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RESEARCH ARTICLE

ECOLOGICAL NICHES AND IMPLICATIONS FOR REFORESTATION OF *PTEROCARPUS ERINACEUS*, *KHAYA SENEGALENSIS* AND *ISOBERLINIA DOKA* IN THE CLASSIFIED FORESTS OF NORTHERN CÔTE D'IVOIRE

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Abstract

Deforestation in Côte d'Ivoire, particularly in the Palé and Pouniakélé classified forests, threatens biodiversity and essential ecosystem services. This study explores the potential of *Pterocarpus erinaceus*, *Khaya senegalensis*, and *Isoberliniadoka* to restore degraded ecosystems through reforestation projects, using maximum entropy modeling. The objective is to analyze the ecological niches of these species in order to optimize reforestation strategies. The results show that *Pterocarpus erinaceus* has a high tolerance to climate variations, with an average AUC of 0.878, and a concentrated distribution in the central and northern savannahs. The main factors influencing its presence are the standard deviation of temperatures (47%) and humidity (15.4%). *Khaya senegalensis*, on the other hand, is well adapted to open environments with low vegetation cover and high climate variability. Its mean AUC of 0.893 indicates a robust prediction, with areas of presence in the central-eastern part of the country. Major contributions include temperature standard deviation (21.4%) and NDVI (18.5%). Finally, *Isoberliniadoka* shows greater sensitivity to stable climatic conditions, with a mean AUC of 0.848 and a presence limited to northern regions, where forest cover (32.1%) and mean temperature (39.7%) are the dominant variables. Ecological differences are observed between species, mainly influenced by climate variability and vegetation density. This implies the importance of adapting reforestation programs to the environmental specificities of each species. This study offers practical recommendations to improve the sustainability of reforestation projects in Côte d'Ivoire, taking into account local ecological challenges.

Introduction:-

Deforestation is one of the major environmental challenges in West Africa, particularly in Côte d'Ivoire, where classified forests are under severe pressure from agriculture, illegal logging, and population growth (Brou *et al*., 2019). The classified forests of Palé and Pouniakélé, located in the north of the country, are a good illustration of these challenges. These forests, once rich in biodiversity, play a crucial role in climate regulation and the

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preservation of ecosystem services, but they are now threatened by degradation and loss of vegetation cover (Koné *et al*., 2020). Faced with this situation, reforestation efforts appear to be a key response to restore the health of forest ecosystems.

Reforestation projects, to be effective, must take into account the ecological specificities of the species planted, because each species has an ecological niche that conditions its adaptation to local conditions and its role in the restoration of ecosystems (Jackson & Hobbs, 2009). The choice of reforested species is therefore crucial, not only to guarantee their survival and growth, but also to allow the reconstitution of lost ecological functions.

Within the framework of the classified forests of Palé and Pouniakélé, *Isoberliniadoka*, *Khaya senegalensis* and *Pterocarpus erinaceus*were selected for their potential to contribute to reforestation. *Isoberlinia Doka* is an endemic species of West African wooded savannas that plays a vital role in soil stabilization and natural forest regeneration (Assédé*et al*., 2012). *Khaya senegalensis* is prized for its high-quality wood and is also renowned for its resilience to drought conditions. As for *Pterocarpus erinaceus*, a native species widely exploited for its valuable wood, it is crucial in reforestation initiatives due to its ecological and socio-economic importance (Nacoulma *et al*., 2011).

This study explores the ecological niches of these three species in the Palé and Pouniakélé classified forests, analyzing their survival potential, their ability to restore degraded ecosystems, and their interactions with local environmental conditions. A better understanding of their ecological needs and their responses to environmental constraints will help optimize reforestation strategies, while taking into account the long-term sustainability of restored forests.

Material and Method:-

Study site

The Palé classified forest is located in the Boundiali department, in the Bagoué region. It covers an area of approximately 37,000 hectares and is mainly composed of wooded savannah and open forest formations, typical of the Sudano-Guinean areas. Historically, this forest was home to a rich biodiversity, including plant and animal species characteristic of the transition zones between forest and savannah (Sangaré*et al*., 2015).

Pouniakélé classified forest, located in the Tchologo region, near the border with Mali, covers an area of 29,000 hectares. It is characterized by mixed formations of wooded savannahs and gallery forests along watercourses, making it essential for the conservation of water resources in this semi-arid region (Ouattara *et al*., 2013). Like the Palé forest, Pouniakélé has been heavily affected by human activity, particularly extensive agriculture and illegal exploitation of forest resources.

The Palé and Pouniakélé classified forests represent key territories for the conservation of forest ecosystems in northern Côte d'Ivoire. However, increasing pressure from human activities continues to compromise conservation efforts. Reforestation projects, although ambitious, face several challenges, including the management of land use conflicts, low awareness of conservation issues among local populations, and increasingly unpredictable climatic conditions linked to climate change (Brou *et al*., 2019).

Data collection

A literature search was conducted to collect information on occurrences, ecological conditions, environmental niches, and performance of the species studied. Scientific databases and online libraries were visited. The Global Biodiversity Information Facility (GBIF) was used to obtain data on the geographic and ecological presence of the species studied. GBIF data will be used to complete the mapping of the current distribution. Occurrences for *Isoberliniadoka*, *Khaya senegalensis*, and *Pterocarpus erinaceus*were downloaded as CSV files from the GBIF portal using the search link https://www.gbif.org. The obtained data were filtered by eliminating duplicates, outliers, and non-geolocalized records. For field data collection, reforestation sites in the Palé and Pouniakélé classified forests were inventoried. Data were collected on 50 mx 50 m plots (0.25 hectares) randomly selected in the reforestation areas. All occurrences obtained were georeferenced.

Data analysis

The physical characteristics considered in this study include relief, precipitation and temperatures. These are data available online that were used. Concerning the relief, the digital terrain model of Côte d'Ivoire was obtained from the WorldClim database and available from the site http://www.worldclim.org . The precipitation data were obtained from the *Climate Hazards Group InfraRed Precipitation with Stations* (CHIRPS) and put online by *the International Research Institute for Climate and Society* (IRI) from the link http://iridl.ldeo.columbia.edu/SOURCES/.UCSB/.CHIRPS/.v2p0/.monthly/.global/.precipitation . The map data of Ivory Coast available in GeoTIFF and CSV formats concerning tree cover, forest cover loss or gain were downloaded from the link https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.7.html . The map information downloaded on Ivory Coast was processed with ArcGIS software to obtain environmental variables. Then, the presence data were compared with the environmental variables with Maxent program. Finally, potential distribution maps were obtained.

Results:-

Outside of reforestation sites, the three species have been reported in the bibliography on Ivorian territory through botanical data collections. The compilation of data made it possible to list 2481 occurrences of *Pterocarpus erinaceus*, 90 occurrences of *Khaya senegalensis* and 57 occurrences of *Isoberliniadoka*.

The maximum entropy treatment for *Pterocarpus erinaceus*presents an omission rate that is consistent with the rate predicted by the algorithm, which shows good accuracy in predicting the areas of presence. The average AUC value of 0.878 with a standard deviation of 0.047. This demonstrates the ability of the model to discriminate well between the areas of presence and absence of the species. The distribution map produced presents a high probability of presence in the center and center-north of the country (Figure 1). Some areas consisting mainly of coastal savannahs are identified in the south of the country.

The standard deviation of temperature (47%) and humidity (15.4%) are the environmental variables that contribute the most to the prediction of the presence of the species, followed by altitude (9.9%). These variables significantly influence (Figure 2) the distribution of *Pterocarpus erinaceus*. The contributions of variables such as forest cover and vegetation loss are relatively low. It is noted that high standard deviations of temperature are favorable to the propagation of the species. It is also to biotopes of high humidity with relatively low altitudes. The Jackknife test shows that the mean temperature is the most informative variable when used alone. However, when altitude is omitted, the model loses the most information, indicating that this variable contains non-redundant information with the others.

The maximum entropy treatment for *Khaya senegalensis* also shows good accuracy in predicting presence areas. The averaged data show a satisfactory performance with a mean AUC of 0.893 and a standard deviation of 0.076. This indicates that the model has a good ability to distinguish between presence and absence areas of the studied species. The presence probability distribution map (Figure 3) shows high presence probabilities in the center and center-east of Côte d'Ivoire. Its presence probability becomes low in other regions of the country outside the coastal savannahs which are favorable biotopes.

The contributions (Figure 4) show that the standard deviation of temperatures is the most contributing variable to the model with 21.4%, followed by NDVI (18.5%), humidity (16%), and forest cover (13.6%). These variables are crucial in determining the distribution of the studied species. Altitude and minimum precipitation also have notable contributions. The permutation of the variables shows that altitude is the variable whose omission affects the model the most, suggesting that it contains unique non-redundant information. *Khaya senegalensis* is favorable to biotopes with high temperature variations, low vegetation cover and high humidity.

The omission rate demonstrates a good ability of the model to predict the presence of *Isoberliniadoka* in the areas where it is observed. The predicted area is well adjusted according to the thresholds, ensuring an efficient match between the predictions and the observed data. The ROC curve averaged over the repeated series displays a mean AUC of 0.848 with a standard deviation of 0.141. The model has a good ability to discriminate between areas of presence and absence of the species. The probabilityof presence distribution map (Figure 5) shows high probabilities of presence throughout the northern part. The highest probabilities of presence are identified in the far north in the areas of the classified forests of Pouniakélé and Palé.

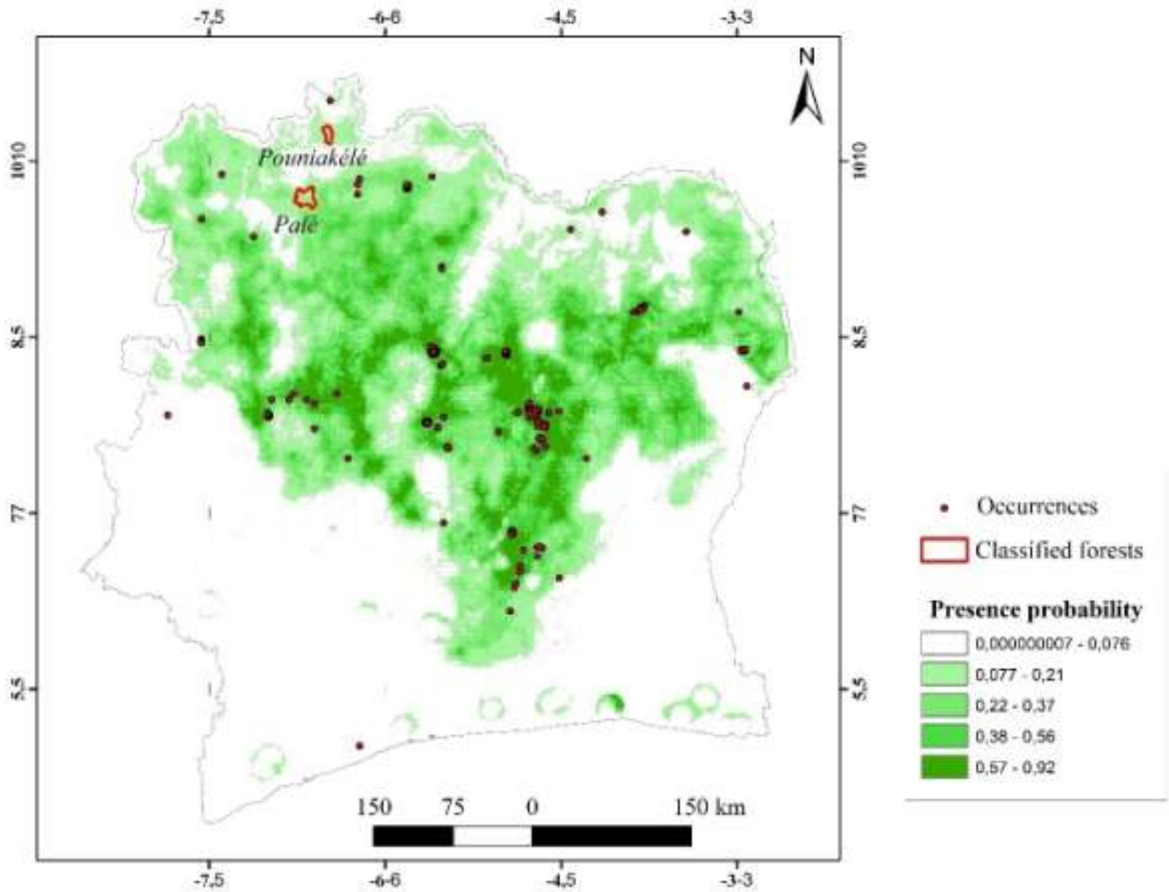

Figure 1:- Potential habitats of *Pterocarpus erinaceus*in Ivory Coast.

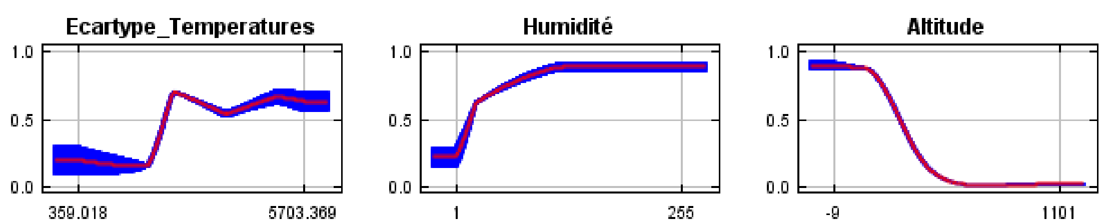

Figure 2:- Most significant variables in the prediction of *Pterocarpus erinaceus.*

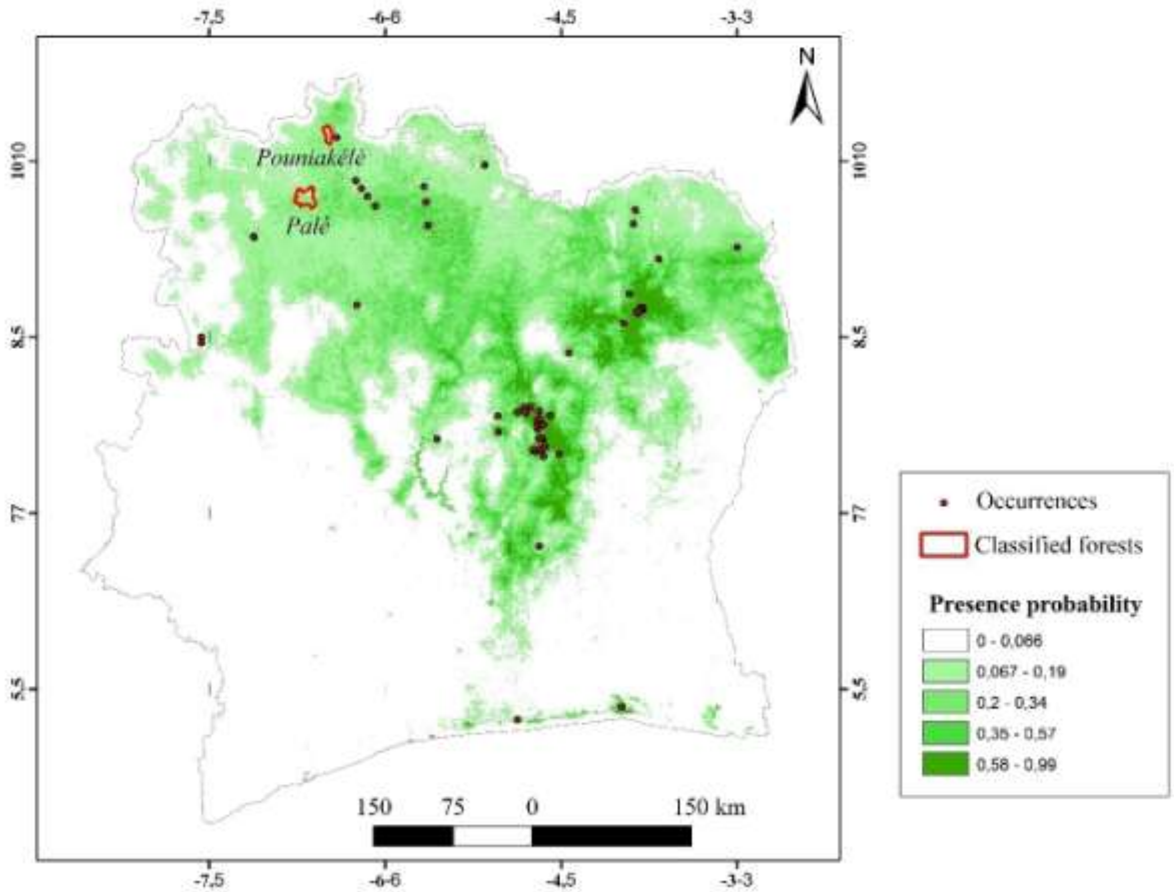

Figure 3:- Potential habitats of *Khaya senegalensis* in Ivory Coast.

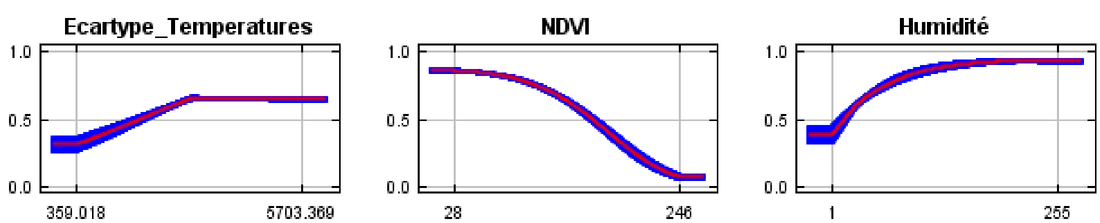

Figure 4:- Most significant variables in the preaching of *Khaya senegalensis.*

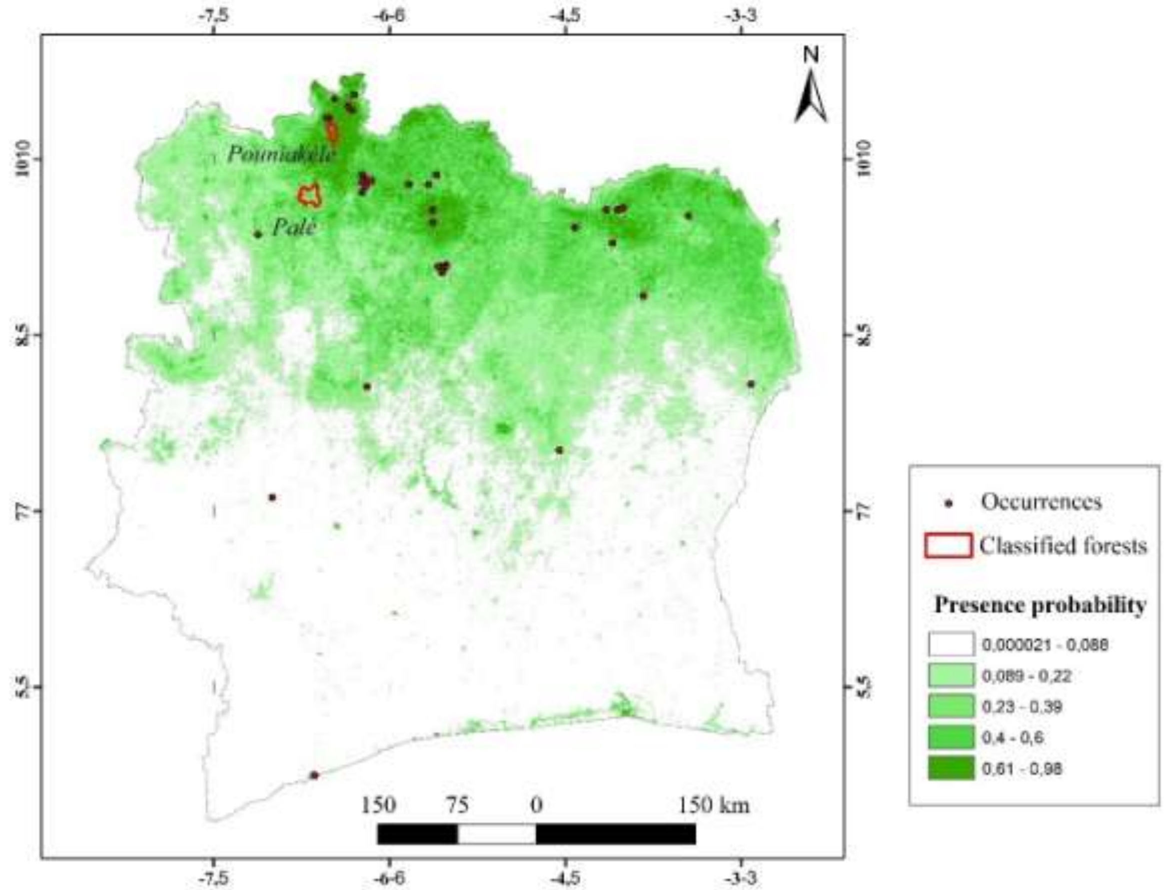

Figure 5:- Potential habitats of *Isoberliniadoka*in Ivory Coast.

The contribution analysis (Figure 6) shows that mean temperature is the most important variable, with a contribution of 39.7%, followed by forest cover (32.1%) and humidity (19.2%). Minimum precipitation and minimum temperature make smaller, but significant contributions, with 3.9% and 2.6%, respectively. The Jackknife test reveals that minimum temperature is the variable with the highest gain when used alone, indicating that it provides valuable information for the model. However, when forest cover is omitted, the model suffers a sharp decrease in gain, showing that it contains non-redundant information crucial for prediction. These results reflect the importance of climatic factors and forest cover in the distribution of *Isoberliniadoka*.

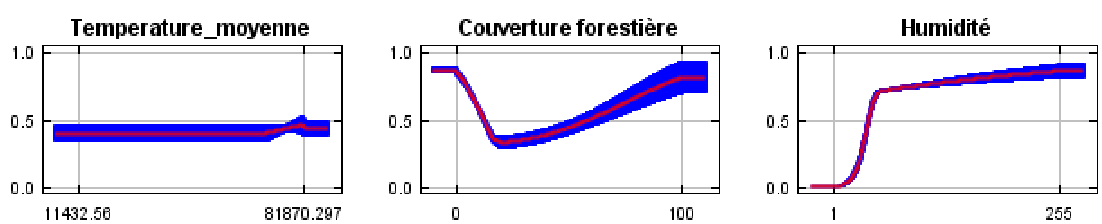

Figure 4:- Most significant variables in *Isoberlinia 's preaching doka.*

Pterocarpus erinaceus, *Khaya senegalensis*, and *Isoberliniadoka*show significant similarities and differences in their ecological distribution and the environmental variables that influence their occurrence. Although all three are influenced by climatic variables such as temperature and humidity, *Pterocarpus erinaceus*and*Khaya senegalensis* prefer areas with climatic variations marked, while *Isoberliniadoka*is more associated with areas with denser forest cover.

Discussion:-

Study of potential habitats of *Pterocarpus erinaceus*, *Khaya senegalensis*, and *Isoberliniadoka*through maximum entropy modeling highlights the determining influence of ecological variables on the distribution of these species in Ivory Coast. The results obtained show that the distribution of these species is strongly conditioned by climatic and vegetation factors, with notable differences between species in terms of sensitivity to environmental variables.

For *Pterocarpus erinaceus*, the standard deviation of temperatures (47%) appears to be the most contributing variable to the prediction of its presence. This shows that this species is particularly sensitive to climatic variations, especially to seasonal changes that characterize the central and northern areas of Côte d'Ivoire, where it is widely present. According to Sinsin and Kampmann (2010), this species is well adapted to dry Sudanian savannas where temperature fluctuations are significant. Humidity (15.4%) and altitude (9.9%) also play a crucial role, consistent with the studies of Jongkind*et al*. (2005), which indicate that this species prefers low-altitude areas with sufficient relative humidity to promote its development. The low contribution of variables related to forest cover (2%) and vegetation loss shows that this species is more adapted to open or semi-open environments, which corroborates the work of Schmidt (2012) on its ecology.

The prediction of *Khaya senegalensis* reveals a preference for areas with high climatic variability (standard deviation of temperatures of 21.4%) and environments with sparser vegetation cover (NDVI of 18.5%). This species is widely distributed in savannah areas where it benefits from light conditions and low competition for resources, as mentioned by Nygård *et al*. (2004). Minimal precipitation and humidity (16%) also influence its distribution, indicating that *Khaya senegalensis* is well adapted to the arid and semi-arid conditions of central Côte d'Ivoire, a conclusion supported by the work of Louppe*et al*. (2008). The results also show that altitude plays a crucial role, which could be explained by the presence of this species in slightly elevated areas, allowing more efficient drainage, as observed in the studies of Becker and Gnoumou (2002).

*Isoberliniadoka*shows a strong dependence on mean temperature (39.7%) and forest cover (32.1%), highlighting its preference for areas with relatively stable climate and moderate vegetation cover. Boffa (2000) describes this species as typical of open savannah forests, where the presence of forest cover helps maintain sufficient soil moisture. The significant contribution of humidity (19.2%) confirms this observation, highlighting the importance of precipitation for the maintenance of this species in the ecosystems of northern Côte d'Ivoire, as reported by White (1983). Furthermore, the low contribution of minimum precipitation (3.9%) indicates that this species is more resilient to periods of drought, an aspect also noted by Aubreville (1950).

The three species show differentiated ecological responses to environmental variables. While *Pterocarpus erinaceus*and*Khaya senegalensis* are more sensitive to climate variability and thrive in semi-arid environments with low vegetation cover, *Isoberliniadoka*appears to be better adapted to biotopes where climatic conditions are more stable and forest cover denser. These ecological differences may be related to their physiology and ecological strategy, with *Pterocarpus erinaceus*and*Khaya senegalensis* showing greater tolerance to environmental variation, while *Isoberliniadoka*favours more stable habitats in terms of temperature and humidity. It would be relevant to adapt reforestation programmes to the ecological preferences of the species. *Pterocarpus erinaceus*, in particular, could be used in open and savannah areas with high climatic variations, while *Isoberliniadoka*would be more suitable for transitional areas between savannah and forest with denser vegetation cover.

Conclusion:-

This study assessed the potential habitats of *Pterocarpus erinaceus*, *Khaya senegalensis*, and *Isoberliniadoka*in Ivory Coast using maximum entropy modeling. *Pterocarpus erinaceus*is distinguished by its ability to tolerate significant climatic variations, with a strong presence in the central and northern savannahs. *Khaya senegalensis*, on the other hand, is better adapted to open environments with low vegetation cover and high climatic variability, particularly in the central-eastern areas. Finally, *Isoberliniadoka*shows greater sensitivity to stable climatic conditions and moderate forest cover, which limits its presence to the northern regions of the country. The ecological differences observed between these three species must be taken into account in reforestation and conservation strategies. Their specific environmental requirements highlight the importance of differentiated natural resource management, taking into account local conditions to maximize the chances of success of ecosystem restoration initiatives. This study offers valuable insights to guide reforestation efforts in Côte d'Ivoire, while strengthening the conservation of local forest species in the face of the challenges posed by climate change and anthropogenic pressure.

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