Comparison of productivity of oil palm (*Elaeis guineensis* Jacq.) grown on tertiary sand and swampy area of Southern of Côte d'Ivoire

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Abstract- Over the past several years, there has been a decrease in rainfall, resulting in an increase in the water deficit in the forest area of Côte d'Ivoire. It is with the aim of looking for new areas suitable for the cultivation of oil palm that experiments have been conducted on the hydromorphic soils of La Mé and low-bottom divo. The objective of this study is to compare the productivity of oil palm grown on tertiary sands and in marshy areas. The experiments were carried out on the CNRA stations in The South-East and Divo and on the Palmci production plantation in Divo, in the south-central area. The methodology is based on the time between initiation and maturation of diets. It takes 3 years between the initiation of the female inflorescence and the harvest of the diet. This evolution of inflorescence is influenced by rainfall and water deficit. The parameters measured were rainfall heights, water deficit, number of diets, average diet weight and performance. The results showed that the rainfall was higher at the Me compared to that recorded in Divo. During the four campaigns, yields were significantly higher on plantations on the hydromorphic soils of the Me and Divo lowlands than on those on the soils of the Me and Divo plateaus. The yield obtained during the 2005 season on the various plantations was 22,000 kg/ha/year in the hydromorphic zone of the Me, 20,500 kg/ha/year in the lowland zone of Divo, 13,000 kg/ha/year on the Mé plateau and 12,500 kg/ha/year on the Divo plateau. Therefore, the choice of hydromorphic zones is currently an interesting solution for improving and increasing the productivity of oil palm in Côte d'Ivoire.

Index Terms- Côte d'Ivoire, oil palm, plateau soils, swampy area, yield

I. Introduction

Today, Africa's population is estimated at more than 831 million, at 3.8 billion by 2100. These demographic changes are imposed by profound environmental changes, due to climate change, which in a region where extensive agriculture is dominant, have a negative impact on agricultural production [1, 2, 3]. In this context of food insecurity risks, it is essential to increase agricultural production in order to address development challenges and reduce the vulnerability of populations.

Like most developing countries, the Ivorian economy relies mainly on agriculture, in particular, on the exploitation of industrial crops (cacao, oil palm, coffee, rubber, etc.). Palm oil, with an estimated annual production of more than 400,000 tonnes, has been the second largest export after cocoa (1, 300,000 tonnes) since 2007. Côte d'Ivoire is the largest exporter of palm oil and the second largest producer of oil palm at African level [4]. These performances are the result of an important plantation creation programme, undertaken since 1961. This programme has combined the creation of industrial units (industrial plantations) of several thousand hectares with multiple village plantations.

Both types of exploitation developed in the southern Ivorian forest, on soils with whole natural fertility, and under appropriate rainfall conditions. These soils, such as ferralsols or tertiary sands, were covered with evergreen forests, playing an important role in maintaining fertility and mitigating climate change [5]. However, the transformation of tropical forests and the intensification of land use patterns result in soil erosion and substantial fertility losses [6]. In Côte d'Ivoire, vegetation cover has declined sharply since independence [7]. Indeed, the expansion of some perennial crops has contributed to the transformation of forests into plantations, the imbalance of natural ecosystems and the degradation of soils [8].

Land degradation remains a major concern due to its adverse impacts on agricultural production, food security and the environment [9]. Most soils in sub-Saharan Africa have low intrinsic fertility associated with increased nutrient loss [10]. As a result, the objective of agricultural increase is met with two constraints: the scarcity of land traditionally developed for oil palm and less favourable climatic conditions than in the past, namely the decline in Rainfall.

Oil palm production is linked to a number of factors: climate, soil fertility, seed genetic potential and farming techniques. Among these factors, water supply appears to be the most important factor of production. The optimal rainfall conditions for the oil palm are characterized by an annual total of up to 1800 mm of water, with a regular distribution [11]. Drier climate conditions can lead to very good yields when the lack of precipitation is offset by the presence of a shallow water table [12]. Rainfall has been reduced for several years, resulting in an increase in water deficit in the côte d'Ivoire forest area [13].

It was therefore important for the development of the oil palm to find new areas suitable for the cultivation of this oilseed, independent of the tertiary sands whose water tables are deep. Hydromorphic zones and shallows meet these criteria. In these areas, water is the main determinant of the environment and plant life. The water table is outcropping or close to the surface of the ground, or often the earth is covered by water. Hydromorphic zones and shallows are among the most productive environments in the world. They are the cradle of biological diversity and provide the water and primary productivity on which countless plant species depend for their survival. The full application of the development technique of these areas results in a gain of about 33% compared to the average productivity recorded on the tertiary sands [14]. The oil palm is, in particular, suitable for their development, because its fasciculated root system does not require a significant lowering of the tablecloth.

It is with a view to the search for new areas suitable for the cultivation of oil palm that experiments have been set up on the hydromorphic soils of La Mé and the low-bottom of Divo in Côte d'Ivoire. The objective of this study is to compare the productivity of oil palm grown on tertiary sands and in marshy areas.

II. Material and Methods

2.1 - Study area

The studies were conducted in the field in two different localities, namely La Mé in the Southeast and Divo in South-central of Côte d'Ivoire.

The experiments were carried out on four plots in the two localities. The tests were set up on a single type of plantation. These are industrial plantations, owned by Palmci, an Ivorian oil palm agro-industry and the National Centre for Agricultural Research (CNRA). The four test plots were:

- Palmci plantation in Divo (South-central of Côte d'Ivoire), installed on plateau soils, such as ferralsols;
- CNRA plantation in Divo (South-central of Côte d'Ivoire), installed on low-lying soils;
- CNRA plantation in La Mé (South-east of Côte d'Ivoire), installed on hydromorphic soils;
- CNRA plantation in La Mé (South-east of Côte d'Ivoire), installed on the tertiary sands, ferralsols type.

The climate of the South-east and South-central of Côte d'Ivoire is subtropically humid with marked seasons. The soils, derived from the tertiary sands, are ferralsols and hydromorphs, gravel and very little rich in organic matter, heavily desaturated, deep, sandy on the surface and without coarse elements. Kaolinite clay has a low ability to exchange cationicly. These pedoclimatic conditions are favourable for the cultivation of oil palm.

2.2 - Plant material

The plant material is composed of oil palm hybrids obtained by cross-country between *Dura* (female) and *Pisifera* (male). The *Dura* type is characterized by fruits with a thin pulp and a thick shell. The *Pisifera* type is characterized by a high abortion rate of the fruit and a very thin or completely absent shell. The *Tenera* hybrid, called C1001F, from the "La Mé x Deli" cross-market, was used. This plant material, characterized by high yield and resistance to *Fusariosis*, is derived from the second cycle of reciprocal recurrent selection. This new plant material is currently popularized in all Ivorian oil palm growing areas. For our study, only palm groves of 5, 6, 7, 8 and 9 years were selected.

In the oil palm, after the natural opening of the spathe of the female inflorescence, then the flowers occur which will be fertilized, no more than three days later, by the pollen grains of the neighbouring trees. The female inflorescence then turns into a diet, which will reach maturity 5.5 to 6 months after knotting. However, from the floral initiation to the maturity of the diet, it takes 30 to 33 months.

2.3 - Sample selection

When planting, a sample of about 5% of the trees is generally considered sufficient. To account for edaphic variations encountered on a culture unit, this sample must be distributed throughout the plot. As a result, one line out of 20 was systematically selected from which all trees were observed (for large areas). In total, these trees or lines were selected, and spread over the entire test plot. The same trees or lines have always been kept in order to be able to possibly adjust the results obtained, after several rounds of harvests, compared to the actual results obtained. The lines were marked with an identical marker on all study plantations, by metal tags bearing the line and tree numbers. This practice makes it possible to better organize diet weighings and to carry out systematic checks.

2.4 - Determining the rainfall and water deficit of the two localities

Rainfall data were recorded over 11 years, from rainfall, in the study locations to track its influence on oil palm production. Rain heights and total rainy day numbers were collected in the two localities studied (Divo and La Mé). These rainfall data were used to calculate annual water deficits (DH) from 1995 to 2005, using the simplified water balance method [15] which does not take into account runoff [16], due to the presence of cover plants.

The water balance (BH) is expressed from a very simplified formula, established in the climatic conditions of West Africa by the OHRI [17], which allows the calculation of the water deficit (DH) by taking stock of the rains, to which the the soil water supply (estimated maximum reserve of 200 mm) is added.

BH - P - R - E, where

BH: Water balance (mm);
P: Rainfall (mm);
R: Initial soil water reserve from one period to the next (limited to a maximum of 200 mm, due to the sandy texture of the soil) [17];
E: Simplified evaluation of adult oil palm evapotranspiration, which takes the value of 120 mm per month when the number of rainy days is greater than 10, and 150 mm per month, if this number is less than 10 [17].

The water balance was based on the difference between inputs (precipitation and initial soil reserve) and water loss (actual evapotranspiration) in the soil. When the water balance is negative, there is a water deficit (DH). The water deficit (DH) is expressed in the following formula:

DH = - BH

2.5 - Yield determination

On palmci's agro-industrial complexes and CNRA research stations (Divo and La Mé), the various productions were recorded for palm groves aged 5, 6, 7, 8 and 9 years. Four agricultural campaigns collected production data, namely 2002, 2003, 2004 and 2005.

Yield components were determined from individual harvests. For this operation carried out every fortnight, a team including a harvester, a weigher and a pointing clerk visits each tree identified in the plot to collect the production data, according to each harvesting system, linked to the age of the palm grove. These include the bunches number per tree (NR/tree) and the binches weight per tree (PR/tree), from which the average weight of diets per tree (PMR/tree) and bunches tonnage or yields (TR/ha/year) were calculated. The binches number per tree is determined by counting all bunches harvested on each useful tree. The bunches weight is determined by weighing, using a scale of all bunches harvested per tree.

The data collected is used to calculate performance using the following formula:

TR/ha/year = DP*NR/tree/year*PMR/tree/year, Where

DP is the actual planting density of which the standard is 143 trees/ha; NR/tree/year is the binches number per tree per year and, PMR/tree/year the average weight per tree per year.

2.6 - Data processing and analysis

The data, collected and recorded using the Excel spreadsheet, was subjected to variance analysis using XLSTAT version 7.5 software. The level of significance of the differences between the averages was estimated using Duncan's test, at the threshold of 5%.

III. Results

3.1 - Evolution of rainfall and water deficit in study locations

Rainfall data from all three communities show high interannual variability (Figure 1). Variations in rainfall at the La Mé and Divo stations are characterized by alternating wet years (high rainfall), moderately wet (near average) and dry (low rainfall). Over the 11 years of data, rainfall as a whole indicated a more decreasing trend in Divo than in La Mé. In general, these results have highlighted a downward trend in rainfall in the South-east and South-central of Côte d'Ivoire.

Annual rainfall in La Mé fluctuated from 1300 to 2000 mm of water over the observation period, with an average of 1700 mm per year. It is a moderately watered area. The South-central is less so, with annual heights exceeding 1200 mm of water, either in Palmci, than at the CNRA in Divo. The rainfall of the forest area decreases as we move inland. In the locality of La Mé, the driest years were 2003 and 2004, with rainfall of about 1300 mm, while 2010 and 2011 were the wettest, with heights well exceeding 1900 mm of water per year.

The annual rainfall at CNRA-Divo varied during this period, from 991 to 1466 mm of water. The annual average recorded in this region was about 1240 mm of water per year. This community was poorly watered. The years 1995, 1999 and 2004 were the wettest, with average heights of more than 1400 mm of water per year. As for the Palmci de Divo site, the annual rainfall has fluctuated between 1008 and 1552 mm of water per year, with an annual average of 1250 mm of water. 1995 and 2005 were the wettest, with heights of 1552 and 1414 mm of water respectively. Divo region was markedly lower in average annual rainfall than La Mé. In general, rainfall in the South-east of the country remained largely very high than the South-central.

The evolution of the water deficit (DH) further explains the deterioration of the climate in the study regions. Over the 11 years, it is more than 200 mm of water each year. The annual water deficit (Figure 2) was higher in the South Central (Divo), with an average value of more than 400 mm of water than in the South-East (The Me), with an average value of 300 mm.

The DH obtained in La Mé varied from 230 to 453 mm of water. As for the Palmci and CNRA stations in Divo, the annual DH fluctuated from 201 to 701 mm and 237 to 668 mm of water, respectively. The information recorded in Divo and La Mé since 1995 shows that, overall, rainfall has been down, while dh has been up slightly.

From the point of view of rainfall and water deficit, the years 1995, 1999 and 2005 appear as the best respectively in Palmci in Divo, CNRA - Divo and La Mé. Values are 1552 mm versus 327 mm, 1523 mm versus 237 mm at CNRA - Divo and 1836 mm of water compared to 296 mm of water deficit for La Mé. The years of lowest rainfall are 1998 with 1245 mm in La Mé, 2002 mm at the CNRA in Divo and 2003 with 1008 mm of water in Palmci.

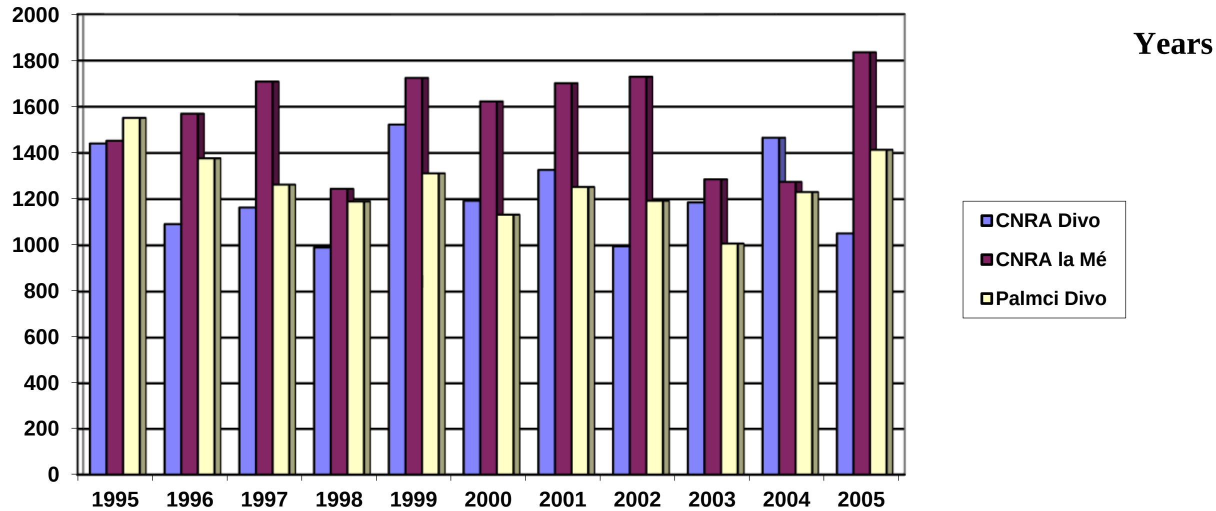

Figure 1. Evolution in annual rainfall on the three weather stations from 1995 to 2005

Table 1 Annual rainfall and water deficit data on the three weather stations from 1995 to 2005

Years / Sites		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CNRA Divo	Rain	1441	1092	1164	991	1523	1193	1327	996	1186	1466	1052
	DH	334	587	563	668	237	459	396	606	444	401	612
CNRA La Mé	Rain	1453	1570	1709	1245	1725	1623	1702	1730	1286	1275	1836
	DH	246	319	426	459	230	447	313	231	291	310	296
PALMCI Divo	Rain	1552	1377	1263	1190	1312	1133	1253	1193	1008	1231	1414
	DH	327	444	564	538	303	554	391	532	701	586	202

3.2 - Evolution of yield in bunches on study plantations

The harvests were made 60 months (5 years) after planting, as under standard elaeiculture conditions so as to legitimize comparisons of oil palm production, of the same age and located in different environments. Production data were assessed through the number of bunches and the weight of bunches that calculate the average weight of bunch and yield per hectare.

3.2.1 - Number of bunches

The number of bunches (NR/tree/year) over the four campaigns was determined on the four plantations studied (Table 2). Analysis of variance reveals that there are differences between averages obtained on the four study plantations over the four campaigns.

During the 2002, 2003, 2004 and 2005 campaigns, the classification, according to Newman-Keuls test, resulted in two distincts groups. The first group, with the highest averages, over the four campaigns, is represented by the averages obtained on the CNRA plantations of La Mé and Divo, installed respectively on hydromorphic and low-lying soils. The highest averages were recorded during the 2005 campaign, with values of 3400 bunches/ha/year on the hydromorphic soils of the Me and 3050 bunches/ha/year on the low-lying soils of Divo.

As for the second group, it consists of the averages obtained on the plantations of the CNRA of Mé, installed on tertiary sand and Palmci de Divo, set up on plateau soil, during the four campaigns. These averages ranged from 1150 (2002) to 1800 buncges/ha/year (2008) on the tertiary sands of the Me and from 950 (2002) to 1,750 bunches/ha/year (2005) on Divo plateau soils. In general, the number of diets harvested on all plantations has changed steadily from the 2002 to 2005 campaign.

Table 2: Summary of the total number of bunches produced on all study plots

Types of plantations	Number of bunches/ha/an			
	2002	**2003**	**2004**	**2005**
CNRA Lamé (Tertiary sand)	1150 b	1450 b	1650 b	1800 b
CNRA Lamé (hydromorphic soil)	2000 a	2350 a	3150 a	3400 a
CNRA Divo (Low lying soil)	1750 a	2250 ab	2400 a	3050 a
PALMCI Divo (Tertiary soil)	950 b	1350 b	1600 b	1750 b

The averages followed by the same letter are not significantly different at the 5% threshold.

3.2.2 - Average weight of bunches

The average weight of bunches on the four plantations was determined by the number of bunches and the weight of bunches over the four campaigns (Table 2). The variance analysis does not reveal any difference between the averages recorded on all plantations during the 2002 campaign. The average weight of bunch ranged from 5.1 (Divo plateau soils) to 7 kg (hyfromorphic soils of La Mé).

For the other three campaigns, 2003, 2004 and 2005, there were differences between the averages recorded on all the plantations studied. The classification according to the Newman-Keuls test resulted in two homogeneous groups during these three campaigns. The first group, with the highest values, consists of the averages obtained on hydromorphic soils of La Mé and low lying soil of Divo, and, during the three campaigns. These averages ranged from 8 (2003) to 12.8 kg (2005) and low-lying soils from 7.7 (2003) to 11.4 kg (2005).

On plantations on Divo plateau soils and tertiary sands of La Mé, the recorded averages constituted the second homogeneous group. In the three campaigns, averages were lowest, with values ranging from 6.8 (2003) to 10 kg (2005) on the tertiary sands of La Mé and from 5.5 (2003) to 9.2 kg (2005) on the Divo plateau soils.

Table 3: Summary of average weight of bunch produced on all study plots

Types of plantations	Average weight of bunch (kg)			
	2002	**2003**	**2004**	**2005**
CNRA Lamé (Tertiary sand)	5,9 a	6,8 b	8 b	10,0 b
CNRA Lamé (hydromorphic soil)	7 a	8 a	9,8 a	12,8 a
CNRA Divo (Low-lying soil)	6,7 a	7,7 a	9,7 a	11,4 a
PALMCI Divo (Plateau soils)	5,1 a	5,5 b	7,1 b	9,2 b

The averages followed by the same letter are not significantly different at the 5% threshold.

3.2.3 - Total of bunches weight or yield

Yields per hectare expressed in kg of bunches per hectare (kg/ha), obtained over the four years of observation, show the high productivity of the swampy areas of Divo and La Mé compared to the tertiary sands on Divo and La Mé plateau.

The variance analysis applied to cumulative production of the three campaigns (2003, 2004, 2005) shows a significant difference between the averages recorded on the four plots studied (Table 4). The classification according to the Newman-Keuls test resulted in two distincts groups. The first group consists of averages recorded on the plantations of the marshy areas of La Mé and Divo, which produced the highest yields. These averages have varied, on the planting of hydromorphic soil of La Mé, from 14,500 (2003) to 22,000 kg/ha/year (2005) and on low-lying soils of Divo, from 13,000 (2003) to 20,500 kg/ha/year (2005).

Yields on plantations, installed on the tertiary sands of La Mé and on the Divo plateau soils, constitute the second homogeneous group. During the 2003, 2004 and 2005 campaigns, yields on the Divo tertiary sands plant were 11,500, 12,500 and 13,000 kg/ha/year, respectively. As for planting on Divo plateau soils, yields ranged from 10,500 kg/ha/year (2003) to 12,500 kg/ha/year (2005). These yields on all plantations change positively with the age of the plots.

During the 2002 campaign, the variance analysis did not reveal any difference between the averages obtained on the four study plots. These averages ranged from 10,000 (Palmci plantation to Divo) to 13,500 kg/ha/year (La Mé hydromorphic zone).

Table 4: Summary of total bunches weight produced on all study plots

Types of plantations	Total bunches weight (kg/ha/an)			
	2002	**2003**	**2004**	**2005**
CNRA Lamé (Tertiary sand)	11000 a	11500 b	12500 b	13000 b
CNRA Lamé (hydromorphic soil)	13500 a	14500 a	20500 a	22000 a
CNRA Divo (Low-lying soil)	12500 a	13000 a	19500 a	20500 a
PALMCI Divo (Plateau soil)	10000 a	10500 b	11500 b	12500 b

The averages followed by the same letter are not significantly different at the 5% threshold.

IV. Discussion

In recent years, rainfall has been low, resulting in an increase in the water deficit (DH) in South-east and South-central of Côte d'Ivoire. This finding, confirmed by this study, has already been mentioned by authors such as [18] Buisson and [13] Yao. The decrease in rainfall and the rise of DH are due to the combined action of man and nature [13]. Overuse of forests in the wetland, combined with natural phenomena, has contributed to a significant reduction in rainfall. Seasonal bushfires, anarchic deforestation without sufficient reforestation and extensive slash-and-burn agriculture, to which southern of Côte d'Ivoire is subjected, contribute to worsening the decline in rainfall [19].

Annual rainfall was significantly higher in La Mé, in the South-east, than in Divo, in the South-central region. The geographical location of La Mé region, close to the sea, and the presence of dense evergreen forests would contribute to increased annual rainfall in the south-east of the country. As for the South-central, vegetation, dominated by dense semi-deciduous forest and gallery forests, is believed to be responsible for the low rainfall recorded at the two Divo stations. The water deficit (DH), resulting from La Mé, remains lower than that recorded in the locality of Divo. The number of rainy days, which were clearly high in both localities, explains the heavy rainfall in La Mé and Divo. The rains, being well distributed throughout the year, thus promote a continuous production of oil palm throughout the year in the South of Côte d'Ivoire.

Rainfall is the main climatic factor for good oil palm productivity. The optimum annual need is 1800 mm of rain, well distributed during the year, or 150 mm per month, on average [20]. Rainfall deficit has an effect on the oil palm reproduction process [21]. Three critical periods of its production are, in particular, susceptible to a lack of water [21]. A lack of water during the period from flower initiation to sexualization, i.e. 42 to 36 months before bunches are harvested, leads to a higher rate of male inflorescences at the expense of female inflorescences. When water deficiency occurs during the period before the inflorescence leaf is emitted, 24 to 20 months before harvest, the risk of aborting this flowering draft becomes high. A lack of water during the increased phase of female inflorescence also increases the risk of abortion, and significantly reduces the size and weight of bunches. This period is between 15 and 6 months before the harvest of the future bunch. According to [22] Caliman, DH is a factor in yield, as a 100 mm increase in the annual deficit in deficit range of 0 to 500 mm causes a variation in yield of 2.1 tons of bunches, or 10% of potential water deficit production at zero.

This influence of rainfall and water deficit on oil palm production would explain the very high yield and its characteristics recorded on plantations installed on the hydromorphic soils of La Mé and Divo, compared to those installed on the plateau doils of La Mé and Divo. Yield, being linked to the total number of bunches and the average weight of bunch, is dependent on rainfall and water deficit.

Exceptional yields are due to the number of bunches and bunch weight produced per tree in hydromorphic areas with shallow water tables, and which are very favourable to the cultivation of oil palm [23]. According to [24] Djegui and Daniel, the increased availability of water from these areas is necessary for the maturation of bunches, which would reduce the coefficient of productivity variation of oil palms, and maintain stable the average weight of bunch. The availability and excess water in hydromorphic areas mitigate production declines during the year. In general, the rainfall patterns that predominate, especially in Southern of Côte d'Ivoire, involve one or two dry seasons of uneven durations during which the rains are less than the potential evapotranspiration, 100 to 150 mm of water per palm groves [25]. The soil would intervene by its water reserves to reduce or compensate for temporary deficits. These situations, where the water table at a shallow depth (2 to 3 m), would compensate for the adverse consequences of a rainfall deficit. With a view to implementing sustainable management systems, low-water soils could provide ideal conditions for the exploitation of water-intensive crops [26, 27].

Soil water characteristics, particularly the available water area, are of paramount importance as they largely determine the agrological value of soils vis-à-vis the oil palm that is very water-demanding [25]. Therefore, the choice of shallow water table areas (hydromorphic soil and low-lying) is currently an interesting solution for improving the productivity of oil palm. The availability of water permanently, in the shallow layers of hydromorphic and shallow soils, would explain the high productivity of oil palm groves installed on these soil types, which can reach or even exceed 25 tons of bunches per year and per hectare, compared to 18 tons, on the tertiary sands [28]. These situations would contribute to the stabilization and high production of bunches on plantations in hydromorphic areas with low water tables, which could constitute the future of oil palm cultivation in Côte d'Ivoire, as the only conversion of tropical forests to oil palm plantations results in loss of biodiversity and reduced productivity [29, 30, 31, 27].

V. Conclusion

It can be concluded that rainfall and water deficit in South-east and South-central of Côte d'Ivoire are discriminating factors in the long-term cultivation of oil palm. With an average of 1700 mm of water per year, the locality of La Mé appears to be more watered than that of Divo, whose average rainfall is 1600 mm of water. However, in both localities, rainfall and DH are favourable for the cultivation of oil palm.

The study also shows a significant difference between the productivity of oil palm groves set up on hydromorphic soils with low water table (CNRA of Divo and La Mé), and those installed on the tertiary sands (Palmci-Divo and La Mé). This difference is marked by the high productivity of palm groves in hydromorphic areas, which produce 23 tons/ha/year of bunches, compared to 17 tons/ha/year on the tertiary sands during the best years, a gain of more than 30%. Therefore, the choice of hydromorphic zones is currently an interesting solution for improving and increasing the productivity of oil palm in Côte d'Ivoire.

References

[1] 1. Wheeler T, von Braun J. Climate change impacts on global food security. Science, 2013; 341 (6145): 508 - 513.

[2] 2. Challinor AJ, Watson J, Lobell DB, Howden SM, Smith DR, Chhetri N.. A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change, 2014 ; 5(4) : 287 - 291.

[3] 3. Leroux L. Suivi et Caractérisation des Dynamiques de la Production Agricole en Afrique de l'Ouest par Télédétection à Moyenne Résolution Spatiale, 2005, 12p.

[4] 4. Anonyme. L'huile de palme, l'autre poumon économique de la Côte d'Ivoire - Afrik.com : l'actualité de l'Afrique noire et du Maghreb - Le quotidien panafricain, 2042 : 1 - 20.

[5] 5. Felton A, Gustafsson L, Roberge J-M, Ranius T, Hjältén J, Rudolphi J, Lindbladh M, Weslien J, Rist L, Brunet J, Felton AM. How climate change adaptation and mitigation strategies can threaten or enhance the biodiversity of production forests : Insights from Sweden. Biological Conservation, 2016 ; 194 : 11–20.

[6] 6. Drescher J, Rembold K, Allen K, Beckschäfer P, Buchori D, Clough Y, Faust H, Fauzi AM, Gunawan D, Hertel D, Irawan B, Jaya INS, Klamer B, Kleinn C, Knohl A, Kotowska MM, Krashevska V, Scheu S. Ecological and socio-economic functions across tropical land use systems after rainforest conversion. Phil. Trans. R. Soc. B. http://dx.doi.org/10.1098/rstb.2015.0275, visited 2016.

[7] 7. Brou Yao T, Oszwald J, Bigot S, Dervat E. Risques de Déforestation dans le Domaine Permanent de l'État de Côte d'Ivoire. Quel avenir pour ces derniers massifs Forestiers ? Télédétection, 2005 ; 5 : 121–205.

[8] 8. Kangah A, Koli-Bi Z. Dynamique et transformation spatiale du littoral ivoirien : cas du littoral Alladjan, à l'Ouest d'Abidjan. Revue de Géographie Tropicale et d'Environnement, 2015 ; 1 : 25–39.

[9] 9. FAO. Notions de nutrition des plantes et de fertilisation des sols, Manuel de formation, Projet Intrants, Niger, 2005, 25.

[10] 10. Sanchez PA, Gichuru MP, Katz LB. Organic matter in major soils of Tropical and Temperate regions. In: Non – Symbiotic Nitrogen Fixation and organic matter in the Tropics. Trans. 12 the Iinternat. Congres. Soil Science (New - Delhi 8 - 16 fev 1982) : 99 - 114.

[11] 11. Fondio L. Étude de l'impact des conditions pédoclimatiques et de l'âge sur la production en régimes du palmier à huile : cas du bas - cavally (EAI de Blidouba et de Néka) et du sud - est (EAI d'Ehania) de la Côte D'Ivoire. Mémoire de fin d'étude agronomique ENSA. Yamoussoukro, 1992, 84.

[12] 12. Quencez P, DE Berchoux C, Hamel P, N'geussan B, Dubos B. Valorisation des zones marécageuses par le palmier à huile. Oléagineux, 1957 ; 42 (2) : 43 - 52.

[13] 13. Yao NR. Les changements climatiques en Côte D'Ivoire : tentative d'explication et esquisse de solutions. Séminaire national sur l'agroclimatologie et la bioclimatologie. Abidjan, Côte D'Ivoire, 1989 : 4 - 6.

[14] 14. Ballo K, Koutou A. Valorisation des sols hydromorphes par des parcelles de palmier à huile. Colloque internationale sur l'avenir des cultures pérennes ; Yamoussoukro, Côte d'Ivoire, 2001 : 1 - 8.

[15] 15. Dufour O, Frère JL, Caliman JP, Hornus P. Présentation d'une méthode simplifiée de prévision de la production d'une plantation de palmiers à huile à partir de la climatologie. Oléagineux, 1988 ; 43(7) : 271 - 282.

[16] 16. Rushton KR, Eilers VHM, Carter RC. Improved soil moisture balance methodology for recharge estimation, Journal of hydrology (Amsterdam), 2006 ; 318 : 379 - 399.

[17] 17. Yao NR, Orsot-dessi DS, Ballo K, Fondio L. Déclin de la pluviosité en Côte d'Ivoire : impact éventuel sur la production du palmier à huile. Sécheresse, 1995, 6, 265 - 271.

[18] 18. Buisson A. Tendances climatiques pour l'évaluation de la pluviométrie durant la saison des pluies de l'Afrique sub-saharienne. Veille climatique satellitaire, 1989; 24: 43 - 51.

[19] 19. Tanina DS, Nagnin S, Yéi MSO, Théophile L, Gbombélé S, Kouassi EA, Biémi J. La variabilité climatique et son impact sur les ressources en eau dans le degré carré de Grand-Lahou (Sud-Ouest de la Côte d'Ivoire), Physio-Géo [En ligne], Volume 5, mis en ligne le 20 février 2011, Consulté le 19 avril 2013. URL: http://physio-geo.revues.org/1581; DOI: 10.4000/physio-geo, 2011, 1581.

[20] 20. Diahuissie A, Boaké K. Le régime climatique de la station de recherche de La Mé de 1990 à 1999. Rapport d'activité, Mars 2000 : 1 - 12.

[21] 21. Houssou M. Amélioration du palmier à huile en zone peu humide. Résultats récents obtenus au Bénin. Thèse Doct. Ing, Université PARIS-SUD ORSAY, 1985, 119.

[22] 22. Caliman JP. Dégradation des propriètés physiques conditionnant la fertilité des sols sous culture du palmier à huile en Côte d'Ivoire, essai de correction. Science Sol, 1992 : 44 - 63.

[23] 23. Cornaire B, Daniel C. Oil Palm performance under water stress. Background to the problem, first results and research approaches, PIPOC Kuala Lumpur, Malaysia, 1993: 1 – 32.

[24] 24. Djegui N, Daniel C. Le développement du palmier à huile au Bénin : une approche spécifique. Oléagineux Corps Gras Lipides, 1996; 3 (2): 125 - 129.

[25] 25. Olivin J, Ochs R. Propriétés hydriques des sols et alimentation en eau des oléagineux pérennes en Afrique de l'Ouest. Oléagineux, 1978 ; 33 : 1 - 13.

[26] 26. Conti FD. Conservation Agriculture and Soil Fauna : Only Benefits or also Potential Threats ? A review. E C Agriculture, 2015 ; 2 (5) : 473–482.

[27] 27. Tao H-H, Slade EM, Willis KJ, Caliman J-P, Snaddon JL Effects of soil management practices on soil fauna feeding activity in an Indonesian oil palm plantation. Agric. Ecosyst. Environ, 2016 ; 218 : 133–140.

[28] 28. Lubis H. Kela sawit di Thailand. Bulletin Pusat Penelitian Perkebunan Marihat, 1991 ; 11(01) : 23 - 24.

[29] 29. Koh LP, Wilcove DS. Is oil palm agriculture really destroying tropical biodiversity ? Conservation Letters, 2008 ; 1 : 60–64.

[30] 30. Gérard A. Experimental biodiversity enrichment in an oil-palm plantation. Frontiers in Plant Science, 2016 ; 7 : 15–38

[31] 31. Ghazali A, Asmaha S, Syafiq M, Yahya MS, Aziz N, Peng T, Norhisham AR, Puan C, Turner EC, Azhar B. Effects of monoculture and polyculture farming in oil palm smallholdings on terrestrial arthropod diversity. Journal of Asia- Pacific Entomology, 2016 ; 19 : 415–421.

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