.7a
CV (%)	22.9	69.3	87.0	52.4	0.9	3.2	0.5	2.4
P > F	<. 0001	<. 0001	<. 0001	<. 0001	<. 0001	<. 0001	<. 0001	<. 0001

Letters a, b and c are indicating the mean values with significant difference for α = 0.05; Reprod: Reproductive

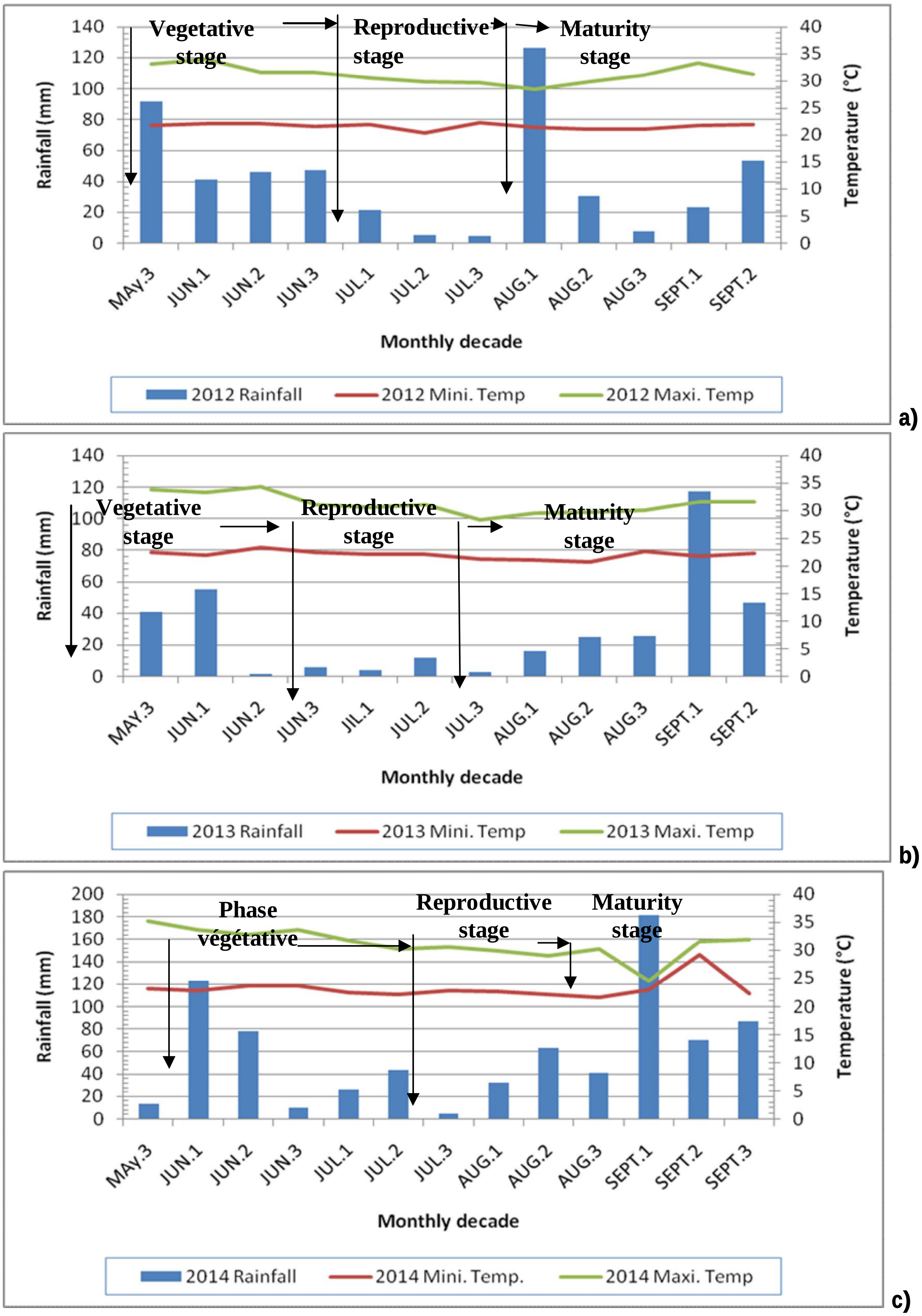

Figure 3: Monthly decade rainfalls and temperatures in 2012 (**a**), 2013 (**b**) and 2014 (**c**) according to rice growth stages

Monthly mean values of standardized precipitation index (SIR) are presented in figure 4 for the cropping periods of 2012 (Figure 4a), 2013 (Figure 4b) and 2014 (Figure 4c). Interannual noticeable variations are observed especially for the months of June and July, as well as in August at certain levels. Except for the year 2014 characterized by monthly SPI closed to the normal ranges (-0.99 – 0.99) or with highest humidity (SIR> 1.5), the years 2012 and 2013 are presenting unless 4 months of extreme drought (SIR< -2) respectively: January, February, November and December for 2012 (Figure 4a) and, January, July, November and December for 2013 (Figure 4b). From May to August, the drought is more pounced in 2013, 2012 and 2014 in decreasing order.

3.4. Effect of climatic parameters on rice development

Table 5 is presenting the mean values of rainfall and temperature as well as the average physiological cycle associated to rice grain yield (GY), straw yield (SY), total dry matter (TDM), harvest index (HI) and the weight of 1000 grains as recorded for years 2012, 2013 and 2014. It is significantly (*P*<0.05) observed a difference between the mean values of studied parameters according to the cropping years. Highest values account for year 2014 and the lowest air temperature (26°C) is observed in 2012. The year 2013 is characterized by lowest rainfall amount and values of agronomic parameters except for the weight of 1000 grains (31.5 g) almost similar in 2014 (31.0 g). The physiological cycle is reduced by 5-12 days in 2013 compared to the durations observed in 2012 and 2014 respectively.

In fact, there is significant positive correlation (0.77 – 0.99) between the rice physiological cycle and the rainfall occurrence during the reproductive stage (Table 6). This result is contrasting with that observed (R = -0.41) for the air temperature during the same development stage of rice while high positive correlation value (R = 0.99) is also characterizing the maturity stage for air temperature and the physiological cycle. Overall, the air temperature has positive and significantly (*P* = 0.015) low correlation (R = 0.25) with the rice physiological cycle however.

Table 5: **Mean values of rainfall, air temperature, rice physiological cycle and yield parameters according to cropping years (2012, 2013 and 2014)**

Year	Rainfall (mm)	Temperature (°C)	Physiological cycle (Day)	GY (tha^{-1})	SY (tha^{-1})	TDM (tha^{-1})	HI (%)	1000 grains weight (g)
2012	327b	26.2c	92b	1.7b	3.1b	4.8b	31.8b	29.3b
2013	164.2c	26.6b	87c	0.4c	1.8c	2.2c	18.7c	31.5a
2014	636.6a	26.9a	99a	4.3a	6.3a	10.6a	40.6a	31.0a
CV(%)	52.4	2.3	5.3	46.5	35.5	38.0	25.1	10.3
P > F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.015

Letters a, b and c are indicating mean values with significant difference for α = 0, 05

Table 6: Pearson correlation coefficients of rainfall and air temperature with rice yield parameters (GY, SY, TDM and HI) and the physiological cycle respectively

	Rainfall (mm)						Temperature (°C)					
	Reproductive		Maturity		Cumulative		Reproductive		Maturity		Cumulative	
Parameters	R	Prob.	R	Prob.	R	Prob.	R	Prob.	R	Prob.	R	Prob.
GY	0.82	<.0001	0.80	<.0001	0.85	<.0001	-0.27	0.008	0.85	<.0001	0.30	0.003
SY	0.78	<.0001	0.78	<.0001	0.82	<.0001	-0.24	0.019	0.82	<.0001	0.31	0.002
TDM	0.81	<.0001	0.80	<.0001	0.84	<.0001	-0.26	0.012	0.85	<.0001	0.31	0.002
HI	0.77	<.0001	0.61	<.0001	0.74	<.0001	-0.46	<.0001	0.74	<.0001	0.03	0.736
1000 grains Weight	-0.09	0.401	0.09	0.381	-0.01	0.697	-0.28	0.005	-0.01	0.915	0.27	0.007
Physiological cycle	0.98	<.0001	0.90	<.0001	0.99	<.0001	-0.41	<.0001	0.99	<.0001	0.25	0.015

a)

b)

c)

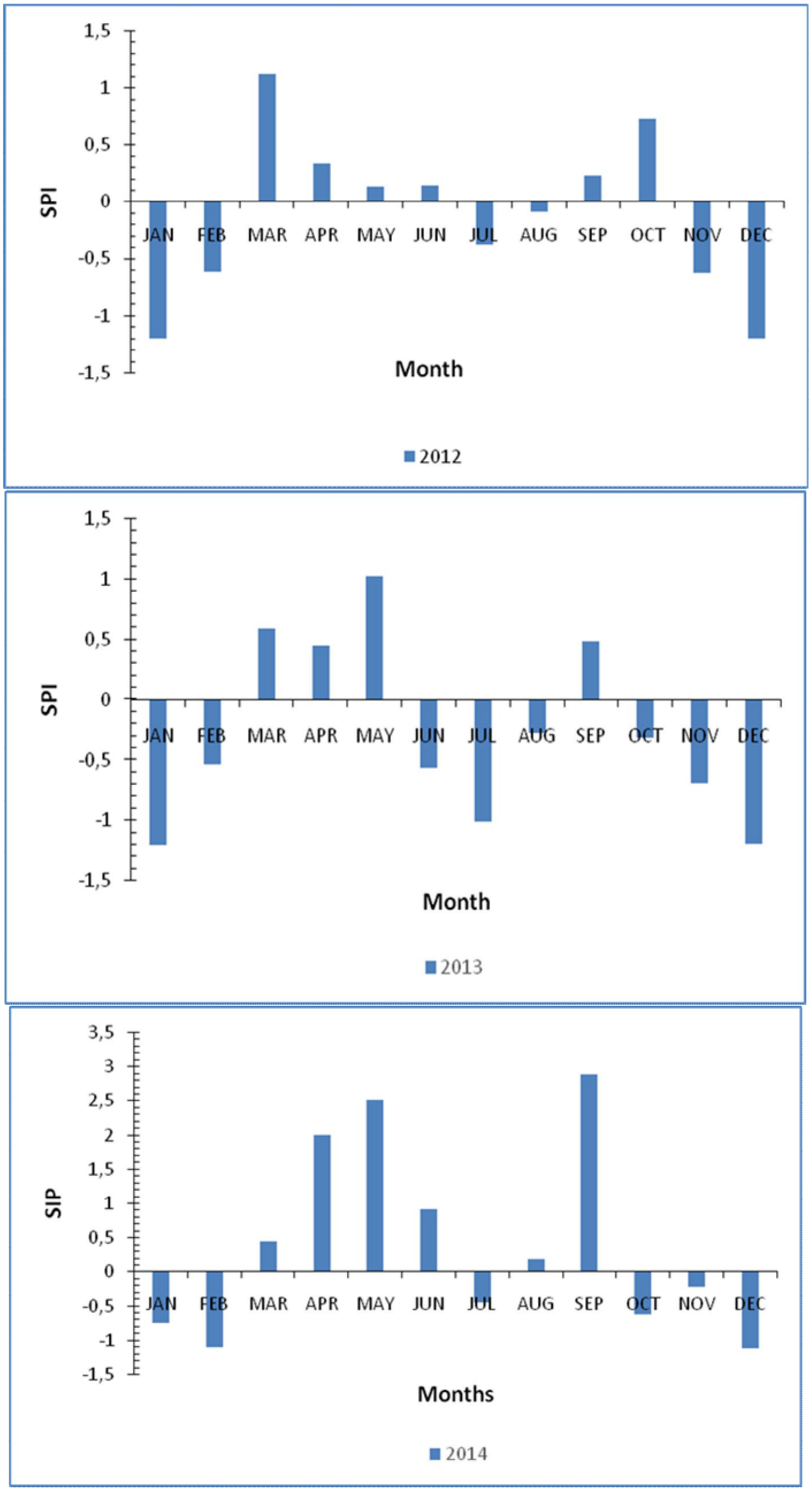

Figure 4: Monthly mean values of standardized index of precipitation (SPI) during years 2012 (a); 2013 (b) & 2014 (c)

No significant correlation (R = -0.21) is observed between the weight of 1000 grains and the rainfall occurrence during the reproductive stage of rice while, almost similar value of correlation coefficient (R = -0.28) is significantly (*P* = 0.05) observed with the air temperature which is roughly and positively correlated (R = 0.27) with the weight of 1000 grains however. In turn, RGY and SY are significantly (*P*<0.05) correlated with the rainfall occurrence independently to the development stages of rice while, their relations observed with the temperature are characterized by positive or negative values according to the rice reproductive and maturity stages respectively. Similar results are observed for IR.

4. Discussion

4.1. Main characteristics of climate in the studied zone

As guinea savanna ecology of transition between forest and savanna, the climate of the studied region has been always characterized by four seasons including two rainy seasons alternating with two dry seasons (Bonvallot *et al.*, 1972). This rainfall pattern was likely consistent along the past period up to 2014 while, increasing contrast was occurring between wet and dry seasons however. Moreover, the increasing of the current rainfall amount and the constancy observed for the air temperature in January, November and December are somewhat contrasting with worldwide data including that of elsewhere in Côte d'Ivoire. Historic (1961 – 1990) data of rainfall showed increasing trend from January to September restricting the dry season to a shorter period of December, January and February in a manner looking likes to a monomodal rainfall pattern. This trend is contrasting with that of recent data of 15 years (Figure 1), and particularly with that of the three cropping seasons (Figure 2) characterized by most pronounced bimodal rainfall pattern. In the light of these analyses, the bimodal pattern of rainfall occurrence in the studied zone as described by Gigou (1973), may be a result of climate temporal modification instead of original characteristic. Moreover, there is more irregularity of rainfall in recent period especially, during the third decade of May and the second of June as random event depreciating the quality of the main raining season for agriculture in a manner to increase rice vulnerability to the mid-season drought already severe: In fact, this irregularity may reduce the consistency of agricultural calendar which is more depending to the sowing date, especially in rainfed condition (Rathnayake *et al.*, 2011).

This situation has challenged the rice growth during the study regarding to the physiological cycle of NERICA 5 in the range of 80 – 90 days and the occurrence of more intensive (25 – 75 mm of rainfall) mid-season drought in 2013. Further rainfall irregularity was observed during the second raining season with highest rainfall occurrence sometimes in the 1rst decade of August or September. The current study is also underlining other significant particularity of the studied ecology in the line with agrosystem recommendation because of the contrast with existing knowledge of rainfall variability in West Africa and especially in Côte d'Ivoire (Servat *et al.*, 1999; Ardoin *et al.*, 2003; Ardoin, 2004, Kouassi *et al.*, 2008): the current average rainfall amount (1224 mm) is somewhat over the that (1198.6 mm) of historic data (1961 – 1990) mainly induced by the highest rainfall recorded during the 1rst raining season though, this finding is not new. In fact, Aguinet (1997) observed more than 1200 mm of rainfall before year 1960 and lower amount of 1000 mm from 1961 to 1990. Therefore, we assume a cyclic variability of rainfall occurrence in the studied ecology because of the increase trend observed in the recent period of 2000 – 2014. If confirm by widest historic data, this assumption will strengthen the theory of Milankovitch (Laskar and Gastineau, 2009) about the cyclic and natural change of climate, especially in the Guinea ecology of West Africa.

Anyway, the change in recent period as characterized by highest rainfall may be an advantage when saving water by construction of dam in order to mitigate the effects of temporal irregularities. Nevertheless, the subsistence agriculture characterizing rice cropping in Africa will still be vulnerable without sound integrated management strategy of drought.

4.2. Heat and moisture deficit occurrences

Climate change in the centre of Côte d'Ivoire is characterized by more pronounced rainfall irregularity resulting a wayward occurrence and longer mid-season drought (June – August) of bimodal rainfall pattern previously observed from July to August. Beside a poor rainfall distribution, there was increase of air temperature about 2°C except for November, December, and January.

However, February and March are still under the influence coolest period named harmattan (1972) further characterized by dusty wind blowing in North – East direction over the normal speed (Koren and Kaufman, 2004). Of these conditions including the increase of air temperature, change may occur in the characteristic of the harmattan mainly inducing more evapotranspiration of plants and torrential events coupled with flooding (Goodin, 2004; Purkey *et al.*, 2008). Therefore, current climatic conditions may be a threat for both rain fed upland and lowland rice cropping. Moreover, the increase of air temperature has arguably an incidence relating to the crop degree-days and temperature-based (Jackson, 1990; Gao *et al.*, 1992): There is more suitability of the studied ecology to rice cropping due to highest degree-days while the temperature-based is remaining constant at 10°C as genotype dependant. However, the extreme values observed between 20°C and 30°C may somewhat constrained the tillering and grain filling respectively (Yochida, 1977). In fact, the optimum temperature required for grain filling is about 25°C while the maximum temperature value was increase from 28°C in the past (Kouassi *et al.*, 2010) to 30°C currently.

A complex analysis including the maximum temperature and moisture deficit may attest their prevailing effect on rice cropping and yield. Indeed, low value of maximum temperature of about 25°C combined with suitable range of standardized precipitation index were characterizing rice reproductive stage in 2014 when recording highest grain yield of 4.3 tha^{-1} against 1.7 tha^{-1} and 0.4 tha^{-1} in 2012 and 2014 respectively. Such scenario of climatic parameters may be considerate among diagnostic factors of yield gap observed in rice agrosystems of Côte d'Ivoire (Koné *et al.*, 2014), especially for lowest productive (1- 1.5 tha^{-1}) upland rainfed rice cultivation (Audebert *et al.*, 1999; Koné *et al.*, 2010). Over all, the current study underlined the depreciation of heat tolerance observed for the rice *O. glabberima* (Dossa *et al.*, 2015) when generating NERICA 5 by crossing with *O. sativa* (Jones *et al.*, 1997). Therefore, a screening of wide genotype of *O. glabberima* is advocated for identification of more heat tolerance trait that may be useful for improving the performance of NERICA 5.

4.3. Climatic potential impacts on upland rice production

Well, there is evidence of modification of climatic parameters in the studied zone, especially characterized by more pronounced bimodal rainfall pattern, highest rainfall irregularity, and increasing heat. According to FAO (1995) report, rainfall irregularity and temperature variation can affect negatively plant growth. The extending of the mid-season drought in June was further constraining agricultural practices as recommended by Gigou (1973) for the studied region suggesting the sowing date in June. When analyzing the results of current study (Table 2 and Figure 4), Marsh is being the most suitable sowing date for more availability of rainfall during the rice growth regarding to the prevalence of rainfall influence on rice agronomic performances (Table 5). In spite of the highest mean value of temperature (26.9°C) in 2014, rice production was better probably because of the highest rainfall amount: highest rainfall may reduce moisture deficit impacting positively the yield parameters (RGY, SY, TDM and HI) indifferently to the occurrence during the growing stages of rice (Table 6). In turn, temperature rising during a specific development stage of rice can affect negatively rice growth as observed in 2013: Highest temperatures (27.5°C and 25.7°C) coupled with lowest rainfall during vegetative and reproductive stages induced lowest agronomic performance except for the weight of 1000 grains (31.5 g) similarly observed for the moistest year 2014 (31.0 g). Of this contrast, we can assert more effect of mid-season drought on spikelet number of grains during 2013 instead of the grain filling (Wardlaw, 1980) resulting the lowest grain yield (0.4 tha^{-1}) observed.

In some extend, global positive effect ($0.22 < R < 0.31$) of air temperature was observed on the agronomic parameters of NERICA 5 probably, because of rice is belonging to the warm regions with 10°C of temperature-based (Nuttonson, 1955). However, the current study pointed out negative effect of temperature rising during the rice reproductive stage: heat stress as induced by the increase of temperature may stop or avoid the dehiscence of anther and the pollen activity hence, affecting grain replenishment (Mackill *et al.*, 1982; Zhang et Mackill, 1982). Having in mind that rainfall amount can impact air temperature hence mitigating its negative effect on rice grain yield as observed in 2014 (Table 5), the significant recommendation of the current study is relative to the sowing date which is no longer in June: sowing date in Marsh needs to be implemented for confirmation during further study.

5. Conclusion

The study revealed a more pronouncing bimodal rainfall pattern along thirty years period in the studied climatic zone. The two peaks of rainfall were differing in intensity (179 mm ≠ 146 mm and 190 mm ≠ 268 mm) especially for the main rainy season when comparing the past and recent periods.

The mid-season drought formally occurring between July and August is now extending from June to September with highest severity in August instead of July as observed in the past. In contrast, higher rainfall amount was accounting for the recent period though; there was increase of air temperature about 2°C while ranging from 20°C to 30°C. A reduction of the rice physiological cycle and the grain number per spikelet were the consequences of moisture and heat stresses respectively. Marsh was suggested for sowing and further investigation was recommended for strengthening heat tolerance of NERICA by valorization of relevant genotypic properties characterizing *O. glabberima*.

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