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RESEARCH ARTICLE

INVASIVE ALIEN PLANTS OF CÔTE D'IVOIRE: AN UPDATE AND PROPOSED CLASSIFICATION BASED ON ENVIRONMENTAL IMPACTS

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Abstract

Background and aims: Scientific data on alien plants and classification of invasive alien plants on the basis of environmental impacts are lacking in Côte d'Ivoire. The present study was carried out to improve the knowledge on exotic and invasive plants in Côte d'Ivoire.

Methods: In order to compile a list of alien and invasive plants in Côte d'Ivoire, published books and articles as well as national, regional and international online databases were consulted. Alien species were classified into cultivated and naturalized species. The naturalized species were further subdivided into proven invasives, potential invasives, plants to watch and plants without status in Côte d'Ivoire. For the list of proven invasive plants, the 4 stages of the different stages in the invasion process were applied. Finally, the proven invasive plants were classified taking into account the major and minor impacts on the environment.

Key Results: The Ivorian flora includes 851 introduced or exotic species distributed in 524 genera and 137 families. These taxa are divided into 127 cultivated species and 724 naturalized species. Of all the naturalized taxa, 28 species are proven invasive plants or invasives, 34 are potential invasives, 283 are plants to be monitored and 379 are without status. The classification of the 28 proven invasive plants is divided into : 4 plants with massive impacts (MA), 10 plants with major impacts (MR), 6 plants with moderate impacts (MO) and 8 plants with minor impacts (MI).

Conclusion: This study proposes a list of alien and invasive plants in Côte d'Ivoire. It also proposes a classification for proven invasive alien taxa according to their environmental impacts. It could constitute an important database on exotic, naturalized, proven invasive, potential invasive plants and plants to be monitored in Côte d'Ivoire. Biodiversity managers could thus rely on this work to establish effective strategies to control invasive plants in Côte d'Ivoire.

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Introduction:-

An alien species is a taxon that is intentionally or accidentally introduced into a territory or part of the territory where it was previously absent (Falk-Petersen et al. 2006; Brun 2007). Some of these introduced species manage to settle in their new environment, acclimatise to the new environmental conditions, reproduce and form new viable populations without the help of humans (Pieret et al. 2008). These species are called naturalized. Unfortunately, some of these naturalized species then spread explosively in their area of introduction: they are called invasive species (Pieret et al. 2008). Invasive alien species are non-native plant or animal species whose introduction or spread constitutes a threat to biodiversity and ecosystem services (Soubeyran 2008; Tassin et al. 2017). Several of these species are particularly damaging to the environment because they modify the biological diversity, structure and functioning of ecosystems. Others are highly allergenic or irritating and cause public health problems. This results in economic impacts such as the loss of ecosystem services and the costs incurred to repair or contain the negative effects of these species (Quéré et al. 2011; CaillonandLavoué 2016; Dortel and Le Bail 2019). Pimentel et al. (2001) estimated the loss of agricultural yields caused by invasive species at around $250 billion worldwide. In Europe, the economic costs of invasive species exceed €12 billion annually (Kettunen et al. 2008).

Like many countries, Côte d'Ivoire is also prone to invasion by alien species (Neuba et al. 2014; Noba et al. 2017). The issue of invasive alien plants has been addressed by a number of authors. These studies have focused on the ecology and distribution of invasive plants (Gautier 1992; Tiébré et al. 2012; Dogba et al. 2018; Akaffou et al. 2019; Pagny et al. 2020), the biology of invasive plants (Tiébré et al. 2012; Dogba et al. 2018), population perception of invasive plants (Maroun 2017; Tiébré et al. 2018), impact on ecological and environmental ecosystem services (Egnankou 1995; Egnankou 2015; Tiébré et al. 2014; 2015; Tiébré and Gouli Gnanazan 2018; Akaffou et al. 2019) and, proposals for a list of invasive plants (Neuba et al. 2014; Noba et al. 2017; Kouassi et al. 2018; Akaffou et al. 2019; GRIIS, http://www.griis.org; the GloNAF (Global Naturalized Alien Flora) initiative, https://glonaf.org). However, there is no existing data on the list of introduced or alien plants in Côte d'Ivoire. Furthermore, the work carried out on invasive plants is disparate; hence the need for a synthesis of data in order to draw up a list of invasive plants in Côte d'Ivoire. The establishment of lists of invasive species is a better predictor of the capacity of a plant species to invade an area or invasiveness (Lavergne 2016). In addition, the revision of the list of these species every year or at most every two years is also very important because new species regularly appear in the environment and other very dynamic species can also change their invasiveness category (Lavergne 2016). These lists form the basis of the early warning systems of the International Union for Conservation of Nature (IUCN) and the Global Invasive Species Program (GISP) (Reichard and Hamilton 1997). Moreover, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) encourages the development of the list of invasive plants as a basis for their management and control (IPBES 2019). This allows for coordinated efforts, reducing the threats of invasive alien species at national, regional and continental scales (Meyer et al. 2006).

Furthermore, studies on the classification of invasive plants in Côte d'Ivoire taking into account environmental impacts have not yet been addressed. However, classifying invasive species according to environmental impacts makes it possible to categorise the various exogenous taxa by assessing and comparing the extent of their different impacts (Hawkins et al. 2015). This will provide biodiversity managers and conservationists with a basic set of data on invasive plants for the development of sustainable management strategies (Varray et al. 2018).

Thus, several questions arise: (1) Which plants are considered to be introduced or exotic in Côte d'Ivoire? (2) How can we categorise introduced or exotic plants in Côte d'Ivoire? (3) Which introduced or exotic plants are considered to be proven invasives, potential invasives and plants to be monitored in Côte d'Ivoire? (4) How can we prioritise proven invasive or invasive plants according to their environmental impacts?

The present study was therefore initiated to answer the above questions. Its general objective is to improve knowledge on exotic and invasive plants in Côte d'Ivoire. More specifically, it aimed to (1) List the introduced or exotic plants of Côte d'Ivoire; (2) Categorise the introduced or exotic plants of Côte d'Ivoire; (3) Identify the invasive or proven invasive exotic plants, potential invasives, and plants to be monitored of Côte d'Ivoire; (4) Sort the invasive or proven invasive exotic plants according to their environmental impacts.

Materials and Methods:-

Study site

The study took place in Côte d'Ivoire, a coastal country in West Africa. The country covers an area of about 322,462 km2 between 4°30 and 10°30 North latitude and 2°30 and 8°30 West longitude (RGPH 2014). It is bordered to the south by the Atlantic Ocean, to the north by Mali and Burkina Faso, to the east by Ghana and to the west by Liberia and Guinea. Côte d'Ivoire has a relatively flat and uneven terrain, consisting of plains and plateaus, except in the western part of the country, which has a mountainous terrain. Overall, the soils that cover the territory of Côte d'Ivoire can be grouped into four main entities of unequal importance: ferralsols, tropical ferruginous soils, soils on basic rocks with areas of armouring, hydromorphic soils or coastal soils (Perraud 1971; FAO 2006). Côte d'Ivoire belongs to the hot climates of the intertropical zone. It is characterised by four types of climate according to the different zonations: the sub-equatorial climate, the humid tropical climate, the tropical climate and the mountain climate (Eldin 1971; Avit et al. 1999; Peel 2007). The country is divided into two vegetation zones. From north to south, there is a transition from savannah to equatorial forest, which becomes increasingly dense in the south (Ministry of Environment and Sustainable Development of Côte d'Ivoire 2020). The northern part is covered by savannah. In the centre, there are open forests or wooded savannahs (Ministry of the Environment and Sustainable Development of Côte d'Ivoire 2020). In the southern part, the basic vegetation consists of dense forests, subdivided into mesophilic and hygrophilic forests (Ministry of the Environment and Sustainable Development of Côte d'Ivoire 2020). The coastline is lined with coconut and roast trees. There are also mangroves (Guillaumetand Adjanohoun 1971; Ministry of the Environment and Sustainable Development of Côte d'Ivoire 2020).

Data collection

Identification and categorisation of introduced or exotic plants in Côte d'Ivoire

A list of exotic plants as well as the classification of invasive plants according to environmental impacts is currently unavailable for Côte d'Ivoire. In order to obtain this list, a bibliographical synthesis of the work carried out on plant species was made. Thus, scientific reports (De Foresta 1995; UICN/PACO 2013), scientific articles (Egnankou 1995; 2015; Gautier et al. 1999; Aké-Assi 2001; 2002; Neuba et al. 2014; Noba et al. 2017; Dogba et al. 2018; Tiébré and Gouli Gnanazan 2018; Gouli Gnanazan and Tiébré 2018; Akaffou et al. 2019; Van der Meersch et al. 2020); the database of invasive species of the herbarium of the National Centre for Floristics (Kouassi et al. 2018); the list of invasive plants of Côte d'Ivoire established by Professor Aké-Assi from personal observations during field missions were consulted. In addition, several international online databases were consulted: the World Invasive Species Database (www.issg.org/database/welcome), the CABI invasive species compendium (www.cabi.org/isc), the Global Register of Introduced and Invasive Species (GRIIS) (http://www.griis.org), the Global Naturalized Alien Flora (GloNAF) initiative (https://glonaf.org), the Global Biodiversity Information Facility (https://www.gbif.org), and the list of invasive plants in West Africa (http://issg.org/pdf/puplications/GISP/Resources/ wAfrica-EN.pdf). Finally, the data from the different databases were cross-referenced to generate the list of introduced plants in Côte d'Ivoire.

Following Blackburn et al. (2011), invasive plants are derived from introduced plants and are a subgroup of naturalized species. Therefore, in the present study, introduced species were categorised into cultivated and naturalized species. These databases were cross-referenced with the database of introduced or exotic species in Côte d'Ivoire to generate a list of cultivated plants and a list of naturalized plants in Côte d'Ivoire.

Identification of invasive plants in Côte d'Ivoire

The identification of invasive plants in Côte d'Ivoire was carried out (1) by first consulting the list of naturalized plants in Côte d'Ivoire; (2) by following the four stages of the invasion process. According to Blackburn et al. (2011), these are: Transport: the species is transported outside its natural range to reach a new geographical area in which it can establish itself. During this phase, the species crosses geographical barriers, such as a mountain range or an ocean, that were previously impassable without intentional or accidental human intervention; Introduction: the species must cope with the environmental conditions of the new environment; Establishment: the species must be able to survive and reproduce sexually and/or asexually without human intervention in order to become established and develop in the area of introduction. By crossing the reproductive barrier, the species is considered a naturalized species; Propagation or Dispersal: the range of the species then extends beyond the area of introduction. The species disperses within the area of introduction and its descendants succeed in adapting to the environmental conditions they encounter by gradually invading new environments. A naturalized taxon is a non-native taxon that reproduces consistently and maintains its population through several life cycles without direct human intervention. It reproduces and generates offspring sexually or vegetatively, often in close proximity to adult plants and does not necessarily invade natural or semi-natural ecosystems.Non-status naturalized taxa are non-native taxa that have no invasive

character within the territory considered and/or in bordering or climatically close regions and/or in other regions of the world; (3) Based on the classification method of Dortel and Le Bail (2019) which defines three categories of invasive plants. Proven invasives : non-native plant having, in its territory of introduction, a proven invasive character and having a negative impact on biodiversity and/or on human health and/or on economic activities; potential invasive plants : a non-native plant currently showing a tendency to develop an invasive character within natural or semi-natural communities and whose dynamics within the territory under consideration and/or in neighbouring or climatically close regions are such that there is a risk that it will become a known invasive in the more or less long term; plants to be monitored : a plants to be monitored is a non-native plant that does not currently (or no longer) have a proven invasive character or negative impact on biodiversity in the area under consideration, but for which the possibility of developing these characteristics (by sexual reproduction or vegetative propagation) has not been completely ruled out, particularly in view of the invasive character of this plant and the impacts on biodiversity in other regions of the world. Thus, by following the different steps mentioned above, the naturalized plants could be categorized into proven invasive plants, potential invasive plants, plants to be monitored and plants without status. The following scientific literature and international online databases were consulted: Aké-Assi 1977; Aké-Assi 1980; Alexandre 1982; Egnankou 1995; 2015; Lowe et al. 2000; Nair 2001; Minakawa et al. 2008; Raizada andRaghubanshi 2010; GEE 2012; Seema 2012; Tiébré et al. 2012; 2018; Neuba et al. 2014; Touré et al. 2016; Tiébré and Gouli Gnanazan 2018; Akaffou et al. 2019; Van der Meersch et al. 2020, the Global Invasive Species Database; the CABI Invasive Species Digest; GRIIS (http://www.griis.org); the GloNAF initiative (Global Naturalized Alien Flora, https://glonaf.org) and the Global Biodiversity information Facility website (https: //www.gbif.org). The Global Biodiversity information Facility website (https: //www.gbif.org) has made it possible to specify for each naturalized species the countries of introduction and the evidence of the impact of the introduction of these species in these countries.

Classification of proven invasive plants according to environmental impacts

In this study, only proven invasive plants were classified according to environmental impacts because they have undergone the different stages that govern an invasive plant and have a negative impact on biodiversity and/or human health and/or economic activities. To classify proven invasive plants according to environmental impacts, the following scientific works and international online databases were consulted: Aké-Assi 1977; Aké-Assi 1980; Alexandre 1982; Egnankou 1995; 2015; Lowe et al. 2000; Nair 2001; Minakawa et al 2008;; Raizada andRaghubanshi 2010; GEE 2012; Seema 2012; Tiébré et al. 2012; 2018; Neuba et al. 2014; Touré et al. 2016; Tiébré and Gouli Gnanazan 2018; Akaffou et al. 2019; Van der Meersch et al. 2020, the Global Invasive Species Database; the CABI Invasive Species Digest; GRIIS (http://www. griis.org); the GloNAF initiative (Global Naturalized Alien Flora, https://glonaf.org) and the Global Biodiversity information Facility website (https: //www.gbif.org). Next, the classification adopted by Blackburn et al. (2014) based on the environmental impacts of invasive plants was indexed to each proven invasive plant.The classification defines 5 impact categories, ranging from massive to minimal: (1) Massive impact species (MA): a species is considered to have massive impacts when it leads to the replacement and local extinction of native species, and causes irreversible changes in community structure (chemical, physical and/or structural characteristics of the biotope; changes in nutrient and water cycling; disturbance regimes; changes in natural succession) and abiotic or biotic composition of ecosystems. (2) Major impact species (MR): a species is considered to have a major impact when it causes the local or population extinction of at least one native species, and results in reversible changes in community structure and abiotic or biotic ecosystem composition, and has no impact that classifies it as an MA. (3) Moderate impact species (MO): a species is considered to have moderate effects when it causes a decline in population densities of native species, but no change in community structure or the abiotic or biotic composition of ecosystems, and has no impact that would cause it to be classified in a higher impact category.(4) Minor impact species (MI.): a species is considered to have a minor impact when it causes a reduction in the fitness of individuals in the native biota (growth, reproduction, defence, immunocompetence) but no reduction in native population densities, and has no impact that would cause it to be classified in a higher impact category. (5) Minimal impact species (ML): a species is considered to have minimal impacts when it is unlikely to have caused deleterious effects on native biota or the abiotic environment. Finally, a list of proven invasive plants based on environmental impacts was generated.

Taxonomy, origin, life form, habitats, and mode of introduction

The total number of introduced or alien taxa, cultivated plants, naturalized plants, families, genera, were determined according to the methods of (Raunkiaer 1934; Aké-Assi 2001; 2002; Jongkind 2004). The status of naturalized plants consisted of determining the number of proven invasive plants, potential invasive plants, plants to be monitored and plants without status. In reference to the classification method of Dorteland Le Bail 2019, only proven invasive

plants, potential invasive plants and plants to be monitored were considered as invasive plants for further analysis. The parameters used to characterise these plants are family, genus, number of cotyledons, origin, life form, habitat, longevity, and mode of introduction. Through the literature of Ake-Assi 2001; 2002, the type of cotyledon made it possible to know whether the plant is a Monocotyledon or a Dicotyledon. To analyse the origin of invasive plants, the works of Aké-Assi (2001; 2002), Jacq (2002), Tiébré et al. (2012), Neuba et al. (2014), Noba et al. (2017), Pagny et al. (2020) and Van der Meersch et al. (2020). In addition, the plants of the world online database (https://powo.science.kew.org), the list of invasive plants in West Africa (http://issg.org/pdf/puplications/GISP/Resources/ wAfrica-EN.pdf), pdf/puplications/GISP/Resources/ wAfrica-EN.pdf), the Global Invasive Species List (www.issg.org/database/welcome), the CABI (Center for International Agriculture and Biosciences) list (www. cabi.org/isc/), the Global Register of Introduced and Invasive Species (GRIIS) (http://www.griis.org), the Global Naturalized Alien Flora (GloNAF) (https://glonaf.org), the Global Biodiversity information Facility (GBIF) (https://www.gbif.org). With regard to the life forms and adaptation type of invasive plants, the databases were analysed according to the criteria of Aké-Assi (2001; 2002) and Raunkier (1934). Raunkier (1934) stipulates that the herbaceous stratum includes annual and perennial herbaceous plants less than 0.25 m high; shrubs constitute the low shrub stratum and include plants from 0.25 to 2 m high; the high shrub stratum includes plants from 2 to 8 m high; and the arborescent stratum is formed by plants from 8 to more than 30 m high. For Aké-Assi (2001; 2002), the plants can be either Herbs, Lianas, Shrubs, Bushes or Trees. The living environment specified whether the plant has a terrestrial or aquatic living environment (Neuba et al. 2014; Noba et al. 2017; Dogba et al. 2018; Akaffou et al. 2019). The habitats of invasive plants have been analysed by showing the preferential growth environments of these plants (Aké-Assi 2001; 2002; Gnahoua andLouppe 2003; Chakraborty et al. 2012; Neuba et al. 2014; Noba et al. 2017; Pagny et al. 2020; Van der Meersch et al. 2020). For the vectors of invasive plant introductions, the main sources of information are the works of Aké-Assi (2001; 2002) ; Jacq (2002), Tiébré et al. (2012), Neuba et al. (2014), Noba et al. (2017), Pagny et al. (2020) and Van der Meersch et al. (2020) and the Flore de la Côte d'Ivoire: catalogue systématique, biogéographie et écologie by Ake-Assi (2001; 2002). In the present study, species names follow Lebrun and Stork (1991; 1997) and the nomenclature adopted for families is that of APG IV (2016).All species were checked using the source https://powo.science.kew.org/.

Results:-

Identification and categorisation of introduced or exotic plants in Côte d'Ivoire

This study identified 851 introduced or exotic taxa distributed in 524 genera and 137 families. The most represented genera are Ipomoea and Senna (16 species each), Solanum (15 species), Gossypium (14 species), Euphorbia (12 species), Crotalaria and Mimosa (8 species each). Fabaceae (119 species), Compositae (50 species), Poaceae (46 species), Malvaceae (45 species), Solanaceae (31 species), Euphorbiaceae (30 species), Convolvulaceae (23 species), Rubiaceae (22 species) and Lamiaceae (21 species) are the most dominant families. The introduced or exotic taxa in Côte d'Ivoire are divided into 127 cultivated (15%) species and 724 naturalized species i.e. 85%.

Identification of invasive plants in Côte d'Ivoire

Of the 724 naturalized taxa, 28 species are invasive plants with proven impacts, 34 species are potential invasive plants, 283 species are plants to be monitored and 379 plants have no status (Table 1).

Proven invasive plants

Invasive plants with proven impacts are divided into 25 genera and 18 families (Table 2). About 71% of the species are dicots and 29% are monocots. All dicotyledons belong to 13 families, 18 genera and 20 species. Monocotyledons belong to five families, seven genera and eight species. Angiosperms represent 93% and pteridophytes 7%. Angiosperms belong to 17 families, 24 genera and 26 species. Pteridophytes are represented by one family (Salviniaceae), one genus (Salvinia) and two species (Annex).

The majority (86%) of proven invasive plants come from America, more precisely from South America (60%). The other species (14%) come from Asia. The two species of pteridophyte come from South America. Angiosperms (90%) come from America while 10% come from Asia. Monocotyledons (85%) come from South America. Among the Dicotyledons, plants from the Americas alone account for 87% of the species (Annex).

The distribution of life forms and adaptation type of proven invasive plants was characterised by a prevalence (47%) of perennial grasses against 14% of annual grasses. Woody perennials are represented by 39% of the species. Lianas are represented by only one species: Pueraria phaseolides (Table 2). Most (82%) of the proven invasive plants are terrestrial plants while only 18% are aquatic plants (Annex).

Known invasive plants are widespread (30%) along roadsides. They are also found in wastelands (15%), fallow land (11%), abandoned lawns (11%), aquatic environments (11%), forests (7%), gardens (6%) and 9% in other environments (cultivated areas, shaded areas, waste sites...).

Half (57%) of the proven invasive plants in Côte d'Ivoire were introduced through horticulture. Agroforestry, with 21% of all species, is the second most common way of introducing these plants. There is no information on the mode of introduction of the other proven invasive species which represent 18% of all species. Only one invasive species was introduced accidentally, Chromolaena odorata (Annex).

Potential invasive plants

The potential invasive plants (34 species) are divided into 30 genera and 18 families (Annex).The most preponderant families are the Fabaceae with 9 species and the Poaceae with 3 species. The potential invasive plants are all angiosperms. 28 species or 82% are dicotyledons against 6 species or 18% which are monocotyledons (Annex).

The majority of potential invasive plants come from America (42%), more precisely from South America. The other species come from Asia (33%), Oceania (13%), Africa (10%) and Europe (2%). Plants from Africa originate from Madagascar and North and East Africa. Monocotyledons (56%) originate from Asia, 43% from America and 14% from North Africa. Among the Dicotyledons, plants originating from America represent 43% of the species against 32% for plants originating from Asia (Annex).

The distribution of life forms of potential invasive plants showed that 65% of species are herbs, 20% are trees, 9% are shrubs and 6% are lianas (Table 2). The majority of potential invasive plants are terrestrial (79%) compared to 21% of species that are aquatic. In terms of adaptation type, 79% of potential invasive plants are perennials compared to 21% of species that are annuals. Perennial grasses represent 50% of species against 20% of annual grasses. Woody perennials represent 24% of the species. Perennial lianas represent 6% of the species Annex).

Potential invasive plants are mainly found along roadsides (20%). They are also found in cultivated areas (13%), swampy areas (10%), forests (7%), urban areas as line trees (6%), pastures (5%) and in other environments (39%) such as gardens, meadows, wastelands, parks, abandoned lands. (Annex).

The majority (41%) of potential invasive plants in Côte d'Ivoire have been introduced through horticulture. There is no information on how 40% of these species were introduced. Agroforestry with 19% of all species is one of the modes of introduction of these plants (Annex).

Plants to be monitored

The plants to be monitored (283 species) are divided into 201 genera and 76 families (Table 6). The dominant genera are Senna (9 species), Ipomoea (8 species), Euphorbia (7 species) and Ficus (6 species). The most prevalent families are Fabaceae (28 species), Compositae (24 species), Poaceae (17 species), Convolvulaceae and Euphorbiaceae (14 species each) and the Solanaceae (10 species). Angiosperms are represented by 275 species or 97%, Pteridophytes 6 species or 2% and Gymnosperms 2 species or 1%. 243 species or 86% are dicotyledons against 34 species or 12% which are monocotyledons. Finally, 6 species or 2% are ferns and lycophytes.

The potential invasive plants come from five continents (Africa, Asia, America, Oceania, Europe). The majority (51%) of these plants come from America, more precisely from South America (25%). The other species come from Asia (25%), Africa (13%), Oceania (7%) and Europe (4%). Plants from Africa are mainly (10%) from North Africa, East Africa and Madagascar. 33% of Monocotyledons come from Asia, 31% from America, 19% from Africa, 15% from Oceania and 2% from Europe. ForDicotyledons, 54% are from the Americas, 22% from Asia, 12% from Africa 7% from Europe and 5% from Oceania. Finally, Pteridophytes mainly come from Asia, North Africa and East Africa (Annex).

The distribution of the life forms of the plants to be monitored showed that 59% of the species are herbs, 22% are shrubs, 13% are trees, 4% are lianas and 2% are bushes (Annex). The majority of plants to be monitored are terrestrial (99%) compared to only 1% of species that are aquatic. Concerning the type of adaptation, 72% of the plants to be monitored are perennials against 28% of the species which are annuals. Annual grasses represent 28% of the species against 31% of perennial grasses. Woody perennials are represented by 41% of the species (Annex).

The plants to be monitored are mainly found along roadsides (16%). They are also found in gardens (14%),disturbed areas and pastures (10%), cultivated areas (9%), forests and disturbed forests (7%), along watercourses (4%) and in other environments (40%) such as meadows, wastelands, parks, fallow land, abandoned land, etc. (Annex).

The plants to be monitored from Côte d'Ivoire were introduced mainly through horticulture (64%). There is no information on how 25% of these species were introduced. Agroforestry with 8% of all species is one of the modes of introduction of these plants. Finally, 3% of these species were introduced for various reasons such as fodder, pasture, curiosity and dye use (Annex).

Classification of proven invasive plants in Côte d'Ivoire according to environmental impacts

The classification of the 24 proven invasive plants is divided into : 4 plants with massive impacts (MA) namely Chromolaena odorata, Eichhornia crassipes, Lantana camara, Pistia stratiotes; 10 plants with major impacts (MR) namely Cecropia peltata, Euphorbia heterophylla, Hopea odorata, Leucaena leucocephala, Salvinia molesta, Salvinia nymphellula, Solanum erianthum, Solanum rugosum, Stenotaphrumsecundatum and Tithonia diversifolia; 6 moderate impact plants (MO) namely Alternanthera brasiliana, Cedrela odorata, Croton hirtus, Mimosa pigra, Pueraria phaseoloides and Syngonium podophyllum. Finally, 8 plants with minor impacts (MI) namely Acanthospermumhispidum, Breyniadisticha, Caladium bicolor, Calophylluminophyllum, Mimosa invisa**,**Pycreusmundtii, Tabebuia pallida and Turneraulmifolia (Table 2).

Discussion:-

Identification of introduced and invasive plants in Côte d'Ivoire

Compiling introduced or exotic species is an essential step to launch monitoring and assess their impacts (McGeoch et al. 2016). Côte d'Ivoire is home to a significant number of exotic species.This value represents 22% of the indigenous or native Ivorian flora, which has been estimated at 3882 species distributed in 1218 genera and 192 families (Aké-Assi 1984; 2001; 2002).This value is upper than that of the introduced species in Ghana, estimated at 291 species (Ansong et al. 2019).This could be explained by the fact that in Côte d'Ivoire, the destruction of natural ecosystems as a result of agriculture, urbanization and industrialization has led to a change in forest ecosystems towards a degraded environment, conducive to the establishment of invasive exotic species.Human pressure could be contributing to the high number of exotic species.

Fabaceae is the richest family. This result is similar to that of Bordbarand Meerts.(2020), who reported that Fabaceae is one of the richest families in the exotic flora of the Democratic Republic of the Congo. This study showed that 724 taxa (i.e. about 85% of introduced or exotic taxa) are naturalized. According to Neuba et al. (2014), taxa at the naturalization stage are present for the most part in the form of more or less extensive patches, in highly disturbed environments. Among the naturalized taxa, 28 species divided into 25 genera and 18 families (i.e. 3% of the introduced flora and 4% of the naturalized flora) are invasive alien plants or proven invasives due to their extension and their ecological, health and/or socio-economic impacts. This value is close to the work of Neuba et al. (2014), Noba et al. (2017) but lower than that of Kouassi et al. (2018), Griis (http://www.griis.org) and GloNAF (https://glonaf.org). Indeed, these authors estimated the invasive alien species of the Ivorian flora at 30, 27, 53, 86 and 288 species respectively. Our lower values could be explained by the fact that these authors did not classify invasive species into proven invasives, potential invasives and plants to be monitored. In this study, the 28 species identified represent only proven invasives.

This study showed that the invasive species originated from two continents (America and Asia). Our result is similar toBordbarand Meerts.(2020)in Democratic Republic of the Congo; et Ansong et al. (2019)at Ghana. However, species from South America predominated.The large number of South American species invading Ivorian habitats reflects the same climate of the intertropical zone. The distribution of life forms and adaptation type of invasive plants was characterised by a prevalence of perennial grasses over woody perennials. This result is similar to that of Ansong et al. (2019) in Ghana. These authors also found a prevalence of grasses and a remarkably low number of woody perennials. The reasons are most likely the competitive advantage of herbaceous plants over woody plants. Indeed, herbaceous invasive plants have the ability to produce many seeds which enhances their competitive power (Jelbert et al. 2015; Moravcová et al. 2015).

Invasive species are mainly spread in disturbed areas (roadsides, wastelands, fallow lands, cultivated areas, swampy areas, abandoned lawns...). The likely explanation is that disturbed areas are the preferred growth areas for invasive plants (Dietz and Edwards 2006). This study showed that invasive plants were introduced mainly through

horticulture in Côte d'Ivoire. According to Halford and Mahy (2013), horticulture is considered one of the main vectors of invasive plant introductions. Indeed, most invasive plants are ornamental plants. Initially introduced by man for horticultural purposes in botanical gardens, nurseries, parks and gardens, they have unfortunately escaped and colonised natural environments.

Agroforestry is the second pathway for invasive plants in Côte d'Ivoire. Taxa such as Cedrela odorata, Leucaena leucocephala, Gmelina arborea have been introduced through agroforestry. But, there is no information on the mode of introduction of several invasive species. This result is in agreement with Chatelain et al. (2001) who mention that the most accurate documentation on the history of invasive plants in Côte d'Ivoire concerns only Chromolaena odorata, Cecropia peltata, Eichhornia crassipes and Leucaena leucocephala.

This study identified 34 taxa as potential invasives and 283 plants to be monitored. These naturalized taxa have not yet had a proven impact on the territory of Côte d'Ivoire but are known to be invasive in a neighbouring country or elsewhere in the world in natural environments or environments strongly influenced by humans. Indeed, these plants may have a latency period or have integrated into existing ecosystems. It is therefore necessary to be vigilant about the evolution of these populations, as the latency phase can sometimes be very long (Müller 2004). Moreover, these plants are known to be invasive in other countries. This is the case of Acacia mangiumWild. and CentrosemapubescensBenth. which are respectively invasive in Senegal and Indonesia (Noba et al. 2017; GBIF). Thus, the presence of potential invasives and plants to be monitored on the territory justifies strong vigilance and may require the rapid implementation of preventive or curative actions.

Classification of proven invasive plants in Côte d'Ivoire according to environmental impacts

This study classified invasive plants in Côte d'Ivoire into four categories: those with massive impact (MA), major impact (MR), moderate impact (MO) and minor impact (MI). According to Blackburn et al. (2014), this classification system provides a pragmatic solution where impacts can be rigorously quantified and compared in terms of their magnitude. It is therefore an effective categorisation system with less data available than is necessary to assess the overall impact of a species. This work has shown that four invasive plants are massive impact plants (MA). These are: C. odorata, E. crassipes, L. camara and P. stratiotes. The impacts of these plants on biodiversity, economy and health are significant. Chromolaena odorata and Lantana camara are species directly involved in the disappearance of native species and constitute a real threat to ecosystems (Tiébré et al. 2012; 2018; Maroun 2017; Tiébré and Gouli Gnanazan 2018; Pagny et al. 2020). These plants can cause irreversible changes in the composition of the community. This is the case of Chromolaena odorata, which modifies the chemical properties of the soil by enriching it, while Lantana camara negatively modifies the nutrient content of the soil (Raizada andRaghubanshi 2010; Tiébré and Gouli Gnanazan 2018; Pagny et al. 2020).Invasive species such as : Eicchornia crassipes and Pistia stratiotes cover almost all water bodies in the country and have become one of the most problematic plagues for freshwater bodies, rivers, lagoons and lakes forming impenetrable plugs (Neuba et al. 2014; Egnankou 1995; 2015). They represent a real threat to biodiversity. Indeed, few plant species can resist the rapid growth of E. crassipes. The latter ends up choking native species by forming dense monospecific mats that block light to the lower strata. It also threatens wildlife. According to Gunaratne et al. (2009) some wetland birds may be negatively affected by the presence of this species. When the large biomass produced by E. crassipes decomposes, large quantities of nutrients are released into the water, leading to eutrophication of the environment (Seema 2012; Egnankou 1995; 2015). The impacts of these invasive species on human activities are multiple. The mats formed by these plants make it difficult to travel by boat for fishing, thus reducing economic activities in these regions (Egnankou 1995; 2015). In addition, Lantana camara, E. crassipes and P. stratiotes have a negative impact on human health. Indeed, Lantana camara causes stings and injuries to humans. Tiébré et al. (2018) also found similar results. E. crassipes and P. stratiotes create favourable conditions for the reproduction of some disease vectors. For example, Minakawa et al. (2008) showed that the malaria vector Anopheles funestus takes advantage of the habitats created by E. crassipes mats. P. stratiotes can promote the formation of breeding sites for mosquitoes, vectors of many diseases, in this case mainly dengue (GEE 2012). These four massively impacting invasive species are also invasive in many parts of the world as they have harmful impacts on the environment. According to Lowe et al. (2000) and IUCN (2000), they are among the 100 most damaging invasive species in the world. Plants in this category deserve special attention as they should be prioritised for control actions. The results showed that ten invasive plants are major impact plants (MR). These plants are constantly progressing throughout the Ivorian territory, invading natural and semi-natural environments through their exponential population dynamics. They affect biodiversity and economic activities. For example, Cecropia peltata establishes itself in disturbed areas and competes with pioneer species such as Musangacecropioides (Neuba et al. 2014). Hopea odorata Roxb., Tithonia diversifolia, Solanum erianthum and Solanum rugosum cause the

disappearance of many native species and constitute a real threat to ecosystems (Alexandre 1982; Nair 2001; Tiébré et al. 2012; 2018). Economic impacts Salvinia nymphellula and Salvinia molesta invade water bodies causing damage to economic activities (Aké-Assi 1977; Neuba et al. 2014; https: //www.gbif.org). Six invasive plants with moderate impact (MO) have also been identified: Alternanthera brasiliana, Cedrela odorata, Croton hirtus, Mimosa pigra, Puereriaphaseolides and Syngodium podophyllum. These species cause a decrease in the population densities of at least one native species. This is the case of Cedrela odorata, which has a strong negative effect on the diversity of the native tree community in the Téné forest in central Côte d'Ivoire (Van der Meersch et al. 2020). These species still have a low impact or are limited to a restricted geographical area, allowing the implementation of preventive interventions. Finally, eight invasive plants with minor impacts (MI) have been identified: Acanthospermumhispidum, Breyniadisticha, Caladium bicolor, Calophylluminophyllum, Mimosa invisa, Pycreusmundtii,Tabebuia pallida and Turneraulmifolia. This category of invasive plants should be monitored during control actions.

Table 1:- Categorization of plants introduced from Côte d'Ivoire according to naturalized and cultivated plants.

	Naturalized plants				**Cultivated plants**	
Status	**Proven invasive plants**	**Potential invasive plants**	**Plants to be monitored**	**Plants without status**		**Total**
Number	28	34	283	379	127	851
% of introduced flora	3%	4%	33%	45%	15%	100 %

Table 2:- Classification of proven invasive plants according to environmental impact.

Category	**Taxon**	**Family**	**Impact**
Invasive plants with massive impacts (MA)	Chromolaena odorata (L.)R.M.King et H.Rob.	Compositae	Causes the disappearance of native species, constitutes a real threat to ecosystems, negatively impacts agricultural crop production, positively modifies soil chemical properties.
	Pontederia crassipes Mart.	Pontederiaceae	Covers almost all of the country's water bodies forming impenetrable plugs, also threatens wildlife, threatens biodiversity, harms fishing thus reducing economic activities, harms human health.
	Lantana camara L.	Verbenaceae	Causes the disappearance of native species, negatively modifies the nutrient content of the soil, harms human health.
	Pistia stratiotes L.	Araceae	Covers almost all of the country's water bodies forming impenetrable plugs, also threatens wildlife, threatens biodiversity, harms fishing thus reducing economic activities, harms human health.
Invasive plants with major impacts (MR)	Cecropia peltata L.	Urticaceae	Causes the disappearance of native species.
	Euphorbia heterophylla L.	Euphorbiaceae	Causes the disappearance of native species, negative impact on agricultural crop production.
	Hopea odorata Roxb.	Dipterocarpaceae	Cause a decline in the population densities of native species.
	Leucaenaleucocephala (Lam.) de Wit	Fabaceae	Causes the disappearance of native species.
	Salvinia molestaD.Mitch.	Salviniaceae	Flooding of water bodies causing damage to economic activities.
	Salvinia	Salvi	Flooding of water bodies causing damage to economic activities.

	nymphellulaDesv.	niaceae	
	Solanum erianthumD.Don	Solanaceae	Causes the disappearance of native species.
	Solanum rugosumDunal	Solanaceae	Causes the disappearance of native species.
	Stenotaphrumsecundatum (Walter) Kuntze	Poaceae	Causes the disappearance of native species.
	Tithonia diversifolia (Hemsl.) A.Gray	Compositae	Causes the disappearance of native species and is a real threat to ecosystems.
Invasive plants with moderate impacts (MO)	Alternanthera brasiliana (L.) Kuntze	Amaranthaceae	Negative impacts on native plant diversity.
	Cedrela odorata L.	Meliaceae	Negative impacts on native plant diversity.
	Croton hirtusL'Hér.	Euphorbiaceae	Negative impacts on native plant diversity.
	Mimosa pigra L.	Fabaceae	Causes the disappearance of native species.
	Neustanthusphaseoloides(Roxb.)	Fabaceae	Cause a decline in the population densities of native species.
	Syngonium podophyllum Schott	Araceae	Cause a decline in the population densities of native species.
	Acanthospermumhispidum DC.	Compositae	impact on reproduction of native species without population decline
	BreyniadistichaJ.R.Forst. &G.Forst.	Phyllanthaceae	reducing native species diversity without population decline
	Caladium bicolor (Aiton) Vent.	Araceae	reducing native species diversity without population decline
	Calophyllumino phyllum L.	Calophyllaceae	reducing native species diversity without population decline
	Mimosa invisaMart. ex Colla	Fabaceae	reducing native species diversity without population decline
Invasive plants with minor impacts (MI)	Cyperus mundii(Nees) Kunth	Cyperaceae	Impacts (growth, reproduction, defence, immunocompetence) on native species without population decline
	Tabebuia pallida (Lindl.) Miers	Bignoniaceae	reducing native species diversity without population decline
	Turneraulmifolia L.	Passiflloraceae	reducing native species diversity without population decline

Conclusion:-

This study constitutes a first database on introduced or exotic plants in Côte d'Ivoire. It is also one of the first to categorise the naturalized plants of Côte d'Ivoire into proven invasive alien plants, potential invasive plants and

plants to be monitored. Finally, it proposes a classification for invasive alien taxa according to their environmental impacts. Consequently, this work could constitute an important source of data for biodiversity managers in order to establish effective strategies for efficient control of invasive plants in Côte d'Ivoire.

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