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Cocoa Swollen Shoot Disease in Côte D'ivoire: History of Expansion from 2008 to 2016

Romain Aka Aka[1], Klotioloma Coulibaly[1], Walet Pierre N'guessan[1], Koffié Kouakou[2], Gnion Mathias Tahi[1], Kouamé François N'guessan[1], Boubacar Ismaël Kebe[1], Evelyne Assi[1], Brigitte Guiraud[1], Boaké Koné[1], Nazaire Kouassi[3], Daouda Koné[4], Kouassi René Allou[1], Emmanuelle Muller[5], Nicodème Zakra[1]

[1]Cocoa program, National Centre for Agronomic Research (CNRA), BP 808 Divo, Côte d'Ivoire
[2]ICRAF, World Agroforestry Centre
[3]Université Félix Houphouët-Boigny, WAVE-CI, Pôle Scientifique et d'Innovation Bingerville, BP V 34 Abidjan, Côte d'Ivoire
[4]Université Félix Houphouët-Boigny, WASCAL / CEA-CCBAD, Pôle Scientifique et d'Innovation Bingerville
[5]CIRAD, UMR BGPI, 34398 Montpellier, France

Abstract: Cocoa is one of the major cash crop of Cote d'Ivoire. With 1 964 000 tons in 2018, Côte d'Ivoire is leading the world cocoa beans supply. Unfortunately, this important source of income for the country is under a severe pressure of the Cocoa Swollen Shoot Disease. This disease had been reported for the first time in 1943 in the eastern part of the country. In 2003, important infection areas were reported in the departments of Sinfra and Bouaflé in the Central-West with more than 77.000 ha destroyed. Since that period the disease is reported in several places. But we didn't have a clear idea of all the infected areas. This study aims to study somehow the spread of the disease. The main parameters studied are the incidence and prevalence. The methodological approach consisted in surveys implemented in two steps: 2008-2012 and 2013-2016 on farmer's farms. The study carried out between 2008 and 2012, shows that the CSSD prevalence was 16.37% with 19 regions infected out of 24. The disease reaches 83 departments and 40.680 farms. The second phase of the survey held from 2013 to 2016 shows that the prevalence was 19.51%. It help to highlight a strong progression of the disease in the orchard with 7.734 new farms infected in 111 localities divided into 24 regions. Globally the study shows that the incidence of the CSSD in the orchard ranked from 0% to 76.67 % and the national average is 4.06 %. The areas with low incidence cover 85 localities. The areas with moderate incidence are 25. Doba in San Pedro were the area of highest incidence (76.67%).

1. Introduction

Côte d'Ivoire is leading world cocoa beans supply with about 1 964 000 tons tons in 2018 (ICCO, 2018). According to the BCEAO, cocoa represent 15% to 20% of GDP (Gross Domestic Product) in Côte d'Ivoire and more than 45% of the country's export earnings. It employs nearly 600,000 farmers and supports about 6 million people (BCEAO, 2014). Beside this great performance cocoa farming face many constraints. Among these constraints is the Cocoa swollen shoot Disease (CSSD). This disease is nowadays the most devastating disease of cocoa in Côte d'Ivoire. It is a viral disease discovered for the first time in Ghana in 1936 (Steven, 1936, Posnette, 1945). The CSSD causes a severe damage on cocoa trees, leading to a drastic drop in production (Kouakou, 2011). It is characterized by a red vein banding on young leaves, chlorosis on adult leaves, swelling of shoots and roots (Posnette, 1944, Anon, 1949, Dzahini-Obiatey et al. 2010). The main control measure against this disease consist in cutting of the infected trees, replanting with resistant material, the use of protective barriers involving perennial plants non-host of the virus to surround the replanted area and observation of good agricultural practices (Ollennu, et al. 2005, Dzahini-Obiatey et al., 2005). In Côte d'Ivoire, the CSSD has been reported for the first time in 1943 in Sankadikro and Kongodia in the eastern of the country (Alibert, 1946; Mangenot et al., 1946). Later, infected areas were identified in Daloa, Issia, Soubré and Duékoué in western, Guitry in the south and Adzopé, Aboisso and Grand Bassam

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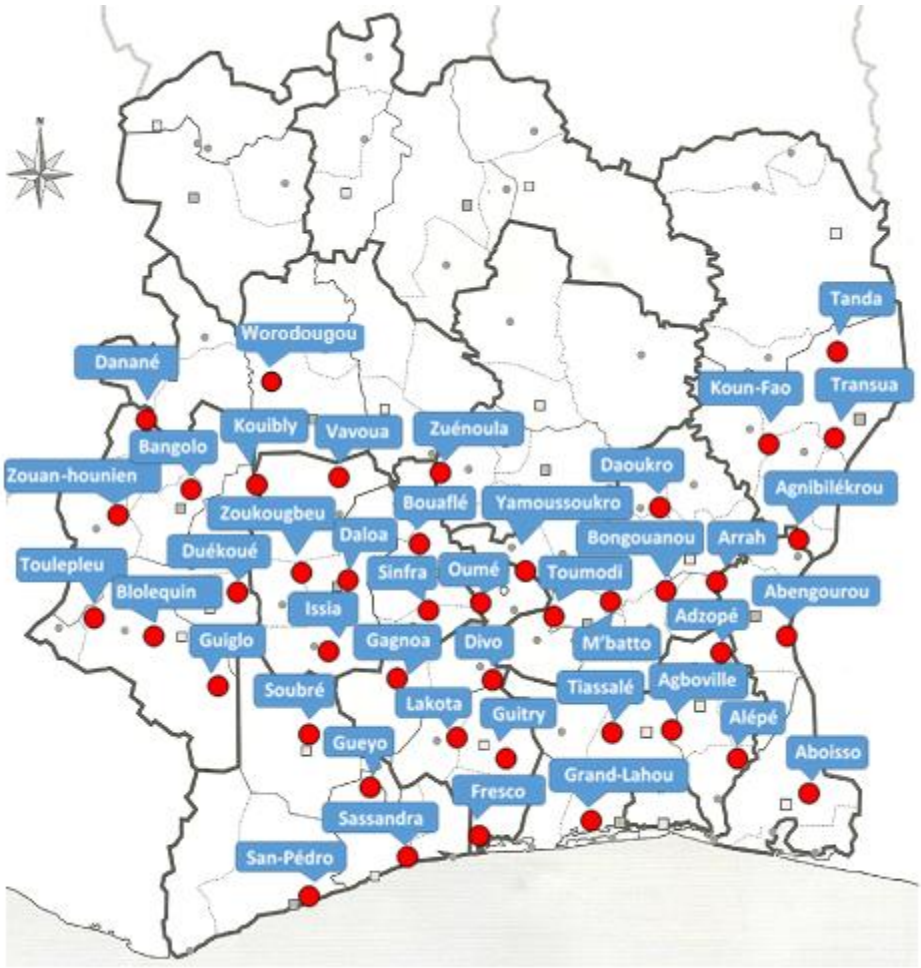
Romain Aka Aka (Correspondence)

in the south-east (Zelensky, 1947; Meiffrein, 1948; Renaud, 1957). In 2003, massive infection were reported in the departments of Sinfra and Bouaflé in the Marahoué region (Central-West) with more than 77 000 ha destroyed (Kébé and N'Guessan, 2003, Kébé et al., 2006, Kouakou, 2011). Today, more than 300,000 ha of the total national area is affected by the disease (Mieu, 2018a). Faced to this alarming situation, the government has launched in 2018 two programs to intensify the uprooting and replanting of orchards infected by the disease. This program of 40 billion FCFA aims to rehabilitate by 2022, 100.000 ha of farm infected. This control plan includes the compensation of producers for 50.000 FCFA per ha destroyed, as well as the distribution of seeds for the replanting of the orchards. The financing of this operation is provided jointly by the CCC and the public-private partnership platform (Mieu, 2018b). But the lack of information on the spread of the virus in the cocoa orchards may jeopardize all the efforts of the government. This study aims to evaluate the incidence and prevalence of swollen shoot in orchard. The methodological approach consisted in surveys implemented on farmer's farms.

2. Materials and Methods

2.1. CSSD survey on farmers farms

The inventory of the CSSD infected farms was carried out in two phases from 2008 to 2012 and from 2013 to 2016 by extension agents of the ANADER (Agence Nationale d'Appui au Développement Rural) trained in the recognition of the disease by CNRA scientists. The prospected sites were selected on the presumptions of disease in the producing regions. Total of 23 regions representing more than 80% of the orchard (Assiri, 2010) and 111 sub-prefectures were surveyed (Figure 1). The process of the survey was based on interviews with farmers in cocoa producing areas. A questionnaire with three sections was designed for this purpose: Section A: Information on the cocoa farmers, Section B: Description of the cocoa plantation and Section C: Swollen shoot diagnosis



Caption

Sites of CSSD surveys

Figure 1: coverage area by surveys between 2008 and 2016

2.2. Assessment of prevalence and incidence of CSSD in the orchards

The prevalence of the disease is the percentage of infected farms in the surveyed areas at the time of the study i.e. in 2008 and 2016 (Savary et al., 2006, Fargette, 1987; Thresh and Fargette, 2001):

fi = number of infected farms
F = Total of farms
P = Prevalence

$P = (fi/F) \times 100$

Incidence is the percentage of new cases of the disease in the area during a given period of time. In the context of our study this period run from 2008 to 2016 (Thresh and Fargette, 2001):

$I = [(fi1-fi0) / F] \times 100$

fit = number of infected farms at t time ;
t= Date of inspection;
F = Total of farms
I = incidence.

The analysis was essentially descriptive. It aims to present the simple and global results helping to generate a set of questions. This analysis helped to understand the spread of the disease in cocoa farms. The data generated from the surveys was analysed using Microsoft Excel. For the visualization, data was blast using Microsoft Power Map for Excel and PowerBI software (Dunlop, 2015).

3. Results

3.1. Prevalence of the disease

The study carried out between 2008 and 2012, covered 24 regions divided into 111 localities, 3.779 villages, 339.633 farmers and 440.180 cocoa farms. It shows that the CSSD was present in 19 regions out of the 23 and 83 departments with 40.680 farms infected. The CSSD prevalence was 16.37%. It show that 16 regions was under 10 % of infections and 3 regions: Haut-Sassandra, Gbôklé and Marahoué was up to 30% of infection. The second phase of the survey held from 2013 to 2016 shows that the CSSD prevalence was 19.51%. This survey highlights a strong progression of the disease in the orchard with 7.734 new farms infected in 111 localities divided into 23 regions. It shows that 18 regions was under 10 % of infections, three region: Lac, N'zi and Bélier had a rate of infection between 10 and 25, and three: Gbôklé, Haut-Sassandra and Marahoué was up to 30% of infection (Figure 2).

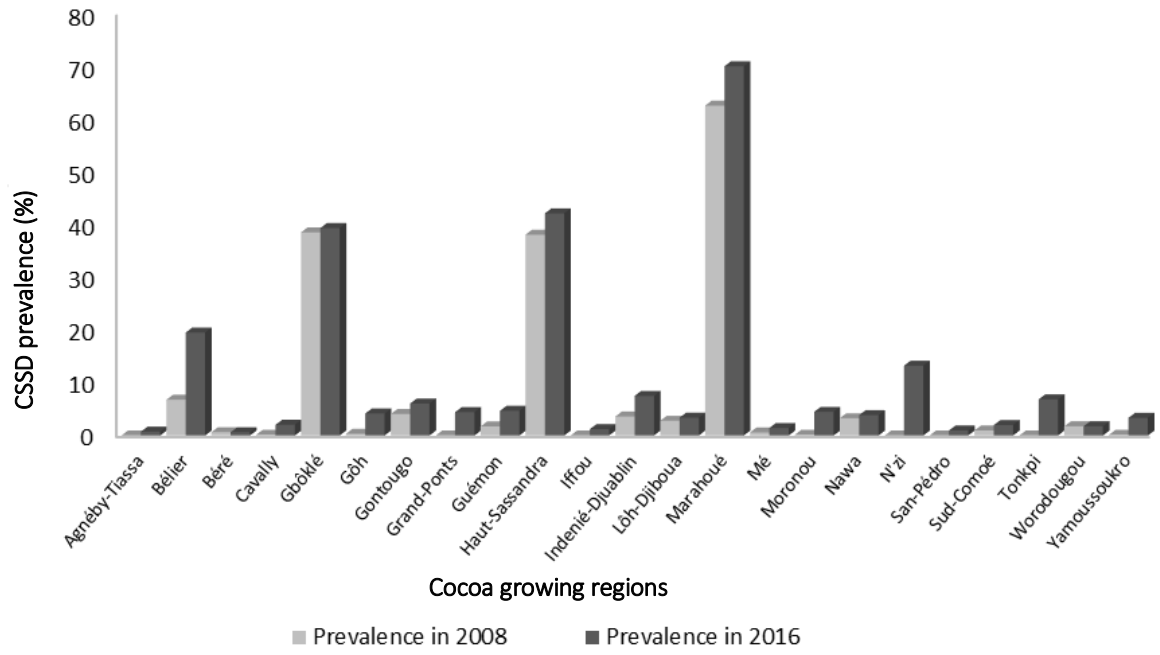


Figure 2: Diagram of the prevalence of the CSSD in the cocoa growing regions of Cote d'Ivoire

Globally based on the data, three infection profiles can considered:

- ***Low infection regions under 10%:*** Agnéby-Tiassa, Béré, Iffou, Tonkpi, Grand-Pont, San-Pédro, Cavally, Moronou, Nawa, Yamoussoukro, Gôh, Mé, , Sud-Comoé, Guémon, Worodougou, Lôh-Djiboua, Indénié-Djuablin and Gontougo
- ***Moderate infection regions between 10 and 25%:*** N'zi and Bélier
- ***Massive infection regions more 25%:*** Gboklé, Haut-Sassandra and Marahoué

The analysis at sub-prefecture level shows that the prevalence of the disease ranged from 0.03 to 98.03 %, which allow to define four classes of CSSD prevalence, represented by a thermal amplitude on a map (Figures 3 A et B):

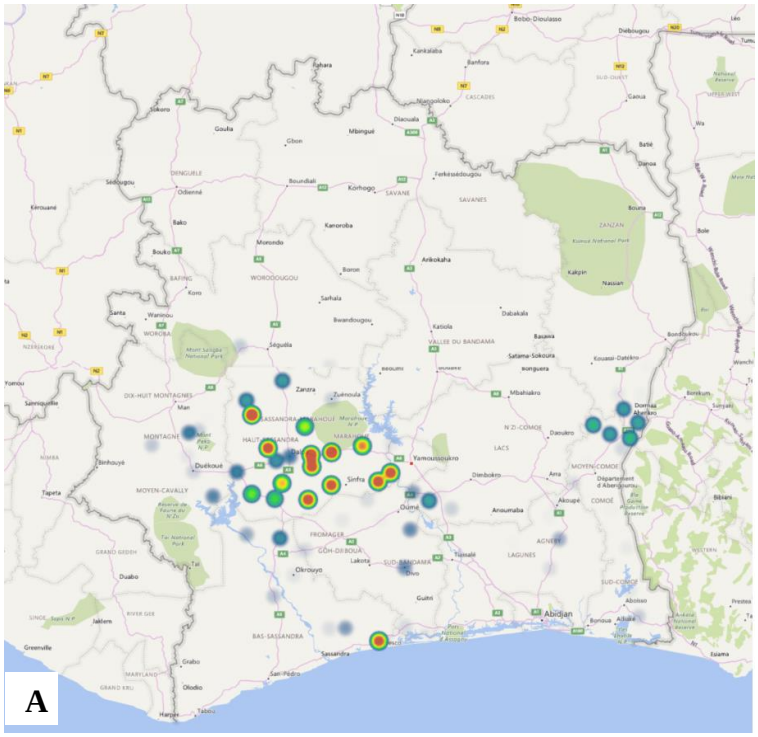
- -areas of low attack with a prevalence of less than 10 % are reflected in colour from pale blue to strong blue
- -Medium attack areas with a prevalence of between 10 and 25 % green result in colour from pal to strong green
- -Strong attack areas with a prevalence of between 25 and 50 % are reflected in colour from pale yellow to strong yellow
- -areas of very strong attack with a prevalence higher than 50 % are reflected in colour from orange to red.

In 2012, the areas of low attack covered 58 sub-prefectures distributed globally in the regions of Bas-Sassandra, Gboklé, Guemon, San Pedro, Cavally, Agneby-Tiassa, Loh-Djiboua, Gontougo, and Indénié-Djuablin with 2.666 farms attacked (Figure 3A). The areas of medium attack concern 9 sub-prefectures distributed in the regions of Haut-Sassandra, Marahoué, and Gontougo with the localities Tankéssé and Transua. These areas represent 2.801 plots attacked. The areas of strong attacks and very strong attacks concern the regions of the haut-Sassandra, Marahoué and Gboklé. They are grouped in 16 sub-prefectures and represent respectively 35.213 farms infected.

In 2016, new infected areas were discovered (Figure 3B). These areas are:

- -Bongo, Noe, Aboisso-comoe, Assikoi, Alepe, Grand morie, Yakasse-mé, Yakasse-attobrou in the south-east
- -Tabagne, Ettrokro, Ebounou, Kouadioblekro, Daoukro, Abengourou, Niable in the east
- -Taabo and Yamoussoukro in the central,
- -Dairodidizo, Lakota, Serihio and Tonla in the central west,
- -Zagne, Blolequin, Binhouye, Zeaglo in the Cavally region in the west
- -Gabiadji and Doba in the south west. The prevalence of the CSSD in Doba locality were 76.67 %.

Areas of weak attack increased from 58 in 2008 to 76 in 2016 with 4.139 plots attacked. They are distributed in 22 regions. The areas of medium prevalence are 15 and represent 3.932 attacked farms. The number of areas with strong prevalence are 7 and represent 8.096 attacked farms. While the number of areas with very strong attacks count 13 localities distributed and grouped 32.296 farms.



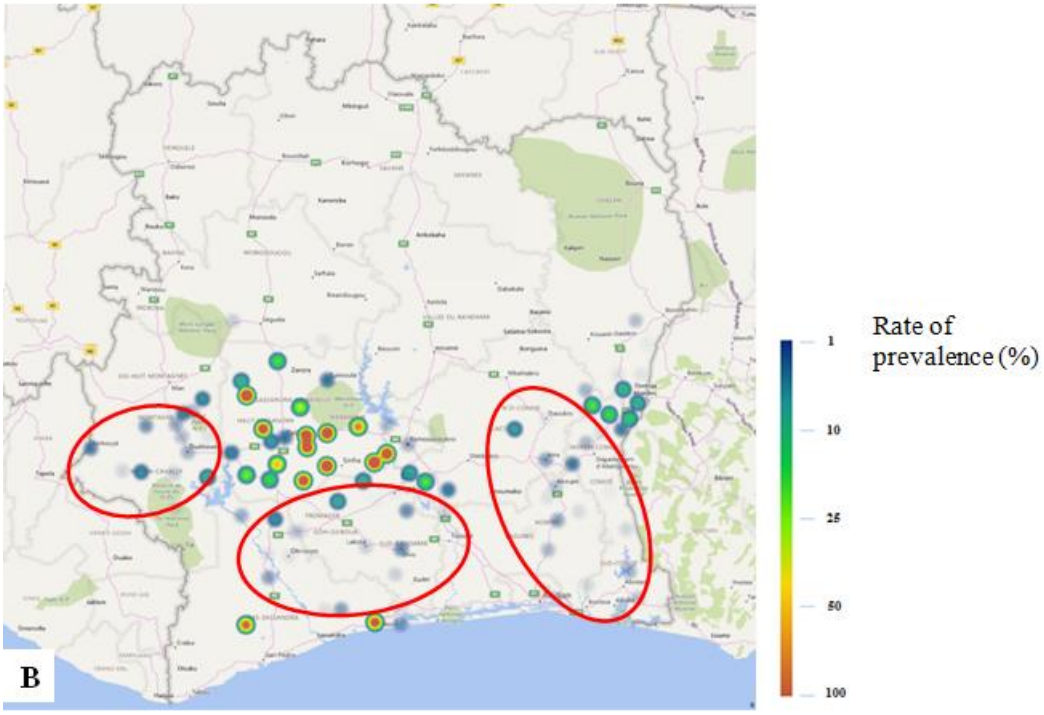


Figure 3: Prevalence of swollen shoot in 2008 (A) and 2016 (B)

The red circles on the map indicate areas where the disease progress

- -areas of low attack with a prevalence of less than 10 % are reflected in colour from pale blue to strong blue
- -Medium attack areas with a prevalence of between 10 and 25 % green result in colour from pal to strong green
- -Strong attack areas with a prevalence of between 25 and 50 % are reflected in colour from pale yellow to strong yellow
- -areas of very high attack with a prevalence higher than 50 % are reflected in colour from orange to red.

3.2. Incidence of the CSSD between 2008 and 2016

The study shows that the incidence of CSSD in the orchard ranked from 0% to 76.67 % and the national average is 4.06 %. Three levels of speed of the disease are pointed out:

- -Areas with low incidence under 5%.
- -Areas with moderate incidence from 5 to 25 %
- -Areas of high incidence from 25 to 100 %.

The number of areas with low incidence are 85 sub prefectures including 16 new: Grand Bereby, Lauzoua, Yocoboue, Grabo, Sago, Rubino, Toumodi, Kongasso, Okrouyo, Dakpadou, Guiberoua, Guitry, Sify, Buyo, Hiré and Zaïbo. The areas with moderate incidence are 25 and areas of high incidence is Doba in San Pedro were more than 161 infected farms (76.67%) was reported in between 2013 and 2016 (Figure 4).

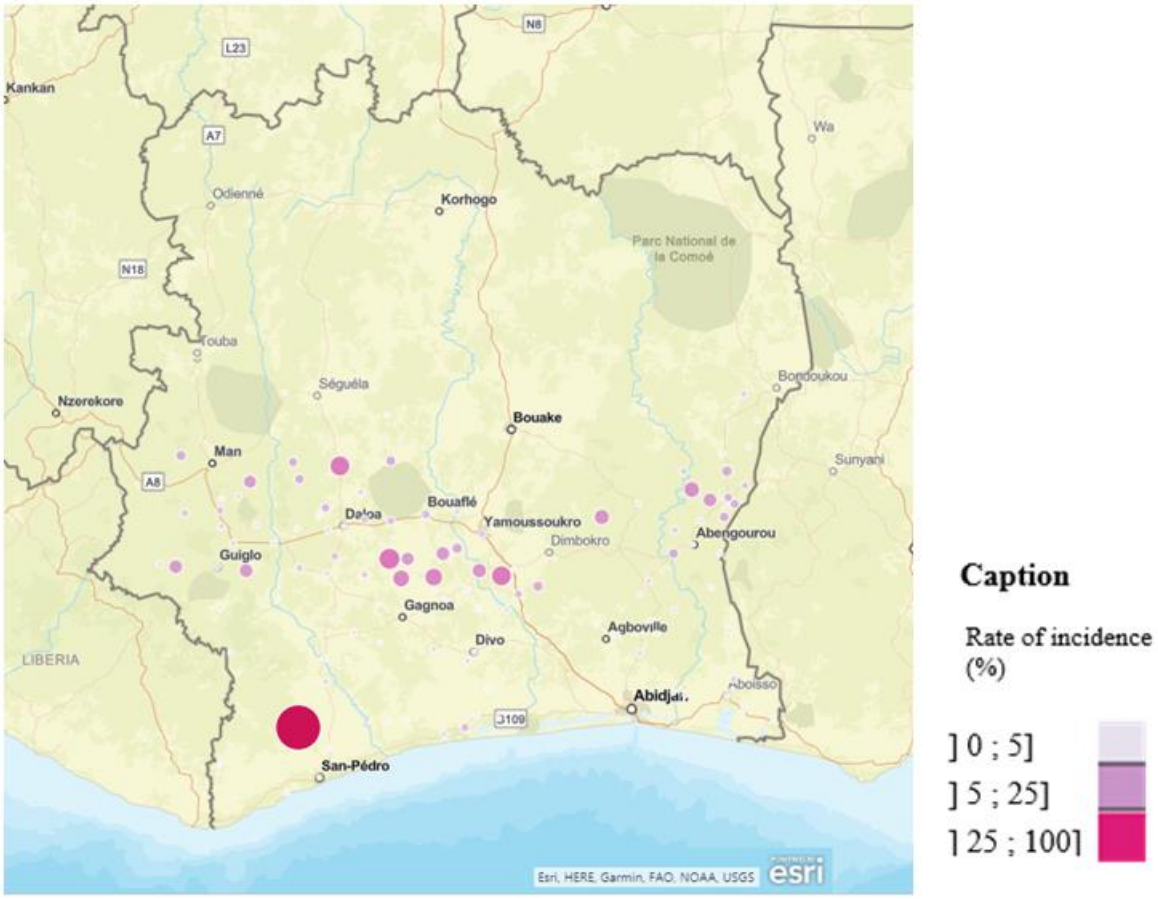


Figure 4: Rate of incidence of the CSSD from 2008 to 2016

4. Discussion

The epidemiological analysis of the CSSD in Côte d'Ivoire cocoa farms from 2008 to 2016 give a view of the distribution of the disease in the orchard. It shows that from 1946 to nowadays the disease has made a clear progress. In fact, between 1946 and 1960, the disease was known to be in the regions of Abengourou, Agnibilékrou, Aboisso, Daloa, Duékoué and Guitry (Basset, 1945, Alibert 1946, Zelensky, 1947 and Meifrein, 1948). To date the disease is almost everywhere in the cocoa producing regions. Massive infection areas are found in the central west and the western part of the country. This large spread of CSSD in these cocoa growing zones could have several explanations. The first may be related to the ignorance of the disease, its symptoms, and control measures (Adegbola, 1971). In fact, at the beginning, in Cote d'Ivoire as well as in the other countries, the disease was assimilated to fungal disease (Ampofo, 1989), insects attacks or lack of nutrient (Adegbola, 1975, Cadbury, 1949) by farmers. So since the year 50s nothing was done like sensitization to enhance farmers' awareness on the swollen shoot disease until 2003 were some cases were reported to research (Kébé and N'guessan, 2003). The second reason is that the first campaigns of combatting the swollen shoot in Cote d'Ivoire were only located in the eastern part of the country (Mangenot, 1946). The western and the central west part were not included. The disease may has started from the untreated foci in these areas. The third is linked to the increasing of crop cultivation in Côte d'Ivoire. In fact, in the 1950s and 1960s, cocoa was mainly grown in the eastern and eastern regions, with production around 100.000 tons. After 1960, the cocoa boom leads to massive migrations to the western, south-west, and west-west looking for land for cacao (Tano, 2012, Freud et al., 2000).

The studies of the disease incidence show areas with low, moderate, and high rate of incidence. In fact some areas has a low incidence because the disease is at the beginning of infection. There are 16 localities in four cocoa growing regions (Moronou, Iffou, Agneby-Tiassa, Gontougo). These areas have been declared infected with the CSSD in 2015 and are in danger because of the presence of the viral species, CSSTBV which is known to be very aggressive. This species is identified in almost all the cacao growing regions (Muller et al. 2018, Muller and Sackey, 2015, Kouakou et al, 2014,). The areas of low infection include the regions of Mé, Sud-Comoé and Indénie-Djuablin where the disease is reported since the year 50s. These areas show a slow incidence maybe

because of the virus species and the control measures implemented at that time. In fact, the regions of Mé and Sud-Comoé are known to be infected with both species the CSSCEV and the CSSTBV (Kouakou et al. 2014). Maybe the CSSCEV is a mild specie by the date we don't know yet. Also the eradication measures initiated in 1946 in the region of Indénié-Djuablin maybe contributed to reduce the pressure of the disease and slows down its progression (Balleyguier, 1949). Some regions like Marahoué, Haut-Sassandra, and Gboklè where the prevalence of CSSD is highest also show low incidence because almost all the cocoa farms are infected. The regions of Guemon, Tonkpi Cavally, Montagnes and Bas-Sassandra in the west and Southeast considered as the new cocoa growing region (Tano, 2012) are exposed to a fast-growing of infection. In fact the disease may has progress from the Area of Massive Infection like Marahoué, Haut-Sassandra and Gboklè where the prevalence of CSSD is higher than 80% following a radial spread (Van Der Plank, 1948, 1949; Thresh et al 1988).

Among the factors, the host need to be taken into account as suggested (Shtienberg, 2000). In fact, the disease progress depend on whether the variety is susceptible or resistant (Walters and Hardwick, 2000). In Cote d'Ivoire, the cacao farms are mostly made with all-around, non-improved planting materials and Amelonado while Amelonado is known to be the more susceptible variety to the virus (Adu Ampomah, 1993, Adu-Ampomah et al, 1996, Adu-Ampomah et al, 2002). The farm practices also may have a part in the disease spread. In fact, Assiri et al. (2009) shows that mostly the cocoa farming profile is monoculture. This farming system enable a continue canopy of inter-locking branches. And as the disease is considered as "crowd" disease (Van Der Plank, 1948, 1949; Thresh et al., 1988) the movement of the mealybug vectors will be easier.

The virus may have emerged and spread to cacao from a few widespread forest tree species known like including *Adansonia digitata*, *Ceiba pentandra*, *Cola chlamydantha*, *Cola gigantea var. glabrescens*, and *Sterculia tragacantha* (Posnette, 1950; 1981; Attafuah, 1965).

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