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Anthropo-Climatic Factors Causing Ahua's Listed Forest Deterioration A Site Located In The Department Of Dimbokro, In The Centre-East Of Côte d'Ivoire.

Facteurs Anthropo-Climatiques De La Dégradation De La Forêt Classée d'Ahua Dans Le Département De Dimbokro Au Centre-Est De La Côte d'Ivoire

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Abstract – In Côte d'Ivoire, forest deterioration has reached a worrying level insofar as protected spaces are threatened. In the context of this situation, the current research study carried out on Ahua's listed Forest aims at showing the anthropo-climatic factors leading to this forest deterioration. So, how do anthropo-climatic factors contribute to the deterioration of Ahua's listed Forest? The different methods used such as Pettit's test, the diachronic method of satellite image analysis, the analysis of main component and field surveys, yielded several results. These results show that the climate has a variability from the date of the break on. The deterioration of this forest is also due to resident people's acts through farming, logging and hunting. Human beings and climate are the real factors responsible for this forest's deterioration. This deterioration impacts on the ecological balance by the extinction of plant species. For so doing, formal structures of management and resident communities used reforestation and sensitization to fight against this phenomenon of deterioration.

Keywords – Ahua, anthropo-climatic factors, deterioration, listed forest

Résumé – La dégradation des forêts en Côte d'Ivoire a atteint un niveau inquiétant dans la mesure où les espaces protégés sont sujets d'agression. Dans ce contexte, la présente étude menée sur la forêt classée d'Ahua vise à montrer les facteurs anthropo-climatiques de la dégradation de cette forêt. Alors, comment les facteurs anthropo-climatiques participent-ils à la dégradation de la forêt classée d'Ahua ? L'utilisation du test de Pettitt, de la méthode diachronique d'analyse d'images satellitaires, de l'analyse en composante principale et des enquêtes de terrain ont permis d'avoir plusieurs résultats. Ces résultats montrent que le climat connait une variabilité à partir de la date de rupture. La population riveraine participe à la dégradation de cet espace par la pratique agricole, l'exploitation forestière et la chasse. Le climat et l'homme sont des facteurs de dégradation de cette forêt. Cette dégradation impacte l'équilibre écologique par la disparition d'espèces floristiques. A cet effet, les structures formelles de gestion et les communautés riveraines ont utilisé le reboisement et la sensibilisation pour lutter contre ce phénomène de dégradation.

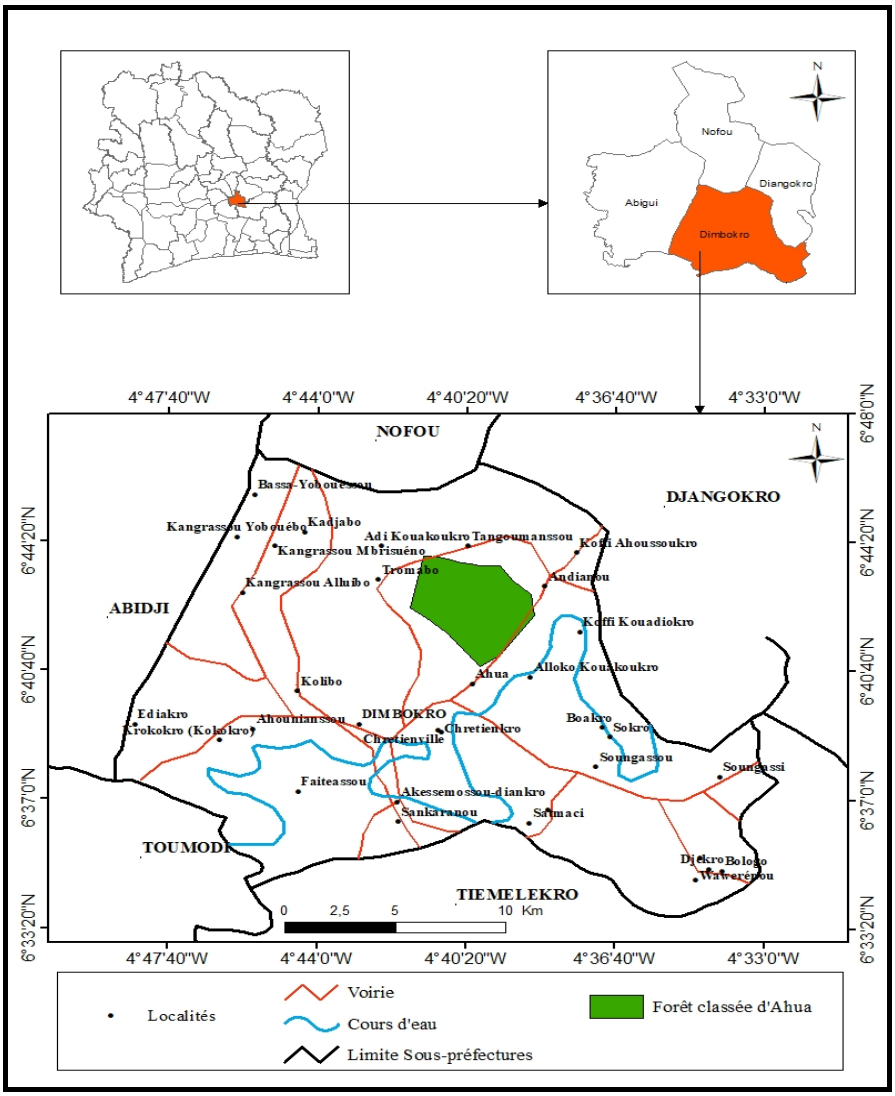
Mots clés – Ahua, Facteur anthropo-climatique, dégradation, forêt classée.

INTRODUCTION

For having undergone fundamental changes in their composition and their quality, most of the forests no longer are in their original state (Larsen, 2003, p2). From 1980 to 1995, the surface area of the world's forests decreased by 180 million hectares (FAO, 1997, p13). At the national level, the primary forest of Côte d'Ivoire has largely been transformed into a mosaic of secondary forests, plantations of cash crops and timber, food crops and wastelands (Brou et al., 2005, p105). The Ivorian Forest cover which was estimated at 16 million hectares in the 1960s currently has reduced to around 2.5 million hectares (Traoré, 2018, p439). The act No.96-766 of October 3, 1996 on the Environmental Code adopted by the government of Côte d'Ivoire; defines the general principles applicable to the preservation and reconstitution of the environment (World Bank, 2016, p38).

Despite the law act on the preservation of the environment, these forests are s coveted for economic ends such as agriculture, logging and even mining. So, the climate is undergoing worse changes on a global scale. This forest is therefore in the vice of climate and anthropisation. Observing these facts leading to the topic "Anthropo-climatic dynamics of the listed forest of Ahua, situated in the sub-prefecture of Dimbokro" appears with a capital interest for it tackles the deterioration issues of forest under state protection. Thereby, how do climatic dynamics and anthropization threaten Ahua's listed forest? This current research study aims at showing the anthropo-climatic dynamics as a factor of the deterioration of Ahua's listed forest in the sub-prefecture of Dimbokro. It specifically aims at characterising the climatic and anthropogenic dynamics in Ahua's listed forest from 1965 to 2020; analysing the climatic and anthropogenic factors that hinder the reconstitution of this forest and identifying strategies for the reconstitution of Ahua's listed forest for a sustainable forest resource.

Ahua's listed forest is located in the department of Dimbokro in the center-east of Côte d'Ivoire, in the transition zone between the forest in the south and the savannah in the north. Precisely, it is located between longitudes 4°66' and 4°40' west and latitudes 6°7' and 6°42' north (see map 1).



Source: CNTIG, 2021 **Production:** Koffi, 2021

Map 1: Location of Ahua's Listed Forest

I. ESEARCH DATA AND METHODS

1-1- The research data

In this research study, the data used can be classified in climatological, satellite and socio-economic types. The climatological data are composed of rainfall and temperature over the period from 1965 to 2020. These data had been provided by Dimbokro station and by the airport, aeronautical and meteorological operating and development company (SODEXAM).

Regarding satellite data, they are Landsat 4 (8bands) and Landsat 8 OLI (12 bands) type images. These images date from the month of January, respectively from 1990 and 2020. The choice of this month is justified by the fact that in January, the cloud cover is less and generates less interference in spectral signatures. These images had been downloaded from the website http://earthexplorer.usgs.gov on March 13, 2021.

Socio-economic data are spatial and population samples geo-located by a GPS on the sites visited. For this research work, out of all the villages of this sub-prefecture we selected six (06) villages located on the edge of this listed forest. They are: Ahua, Tangoumassou, Troumabo, Andianou, Allokokouakoukro, Koffikouadiokro. Totally, 90 people, or 15 people per village, had

been interviewed using a semi-closed questionnaire using the reasoned choice method. Alongside this, an observation survey was carried out to understand the forest deterioration's level.

1-2-Methods of the study

Several methods were used within the framework of this research study. Regarding the climatological data, the Pettitt test was used to analyze the stationarity of the chronological series. It identifies the time at which a change occurs in a series. This method is based on two hypotheses: the null hypothesis (H0) which constitutes the absence of a break in the series and the alternative hypothesis (H1) which includes a break. The possibilities of hypotheses in our case are checked at a confidence rate of 95%. For this purpose, if the null hypothesis is rejected, this would mean that there is a break in the series. If the null hypothesis is not granted, the presence of rupture is disputed in the chronicle. Pettit's test is expressed by the following formula:

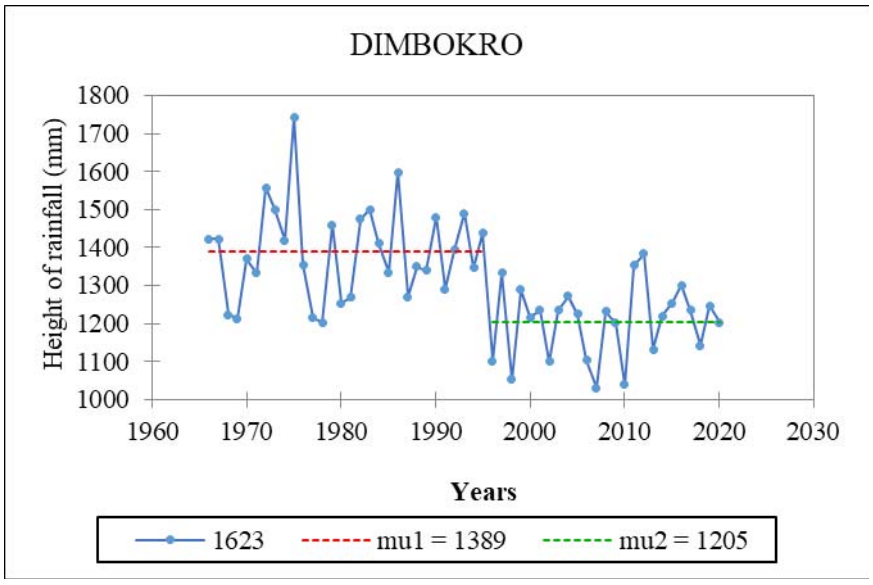
The climatic parameters likely to influence the plant species were the subject of a Principal Component Analysis (PCA) using the XLSTAT 2014 software. The results of this analysis permits to identify the degree of dependence between the climatic parameters and plant species. The various parameters concerned for this analysis are: rainfall, temperature and plant species (tree, shrub, herbaceous and liana).

At the level of satellite images, the diachronic analysis method had been used. For this purpose, these images had been preprocessed and processed. This data preprocessing was carried through the use of ENVI 5.3 software. It consisted of the radiometric and atmospheric correction of the satellite images, respectively by the radiometric calibration and Atmospheric correction modules. In the processing phase, the classification of the images into different large sets of space occupation was carried out by a supervised classification. This step was followed by a recognition of the different occupations already made on the ground using waypoints from the GPS. Then, a true color composition was made to display the image before digitizing the land cover classes, then start the classification. At the end of these different processes, the different classes, namely forest, wooded savannah, crops or fallow land, bare soil and finally watercourses were highlighted.

II. RESULTS

2-1- Lowering rainfall in the listed forest zone

The rainfall in the area of our research study quantitatively decreased. This decrease indicates a two-level evolution of the series (Figure 1).



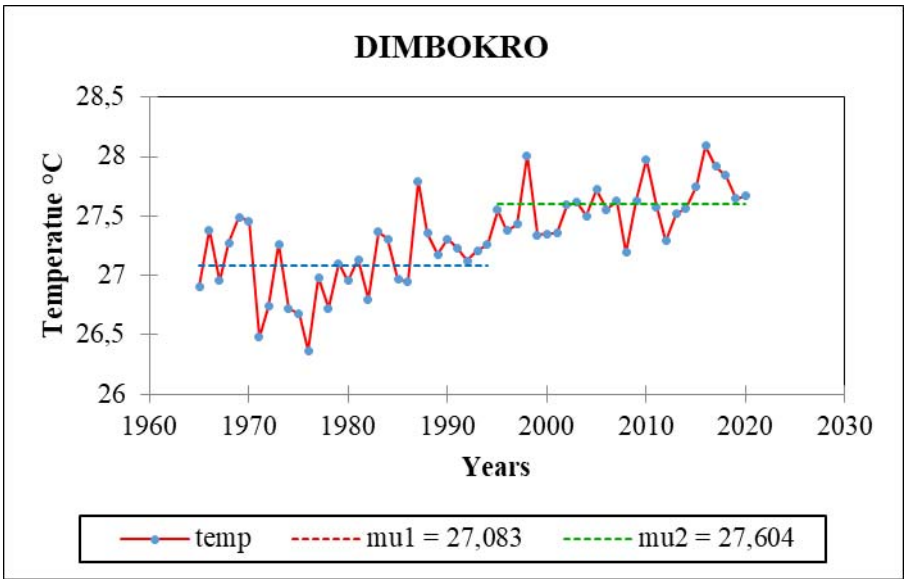
Source: SODEXAM, 2021

Figure 1: Variability of the rainfall series over the period 1965-2020

Figure 1 shows a sudden change of the rainfall in 1995. This break reveals two periods in the evolution of the study series. This is the first phase starting from 1965 to 1994. This phase was the rainiest with a rainfall average of 1389 mm. The second phase begins in 1995 and ends in 2020 with a rainfall average of 1205 mm. This last phase indicates the rainfall average. This heterogeneity of the evolution of annual totals reflects the rainfall variability.

2-2 A rising temperature in the listed forest zone

The evolution of the temperature is highlighted through Figure 2.



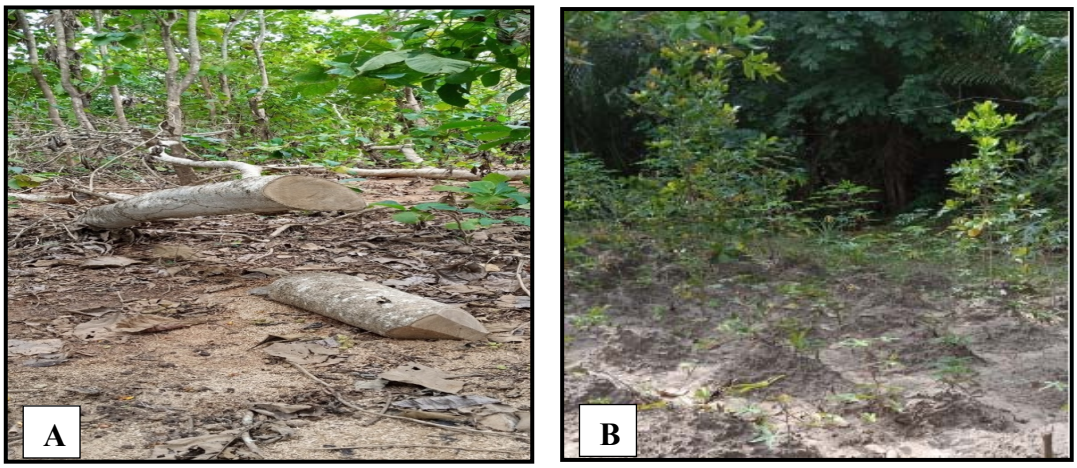
Source: SODEXAM, 2021

Figure 2: Variability of the thermal series

Figure 2 shows the increase of the temperature over the studied period. However, this thermal evolution indicates a break that occurred in 1994 in this chronological series. This temporal break splits this chronological series into two phases; namely a phase before the break and a phase after the break. Concerning the pre-rupture phase, it represents the least hot with an average temperature of 27.08°C. This period starts from 1965 to 1993, i.e. 29 years. Whereas, the post-rupture phase is the hottest with 27.60°C. It goes from 1994 to 2020, i.e. 27 years. The change occurring within the period of this study (1965-2020) shows that there is a thermal variability. In short, the variability of climatic parameters shows the existence of a climatic fluctuation at the scale of the forest area which is also attacked by local residents.

2-3-A listed forest increasingly attacked by man

From time to time, the local populations clandestinely attack this listed forest to meet their food and/or domestic needs, according to the people interviewed (Plate 1).

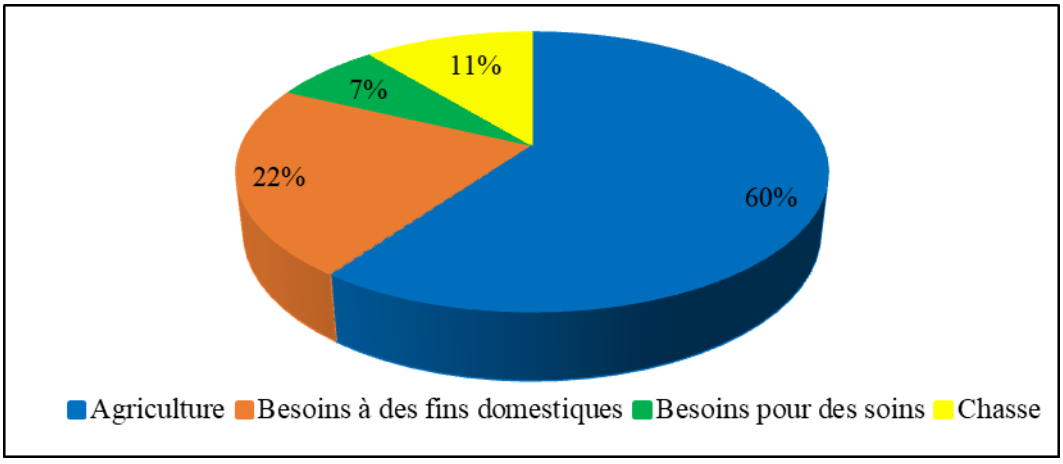


A: Trees' cutting-down by sawyers; **B:** cassava field by local residents

Shooting: Koffi, July 2021

Plate 1: Anthropic origin of the deterioration of Ahua's listed Forest

The main activity of the local population is agriculture. Yam farming undoubtedly takes an important place in this agricultural activity. For the practice of this activity, arable lands are increasingly becoming rare because of the exponential increase of farmers. The living conditions of the local communities are worsening following the increasing difficulties which hinder them to satisfy their primary needs for the population needs space and forest to grow crops. That is the reason why the local community is illegally going to farm the lands of this forest despite they know that this space is an exclusive property of the Government. The practice of agricultural activity represents 60% of the deterioration's factors of anthropogenic origin (figure 3).



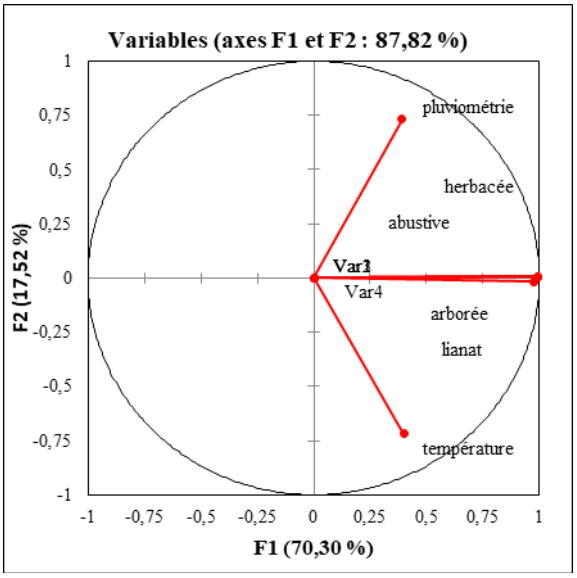
Source: our surveys, July 2021

Figure 3: Deterioration's factors of anthropogenic origin of Ahua classified forest

In addition to agricultural activity, the observation in figure 3 shows that there are other anthropogenic factors. This is the deterioration of the forest for domestic purpose (22%), in particular for the construction of habitats, for firewood and for the manufacture of household utensils (pestles, mortars, etc.). The population also uses the flora for therapeutic care (7%) and the fauna for its hunting needs (11%). These different practices are cultural and traditional habits of the local population. That is why it resorts to the listed forest when their original landscape can no longer meet their basic needs. However, these practices contribute to the deterioration of this protected area.

2-4-Climate as a factor of deterioration of Ahua's listed forest

The inertia of the F1-F2 factorial plan has been made, on one hand based on the variables and on other hand based on the statistical units. The inertia of the factorial plan made, based on the variables to verify the importance of climate and man in the deterioration of this listed forest is illustrated by Figure 4.

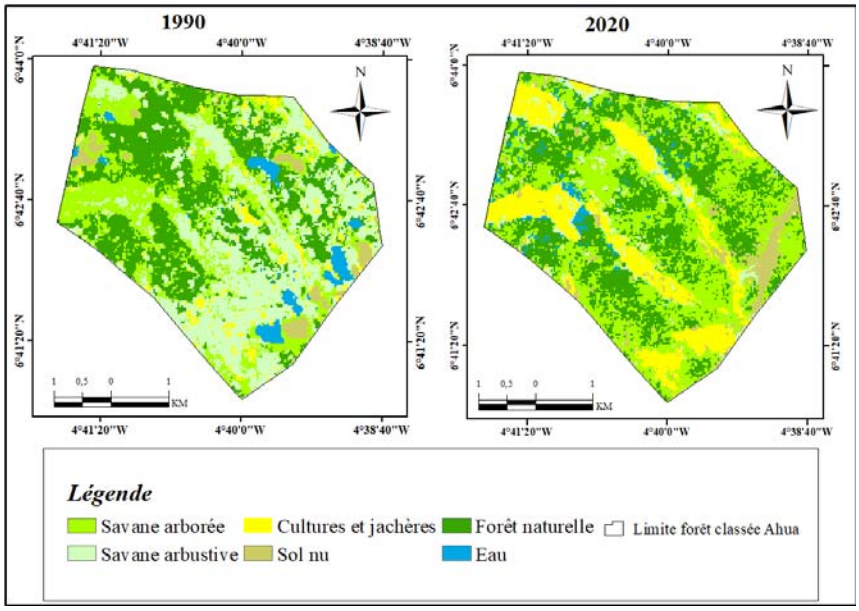


Source: SODEFOR CGA, 2021

Figure 4: Projection of variables in the factorial space F1-F2

In this factorial space, tree, liana, shrub and herbaceous species are grouped together in the positive part of the F1 axis. These species are located each of them in the same one end of the F2 axis. Rainfall and shrub and herbaceous species are linked. That is to say, a decrease of the rainfall certainly leads to a decrease in shrub and herbaceous species. While the temperature is linked to tree species and lianas. The grouping of these species and the temperature reveals that they evolve in the same way and have a similar evolution or are the result of a similar phenomenon. The angle formed between the climatic parameters and the plant species indicates, on both sides, the degree of dependence between these variables. This proves that there is a link in the same direction between rain, temperature and plant species. But, the link between the variables is not a very strong one. It means that there are other factors involved in the destruction or extinction of these species, hence this forest. As a result, man has an important part in this deterioration. However, several changes have been made in the forest dynamics as a result of these factors.

The landscape of the Ahua's listed forest has undergone enormous changes from 1990 to 2020 (Plate 2).



Source: Earth explorer, 2021 **Production:** Koffi, 2021

Plate 2: Vegetation dynamics of the Ahua's listed Forest from 1990 to 2020

The observation made on plate 2 shows that there is a change in the proportions of land cover classes in 2020. Unlike in 1990, forest cover decreased from a synoptic point of view. These is an almost total conquest of the landscape. The specificities of the proportions of the land cover classes are recorded in table 1.

Table 1: Surface area of forest landscape components from 1990 to 2020

Land cover	**Surface area in 1990 (hectare)**	**Surface area in 1990 in %**	**Surface area in 2020 (hectares)**	**Surface area in 2020 in %**	**Occupation Dynamics (hectares)**
Natural forest	1 210,27	26,89	606,95	13,49	-603,32
Wooded savannah	1 088,12	24,18	1 799,24	39,99	711,12
Shrub savannah	1 153,29	25,63	590,18	13,12	-563,11
Crops and fallow	674,91	14,99	1 349,34	29,99	674,43
Bare soil	66,99	1,49	111,02	2,48	44,03
Water	67,81	1,51	43,28	0,97	-24,53

Source: Earth explorer, 2021

It emerges from table 1 that the proportions of the components vary according to the location and the category of entities. The natural forest nevertheless encountered a sharp decrease. It reduced from 1, 210.27 ha of forest to 606.95 ha of forest, i.e. a decrease of 603.32 ha from 1990 to 2020. While the wooded savannah increased from 1, 088.12 ha in 1990 to 1, 799.24 ha in 2020, an increase of 711.12 ha. As for the shrubby savannah, it decreased from 1, 153.29 ha to 590.18 ha, i.e. a loss of 563.11 ha of its occupation over the period 1990-2020. While crops and fallow land increased from 674.91 ha in 1990 to 1, 349.34 ha in 2020, an increase of 674.43 ha. While, over this same period (1990-2020), the occupation of bare land increased from 66.99 ha to 111.02 ha, an increase of 44.03ha. All of these increases have been at the expense of natural or dense forest and shrub savannah. During 31 years, Ahua's listed forest experienced severe deterioration which decimated half of its forest capital. Concerning the

increase of crops and bare soils, it can be explained focusing on anthropo-climatic factors which have enormous repercussions on the vegetation of the forest.

2-5-The extinction of plant species as an impact of this deterioration

National-scale Forest inventories were carried out in 1984 by the Tropical Forest Technique Center and in 2017 by the Ivorian Office of Parks and Reserves (IOPR). The results produced permitted to establish the dynamics of species in this listed forest (Table 2).

Table 2: Dynamics of the typology of plant species from 1984 to 2017

Morphological Types	Number of species (1984)	Number of species (2017)
Vine species	149	137
Tree species	124	123
Shrub species	186	161
Herbaceous species	75	63

Source: SODEFOR CGA, 2021

In general, a decrease could be identified in plant species from 1984 to 2017. For a total of 534 plant species in 1984, they decrease to 484 species in 2017, i.e. an extinction of 50 species. This loss represents 9.36%. Specifically, creeper species decreased from 149 in 1984 to 137 in 2017, an extinction of 8.05%. As for tree species, they decreased from 124 in 1984 to 123 in 2017, a loss of 0.80%. While shrub species decreased from 186 in 1984 to 161 species in 2017, i.e. a disappearance of 13.44%. While herbaceous species decrease from 75 in 1984 to 63 in 2017, a loss of 16%. Amongst plant species in Ahua's listed Forest, herbaceous and shrub species have been the most affected by extinction with 12 and 25 species disappearing respectively. To stop this disappearance of plant species from this forest, the forest development company (SODEFOR) is conducting sensitisation and reforestation sessions.

2-6-Sensitisation and reforestation, the main strategies for restoring the forest

Being conscious of the disappearance of this forest, if no measure is taken, SODEFOR has started sensitisation campaigns and set up reforestation plots (Plate 2).

A: Sensitisation panel against bushfire; **B:** Reforestation by teak fields

Shooting: Koffi, July 2021

Plate 2: Activities carried out to halt forest degradation

Image A of plate 2 clearly shows a sensitisation sign to stop bushfires. These sensitisation signs are located in the contours of the forest. Indeed, SODEFOR developed a strategy to fight against forest fires. This strategy, based on prevention and active control, involves the populations surrounding the forest. Besides the sensitisation, there is reforestation. SODEFOR's agents are favour to fight against global warning. The structure also fights for the conservation of existing forests. Thus, this structure organizes training workshops on the techniques of production of forest seedlings for the rehabilitation activities of this listed forest in Ahua under the technical supervision of its experts. To facilitate the achievement of rehabilitation activities, it installs a nursery and production of forest seedlings. In order to express the interest in participating in its gradual rehabilitation, in collaboration with associations and interest groups in the neighbouring villages, SODEFOR puts into action these associations for the distribution of forest seedlings to communities bordering Ahua's listed forest.

III. DISCUSSION

The analysis of the rainfall series shows that there is a variability. This fluctuation of the rainfall heights presents a downward trend in annual accumulations over the entire area of the study. For more than 30 years, OECD (2013, p47) has reported that the hydro-climatic context of West Africa deteriorated considerably. KOUASSI (2020, p76) also argues that Côte d'Ivoire has been affected by these climate changes. The different changes in climate conditions and the current state of plant species showed that the climate has more or less influence on the deterioration of forest cover. Le BORGNE (1990, p27) shows that the determinism of the division between the types of vegetation is essentially climatic, with corrections linked to soil water reserves. AUBREVILLE (1949, p206), considers that water is therefore the key factors in determining the distribution of the types of natural vegetation. Correlatively to this climatic variability, BROU (2005, p153) indicates that years with exceptionally low rainfall have a very low biomass production.

However, it should be noted that certain non-climatic parameters such as anthropization, which results in the destruction of plant species and soil depletion, also contribute to the deterioration of forest cover. For INOUSSA and al. (2011, p3), most of the world's landscapes are modified or transformed by human activities undertaken to meet the socio-economic needs of populations. In this economic context, DIOMANDE (2005, p201) asserts that, since their origin, human societies have exploited and modified their physical and biological environment in many ways. Similar situations exist in other tropical regions. Thus in South America, nibbled away by soybean cultivation and cattle breeding, the Brazilian Amazon has lost 16.3% of its forest area since the 1970s, i.e. 653,000 km^2 (FAO, 1997, p129). According to QUEZEL and al. (2003, p17), in Indonesia, nearly 20% of protected forests have been destroyed by wood looters or farmers looking for land to cultivate.

Facing this change, local and external authorities have set up projects that aim at supporting and developing reforestation activities using tropical timber and forest management. This is for example, the case of the restoration of deteriorated forests through reforestation and agroforestry in Southeast Asia where the reconstitution of forest cover had been achieved in 20 years (MICHON, 2003, p73). In Benin, TOYI, and al. (2018, p217) claim that the Lama listed Forest (southern Benin) had undergone profound changes following restoration and conservation efforts. This current study therefore contributes to an objectification of the debates on the reforestation and regeneration of forest ecosystems under the protection of listed forests in Côte d'Ivoire.

IV. CONCLUSION

The rainfall is reflected by a decrease of 13.24% from the year of the rupture (1995) until 2020. Also, the temperature experiences a rupture in 1994 and an upward trend over the chronological series. This climatic fluctuation is an obstacle to the development of the flora species of Ahua's listed forest in the same way as man. Through agriculture and logging, man participates in the deterioration of this forest. These characteristics are therefore factors of deterioration of Ahua's listed forest. For this purpose, SODEFOR and local communities conduct sensitisation campaigns and reforestation sessions in order to try to stop the momentum of deterioration of this protected forest.

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