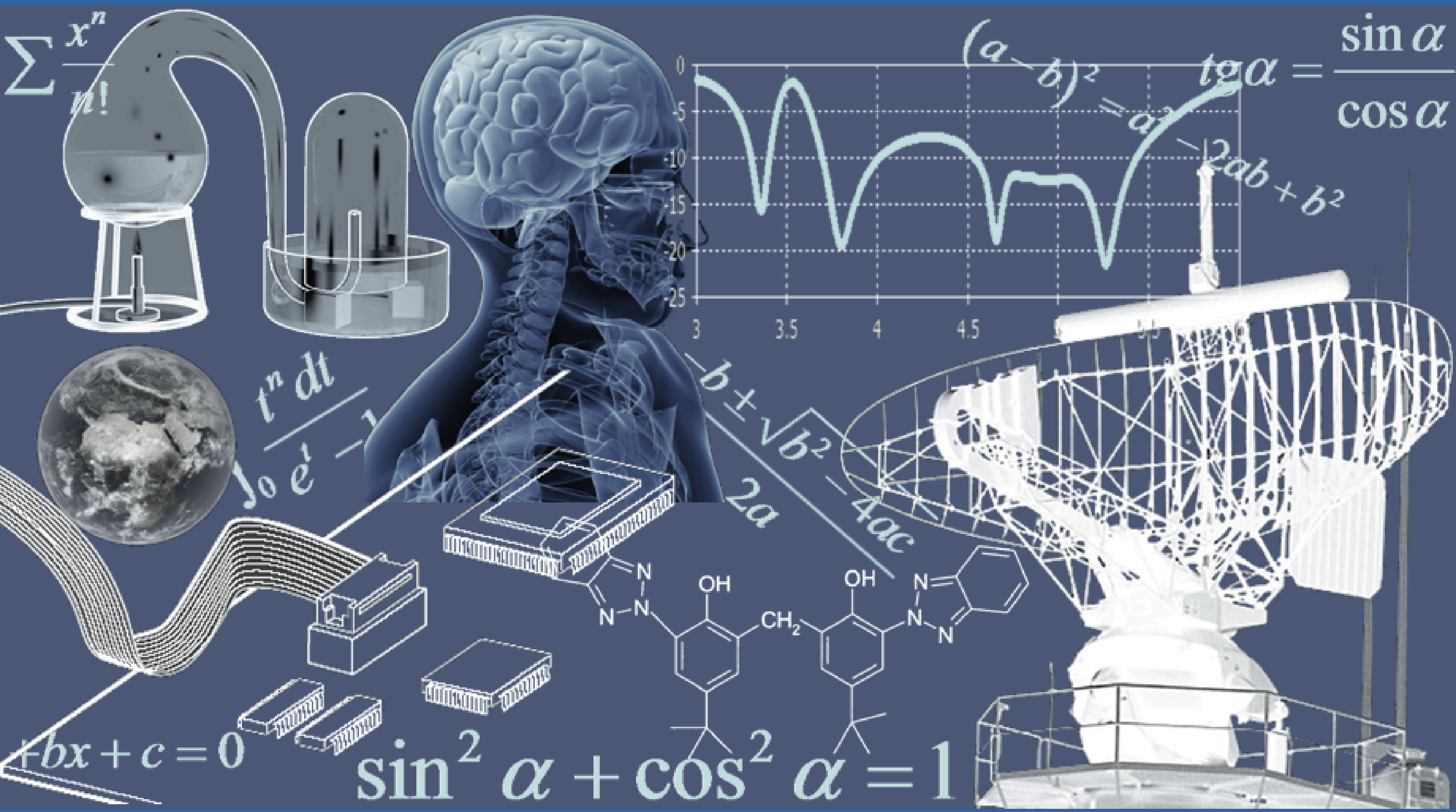
ISSN: 2028-9324
CODEN: IJIABO

Impact Factor: 4.063

INTERNATIONAL JOURNAL OF INNOVATION AND APPLIED STUDIES

Vol. 24 N. 2 September 2018



International Peer Reviewed Monthly Journal

Innovative Space of Scientific Research Journals
http://www.issr-journals.org/

International Journal of Innovation and Applied Studies

International Journal of Innovation and Applied Studies (ISSN: 2028-9324) is a peer reviewed multidisciplinary international journal publishing original and high-quality articles covering a wide range of topics in engineering, science and technology. IJIAS is an open access journal that publishes papers submitted in English, French and Spanish. The journal aims to give its contribution for enhancement of research studies and be a recognized forum attracting authors and audiences from both the academic and industrial communities interested in state-of-the art research activities in innovation and applied science areas, which cover topics including (but not limited to):

Agricultural and Biological Sciences, Arts and Humanities, Biochemistry, Genetics and Molecular Biology, Business, Management and Accounting, Chemical Engineering, Chemistry, Computer Science, Decision Sciences, Dentistry, Earth and Planetary Sciences, Economics, Econometrics and Finance, Energy, Engineering, Environmental Science, Health Professions, Immunology and Microbiology, Materials Science, Mathematics, Medicine, Neuroscience, Nursing, Pharmacology, Toxicology and Pharmaceutics, Physics and Astronomy, Psychology, Social Sciences, Veterinary.

IJIAS hopes that Researchers, Graduate students, Developers, Professionals and others would make use of this journal publication for the development of innovation and scientific research. Contributions should not have been previously published nor be currently under consideration for publication elsewhere. All research articles, review articles, short communications and technical notes are pre-reviewed by the editor, and if appropriate, sent for blind peer review.

Accepted papers are available freely with online full-text content upon receiving the final versions, and will be indexed at major academic databases.

Editorial Advisory Board

Amir Samimi, Islamic Azad University, Iran
Mahsa Ja'fari, Department of Chemical Engineering, Abadan Faculty of Petroleum, Petroleum University of Technology, Abadan, Iran
Alin Velea, Paul Scherrer Institute, Switzerland
Kamyar Hasanzadeh, Aalto University, Finland
Ogbonnaya N. Chidibere, University of East Anglia, United Kingdom
Oumair Naseer, University of Warwick, United Kingdom
Wei Zheng, University of Texas Health Science Center at San Antonio, USA
Hu Zhao, University of Southern California, USA
Haijian Shi, Kal Krishnan Consulting Services, Inc, USA
Syed Ainul Abideen, University of Bergen, Norway
Fabio De Felice, University of Cassino and Southern Lazio, Italy
Giovanni Leonardi, Mediterranea University of Reggio Calabria, Italy
Siham El Gouzi, Instituto Andaluz de Ciencias de la Tierra, Spain
Mohamed KOSSAÏ, European Business School EBS Paris, France
Mustafa Batuhan AYHAN, Marmara University, Turkey
Andrzej Klimczuk, Warsaw School of Economics, Poland
Corinthias P. M. Sianipar, Tokyo University of Science, Japan
Irfan Jamil, Sinohydro Engineering, China
Sukumar Senthilkumar, Chonbuk National University, South Korea
Bratu (Simionescu) Mihaela, Bucharest University of Economic Studies, Romania
Mirela Maria Codescu, National Institute for R&D in Electrical Engineering ICPE-CA, Romania
Milen Zamfirov, St. Kliment Ohridski Sofia University, Bulgaria
Svetoslava Saeva, Neofit Rilski South-West University, Bulgaria
Dimitris Kavroudakis, University of the Aegean, Greece
Vaitsa Giannouli, Aristotle University of Thessaloniki, Greece
Nataša Pomazalová, Mendel University in Brno, Czech Republic
Hazem M. Shaheen, Damanhour University, Egypt
Shalini Jain, Manipal University Jaipur, India
Amin Jula, National University of Malaysia, Malaysia
Mahdi Moharrampour, Islamic Azad University, Buin zahra Branch, Iran
Ricardo Rodriguez, Technological University of Ciudad Juarez, Mexico
Yuniel E. Proenza Arias, Universidad de las Ciencias Informáticas, Cuba
Elizabeth Bissell Miller, University of Missouri, Columbia
Bertin Désiré SOH FOTSING, University of Dschang, Cameroon
Antonella Petrillo, University of Cassino and Southern Lazio, Italy
Hong Zhao, The Pennsylvania State University, USA
Jianjun Chen, The University of Chicago, USA
Shaju George, Royal University for Women, Kingdom of Bahrain
Chandrasekaran Subramaniam, Kumaraguru College of Technology, India
Ilango Velchamy, New Horizon College of Engineering, India
M. Kumaresan, M.P.N.M.J. Engineering College, India
Mohammad Valipour, University of Tehran, Iran
Mohameden Sidi El Vally, King Khalid University, KSA
Mona Hedayat, Boston Children's Hospital, Harvard Medical School, USA
Suresh Kumar Alla, Advanced Medical Technologies, BD Technologies, USA
Ahmed Hashim Mohaisen Al-Yasari, Babylon University, Iraq
Aziz Ibrahim Abdulla, Tikrit University, Iraq
Khalid Mohammed Shaheen, Technical College of Mosul, Iraq
Baskaran Kasi, Kuala Lumpur Infrastructure University College, Malaysia
Nurul Fadly Habidin, Universiti Pendidikan Sultan Idris, Malaysia
Adnan Riaz, Allama Iqbal Open University, Pakistan
Syed Noor Ul Abideen, KPK Agricultural University, Pakistan
Arab Karim, M'Hammed Bougara University of Boumerdes, Algeria
Zoubir Dahmani, UMAB University of Mostaganem, Algeria
Mohsen Brahmi, Sfax University, Tunisia
Mongi Besbes, University of Carthage, Tunisia
Mai S. Mabrouk, Misr University for Science and Technology, Egypt
Olfat A Diab Kandil, Misr University for Science and Technology, Egypt
Munir Ahmed G. Timol, Veer Narmad South Gujarat University, India
Saravanan Vasudevan, Arunai Engineering College, India

Table of Contents

International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 24 No. 2 Sep. 2018, pp. 773-788
© 2018 Innovative Space of Scientific Research Journals
http://www.ijias.issr-journals.org/

Impact of *Chromolaena odorata* (L.) R.M. King & H. Rob. (Asteraceae) on the floristic composition and the physico-chemical properties of the soil of a coastal relict forest

TIÉBRÉ Marie-Solange and GOULI GNANAZAN Zinsi Roseline

UFR Biosciences, Laboratory of botany, University Félix Houphouët-Boigny,
Cocody (Abidjan), 22 BP 582 Abidjan 22, Côte d'Ivoire

ABSTRACT: Biological invasions have many impacts on the composition of flora and soil chemistry. In this study, we analyzed the impacts of an invasive exotic plant, *Chromolaena odorata* on the floristic diversity and the physico-chemical composition of the soil of the Banco National Park. For this, we compared the floristic and physicochemical parameters of 4 biotopes: forests, ruderal zones without *C. odorata*, ruderal zones with a young *C. odorata* invasion and ruderal zones with an old invasion of *C. odorata*. Floristic inventories and soil samples of 0-20 cm depth were made in quadrats of 4 m^2 (2 m x 2 m) of each biotope. A total of 36 quadrats were placed due to 9 repetitions per biotope. The results showed that: Floristically, the ruderal areas with an old invasion of *C. odorata* had a low floristic richness and a low floristic diversity. In addition, the abundance of native species in these areas was reduced. At soil level, 5 chemical minerals showed significant differences. There are: organic carbon, hydrogen, exchangeable potassium, exchangeable sodium and humus. Our results also showed that areas invaded by *C. odorata* consume exchangeable potassium as they increase the exchangeable sodium concentrations in soils. Consequently, these two minerals could play an important role in the growth and colonization of environments by *C. odorata* to the detriment of native plants. Furthermore, ruderal areas with old *C. odorata* invasion were rich in chemical minerals unlike other biotopes.

KEYWORDS: Biological invasion, *Chromolaena odorata*, Floristic diversity, Physico-chemical composition, Banco National Park.

1 INTRODUCTION

Biological invasions represent a major challenge for the conservation of biodiversity. They are now considered to be one of the leading causes of biodiversity loss worldwide [1], [2] because of their impacts on local communities and ecosystems [3]. These potential impacts include changes in plant composition, significant economic losses, and adverse effects on human health [4], [5], [6], [7]. At the local level, the impact of biological invasions can be manifested by a temporary increase in species richness [8], [9]. However, this increase should not be considered beneficial for the environment as it may be accompanied by loss of endemic species or ecosystem dysfunction [8], [9]. Moreover, this apparent local increase in the number of species goes hand in hand with a decrease in species richness on a global scale, the same species tend to become dominant in different ecosystems everywhere throughout the world [8], [9]. Biological invasions can also have direct and indirect effects on soil chemistry and ecosystem function [10]. Indeed, invasive alien species can change soil composition by root exudates that affect soil structure and mobilize or chelate nutrients. The long-term impact of litter and root exudates can transform soil nutrient stores and there is evidence that invasive plant species can alter nutrient cycles differently than native species [10].

In Côte d'Ivoire, the Banco National Park is a coastal relict forest embedded in the urban area of Abidjan. This park contains many animal and plant species threatened with extinction [11], [12]. This diversity in patrimonial species gives it an importance in terms of conservation for biodiversity and mitigation of carbon. Recent studies shown that this urban forest is plagued by many anthropogenic pressures and by invasive alien species [13], [14], [15]. In fact, agricultural pressure and rapid urbanization contribute to the artificialization of the peripheral zones of the park increasing the ruderal areas. The ruderal zones group the man-influenced terrains that is to say: the edges of paths, the edges of forest massifs, the trampled areas, the wastelands, the railway tracks, the electric wire tracks and dumps, etc.). But also, the resting places of domesticated animals, stables, pens, and the edge of the watering troughs [16]. Several studies shown that invasive alien plants use ruderal areas as an access base to invade natural ecosystems [17]. *Chromolaena odorata* (L.) R.M. King & H. Rob. (Asteraceae) is a good example of a case study of the impact of biological invasions on the ruderal areas in the Banco National Park. Originally from Central America, *C. odorata* was introduced in India around 1880 and later in Malaysia and Siam from where it was found to spread to Laos, Cambodia, Vietnam and Indochina [18], [19]. It continued to expand into northeastern Australia [20]. It was introduced to Africa specifically in Nigeria around the 1940s, probably imported with seeds of *Gmelina arborea* from Ceylon or as a cover crop [21]. *C. odorata* spread widely throughout West Africa, South Africa, East Africa and Central Africa [22], [23]. It was studied throughout the world. According to [24], [25], [22], *C. odorata* has many negative impacts on farming systems, the economy, and the conservation of biodiversity. In Asia, specifically in Sri Lanka, Indonesia and Malaysia, this plant is ranked among the three most serious weeds of coconut, rubber and oil palm. *C. odorata* has been identified as the greatest threat to northern Australia, due to its rapid spread and its potential to harm agriculture and the environment [26]. In Central Africa, it is responsible of the poisoning of cattle in pastoral lands [27]. It colonizes the savannahs by rising higher than the Gramineae [28]. In Ghana, the exotic *C. odorata* shown to have a negative impact on crops and to be dominant as weed [29]. All these facts give it the status of the world's most invasive and most problematic tropical invasive species [30]. As a result, several chemical, mechanical and biological methods of fight have been applied worldwide against *C. odorata* [31], [32]. Despite these efforts, there are no proven control or management strategies to block the spread of this weed [33]. In Côte d'Ivoire, various studies were conducted on the taxonomy and the distribution of these species [34], its medicinal uses [35], [36], its agronomic potential [37], [38], [39] and its impact on species diversity [40]. However, no studies were conducted on the simultaneous impact of *C. odorata* on plant communities and ecosystems.

Studies on the impact of invasive species have so far been carried out only by considering the impact on plant communities and soil composition separately [41], [42], [43], [44]. This does not allow to understand the impact in its entirety, leading to contradictory results and conclusions of the role of a given factor in the processes and ecosystem services [45]. It becomes important to study the impact of biological invasion by considering at the same time variables on flora and soil simultaneously [45], [46] [47]. Investigating the simultaneously impact of invasive species is crucial because different ecosystem processes or services may be affected by a given factor, but in different ways [48], [49], [50], [51]. In this study, we use a combination of floristic and soil parameters to determine the impact of *C. odorata* on the ecosystem invaded. We address the following question: does the presence of *C. odorata* change the diversity and the floristic composition of the soil to the point of changing the floristic composition and the mineralogy of the ecosystems that it invades? Our main objective is to determine the changes induced by *C. odorata*. More precisely, this implies (1) to analyse the impact of *C. odorata* on the richness and floristic diversity; (2) to determine the soil parameters that fit the invasion of *C. odorata* and, (3) to analyse the changes induced by *C. odorata* on the soil and plant communities.

2 MATERIALS AND METHODS

2.1 STUDY SITE

The study took place in the city of Abidjan more precisely in the Banco National Park (5 ° 21 '-5 ° 25' N and 4 ° 1'-4 ° 5 'W). Its area is 3474 ha (Figure 1). In general, the climate is of tropical type [52] characterized by four seasons, including: two dry seasons from August to September and from December to March and two rainy seasons ranging from April to July and from October to November [53]. The average annual rainfall recorded by the SODEXAM meteorological station for the period from 2005 to 2015 is about 2000 mm. The average annual temperature is around 26 ° C with an amplitude of 4.3 ° C. The soil of the park is of the ferrasol type [54] characterized by a sandy, ferralitic soil, strongly desaturated [55]. According to Lauginie et al. (1996), this park is an evergreen forest. The dominant trees are: *Turraeanthus africanus*, *Synsepalum afzelii*, *Berlinia confusa*, *Blighia welwitschii*, *Coula edulis*, *Dacryodes klaineana*, *Lophira alata*, *Petersianthus macrocarpus* and *Piptadeniastrum africanum*. Recent studies shown that this park is subject to several anthropogenic threats including biological invasion [13], [14], [15].

2.2 BOTANICAL SURVEY

To evaluate the impact of *Chromolaena odorata* (L.) King & Robinson (Asteraceae), three sampling sites (Anonkoi, Ecotourism and N'dotre) were selected in the park. The following criteria were used: (1) homogeneous soil, (2) highly anthropogenic areas and, (3) known presence of the invasive *C. odorata*. Four biotopes were selected in each site: closed forests, ruderal zones without *C. odorata* (roadsides, under the wires), ruderal areas with young *C. odorata* invasion (populations invaded by *C. odorata* seedlings) and ruderal zones with old *C. odorata* invasion (populations invaded by old *C. odorata* plants with lignified stems, well developed and massive shrubs). Closed forests and ruderal areas without *C. odorata* served as controls. Thirty-six 4m^2 quadrats were installed, 3 quadrats for each biotope according to [56] and [57]. These quadrats were placed at random to respect the homogeneity of the environmental parameters. In each quadrat, all plant species encountered were identified. The abundance of all vascular plant species was estimated according to the [58] scale (9:> 75% abundance, 8: 50-75%, 7: 25-50%, 6: 15-25%, 5: 10-15%, 4: 5-10%, 3 <5%, 2: 2 individuals, 1: 1 individual). Unknown species were collected for the preparation of a herbarium and subsequently identified in the laboratory.

2.3 SOIL COLLECTION

Samples were made in each quadrat (four at the corner and one in the centre) at a depth of 0-20 cm with an Auger and then, mixed to form a single sample. They were air dried for 48 hours and sieved through a 2 mm sieve. Twenty-five variables were collected: P, K, Mg, Ca, Al^{3+}, H^+, organic C, CEC, total N, C/N ratio, exchangeable K, exchangeable Mg, exchangeable Na, exchangeable Ca, pH KCl, pH eau, clay, humus, index of battance, fine silt, coarse silt, total silt, fine sand, coarse sand and total sand. For pH analyses, the samples were pre-treated following the ISO11464 method. The water pH and the KCl pH were obtained with electrode measurements according to NF-ISO 10390. The concentrations of hydrogen ions (H^+) were determined from the measurement of the soil solution (the water of the soil and its dissolved substances) when measuring soil pH [59]. Determination of organic C was performed by the method of Walkley and Black [60]. Total nitrogen was determined by the Kjeldahl method [61]. Al, Ca, K, and Mg were dissolved in total solution by hydrofluoric acid and perchloric acid according to NF-ISO 14869-1. Humus was determined with a phosphoric acid solution after centrifugation and then extracted with sodium hydroxide [62]. The determination of the exchangeable bases (Mg^{2+}, Ca^{2+}, K^+, Na^+) and the CEC was carried out using the 1N ammonium acetate method at pH 7.0 according to NF-X 31-108-NF X 31-130 standard. The available phosphorus determination was extracted according to the Bray-1 procedure [63] and determined using a Technicon Auto Analyzer [64]. The samples used for texture analysis were dispersed with sodium carbonate solution (Na2CO3) and sodium exametaphosphate and pre-treated following the ISO11464 method. The granulometric analyses of the clay and silt were then carried out according to the Robinson pipette method (standard AFNOR-NF X 31-107) with a Texsol24B sedimentation automaton (LCA Instruments, France). The sand fraction was obtained by wet sieving at 200 µm. All these analyses were carried out at the Laboratory of Ecology and Soil of Gembloux Agro-Bio Tech, University of Liege in Belgium.

2.4 STATISTICAL ANALYSES

To know the floristic and the diversity richness of the different biotopes, the number of species has been determined and the Shannon (H) diversity and Piélou (E) equitability indices were calculated [65], [66]. If we denote by N the number of S species considered, or the size of the individuals of a species *i* and *Pi* (*ni / N*) the relative abundance of species *i*, then the Shannon index can be summarized as the following mathematical expression:

$$H = -\sum_{i=1}^{s} Pi \times ln\, Pi$$

The index of equitability is calculated according to the following mathematical formula:

$$E = \frac{H}{ln\, S}$$

with H = Shannon index; S = total number of species of a given biotope; ln S = the maximum diversity of the biotope. The software MVSP version 3.1. was used for the treatment of his floristic data.

To show significant differences between the numbers of species encountered by biotope and to compare the most significant soil parameters discriminating biotopes, a one-way ANOVA followed by pairwise comparisons with post hoc Tukey-HSD tests been realized. The Kruskal-Wallis test was also used to compare Shannon indices and regularity indices for the different biotopes. Whenever the difference was significant, the Dunn test was performed to compare the averages and to assess significant differences between them. To measure the relationship between the *C. odorata* and the other species, a Pearson correlation test was used. Averages are given with their standard deviation. To evaluate the most appropriate floristic and edaphic parameters that characterize each biotope, all data collected were subjected to a Multiple Factor Analysis (MFA). The MFA is a factorial method of multidimensional descriptive statistics. It allows to balance the influence of the various groups because if a group presents many variables, it may influence the total analysis than another presenting few variables [67]. These analyzes were performed using XLSTAT 2014.5.03 (Addinsoft, France) and R version 3.2. (Foundation R).

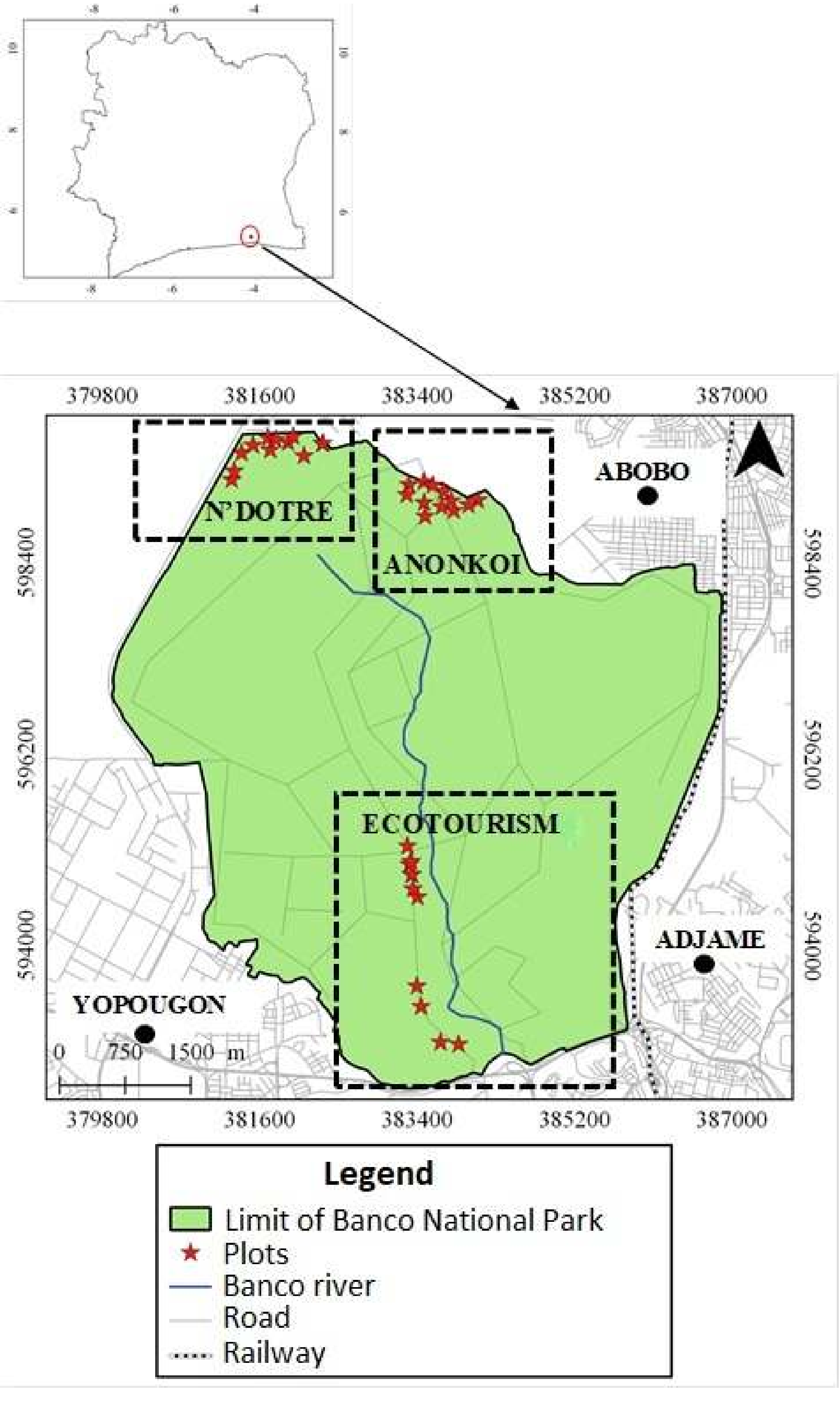


Fig. 1. Location of the Banco national park with sampling sites

3 RESULTS

3.1 IMPACT OF *C. ODORATA* ON THE SPECIFIC RICHNESS AND THE FLORISTIC DIVERSITY

In this study, a total of 147 species were inventoried. Sixty-six (66) species were found in forest zone, 67 species in ruderals without *C. odorata*, 72 species in ruderals with young *C. odorata*, and 50 species in ruderals with old *C. odorata*. These species were divided into 118 genera and 57 families. The most important families are Fabaceae (21 species), Malvaceae and Poaceae (9 species, each). The most important genera are *Dichapetalum* (4 species), *Adenia*, *Baphia*, *Cola* and *Culcasia* (3 species, each). Seventeen species (17) with status were identified including 5 endemic species to the West African Forest Block (GCW), 4 endemic species to Côte d'Ivoire, 3 plants cited as rare and/or threatened with extinction from Ivorian flora [68], and 6 plants cited on the International Union for Conservation of Nature (IUCN) Red List [69]. The endemic species to the West African Forest Block are *Afzelia bella* Harms var. *gracilior* Keay, *Albertisia scandens* (Mangenot & Miège) Forman, *Chassalia afzelii* (Hiern) K. Schum., *Neuropeltis prevosteoides* Mangenot et *Platysepalum hirsutum* (Dunn) Hepper. The endemic species to Côte d'Ivoire are *Albertisia cordifolia* (Mangenot & Miège) Forman, *Baphia bancoensis* Aubrév., *Leptoderris miegei* Aké Assi & Mangenot et *Rhigiocarya peltata* Miège. The 3 species cited as rare and/or threatened with extinction from Ivorian flora are *Buxus acutata* Friis, *Cola heterophylla* (P. Beauv.) Schott & Endl. et *Rhigiocarya peltata* Miêge. The 6 species on IUCN red list are *Acroceras zizanioides* (Kunth) Dandy, *Albizia adianthifolia* (Schum.) W. F. Wright, *Baphia nitida* Lodd, *Culcasia dinklagei* Engl., *Paspalum scobiculatum* L. var. *scrobiculatum* et *Turraeanthus africanus* (Welw. ex C. DC.) Pellegr) (Table 1). The mean value of species richness of old *C. odorata* invasion (11.22 ± 3.12) differed significantly from that of young *C. odorata* invasion (15.55 ± 2.98) (Anova test $F = 2.75$, $P < 0.001$). The forests and ruderals without *C. odorata* had intermediate mean values of specific richness (Table 2). The lowest mean value of the Shannon index is obtained in ruderal zones with old *C. odorata* invasion (1.05 ± 0.17). The highest one is obtained in ruderal zones without *C. odorata* (2.28 ± 0.17). The difference between these mean values is statistically significant ($F = 10.37$, $P < 0.05$). When considering the different biotopes, the equitability index varies from 0.43 ± 0.11 in ruderal areas with old invasion of *C. odorata* at 0.88 ± 0.24 in ruderal without *C. odorata*. The differences between these mean values are statistically significant ($\chi^2 = 19.26$, $P < 0.05$) (Table 2). A significant relationship was found between the cover *C. odorata* and that of the other plant species ($r = -0.93$, $P < 0.001$ for ruderal areas with young *C. odorata* invasion and $r = -0.99$, $P < 0.0001$ for ruderal areas with old *C. odorata* invasion) (Figure 2).

Table 1. List of 17 species with status identified in the Banco national park

		Status			**Number of species per biotope**			
N° Specie	Families	Geographic distribution	Aké-Assi (1998)	UICN (2015)	Forest	Ruderals	Young *C. odorata*	Old *C. odorata*
1. *Acroceras zizanioides* (Kunth) Dandy	Poaceae	-	-	LC	-	X	X	X
2. *Afzelia bella* Harms var. gracilior Keay	Fabaceae	GCW	-	-	X	-	-	-
3. *Albertisia cordifolia* (Mangenot & Miège) Forman	Mennispermaceae	GCi	-	-	X	X	X	X
4. *Albertisia scandens* (Mangenot & Miège) Forman	Mennispermaceae	GCW	-	-	X	X	X	-
5. *Albizia adianthifolia* (Schum.) W.F. Wright	Fabaceae	-	-	LC	X	X	X	-
6. *Baphia bancoensis* Aubrév.	Fabaceae	GCi	-	-	X	X	X	-
7. *Baphia nitida* Lodd.	Fabaceae	-	-	LC	X	X	X	-
8. *Buxus acutata* Friis	Buxaceae	-	PRE	-	X	-	-	-
9. *Chassalia afzelii* (Hiern) K. Schum.	Rubiaceae	GCW	-	-	X	X	X	-
10. *Cola heterophylla* (P. Beauv.) Schott & Endl.	Malvaceae	-	PRE	-	X	X	X	-
11. *Culcasia dinklagei* Engl.	Araceae	-	-	LC	X	-	-	-
12. *Leptoderris miegei* Aké Assi & Mangenot	Fabaceae	GCi	-	-	-	X	X	-
13. *Neuropeltis prevosteoides* Mangenot	Fabaceae	GCW	-	-	X	-	-	-
14. *Paspalum scobiculatum* L. var. scrobiculatum	Poaceae	-	-	LC	-	X	X	-
15. *Platysepalum hirsutum* (Dunn) Hepper	Fabaceae	GCW	-	-	X	X	-	-
16. *Rhigiocarya peltata* Miège	Mennispermaceae	GCi	PRE	-	X	X	X	X
17. *Turraeanthus africanus* (Welw. ex C. DC.) Pellegr.	Meliaceae	-	VU	-	X	-	-	-
Total number of species by biotope					14	12	11	3

VU: vulnerable; PRE: rare, endangered and threatened with extinction plants; LC: minor concern; Aké-Assi: status according to Aké-Assi (1998); GCW: endemic to the West African forest block, including Ghana, Côte d'Ivoire, Liberia, Sierra Leone, Guinea, Guinea Bissau, Gambia and Senegal.

Table 2. Mean and standard deviation of species richness, Shannon diversity and equitability indices of the different biotopes studied in the Banco National Park

	Old *Chromolaena*	Young *Chromolaena*	Forests	Ruderals	Anova and Kruskall-Wallis tests statistics
Specific richness	11,22 ± 3,12^{a}	15,55 ± 2,98^{b}	13,55 ± 2,27^{ab}	13,44 ± 2,27^{ab}	*F* = 2,75***
Shannon's index	1,05 ± 0,17^{a}	2,04 ± 0,17^{b}	2,07 ± 0,17^{b}	2,28 ± 0,17^{b}	*F* = 10,37
Equitability index	0,43 ± 0,11^{a}	0,74 ± 0,13^{ab}	0,80 ± 0,14^{b}	0,88 ± 0,24^{b}	19,26***

*The same superscript letter indicates no significant difference between species. Comparisons between taxa were performed using one-way ANOVA followed by the Tukey-HSD test. Comparisons between taxa were made using a Kruskal-Wallis test followed by Dunn's test for equitability index. * P < 0,05 for Shannon diversity index. *** P < 0,001 for species richness and equitability index*

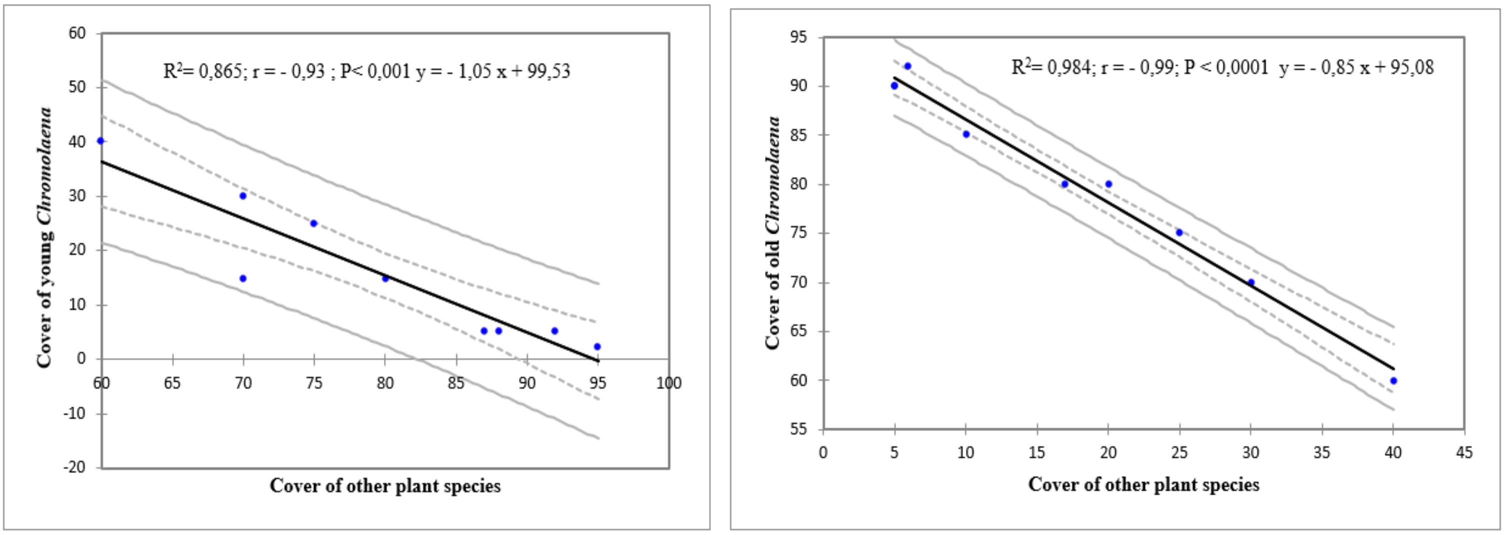


Fig. 2. The relationship between the cover of young and old C. odorata and the cover of the other plant species. A Pearson correlation test was used for linear regression

3.2 IMPACT OF *C. ODORATA* ON THE PHYSICO-CHEMICAL PROPERTIES OF SOIL

Table 3 summarizes the statistics of the 25 soil variables obtained in the four biotopes after soil analysis. Five (5) soil variables such as: organic carbon, hydrogen, exchangeable potassium, exchangeable sodium and humus showed significant differences between the means of concentration from one biotope to another (organic C, *F* = 5.24, *P* <0.001, H$^+$, *F* = 11.62, *P* <0.001, exchangeable K, *F* = 55.73, *P* <0.001, exchangeable Na, *F* = 71.07, *P* <0.001; humus, *F* = 5.26, *P* <0.001) (Table 3). These results indicated that organic C was as high in forests as in ruderal areas with invasion of *C. odorata*. H$^+$ was high in forests but low in the other biotopes. The exchangeable K was high in the ruderal zones with a young invasion of *C. odorata* and decreased in the ruderal zones with old invasion of *C. odorata*. However, it was low in forests and ruderal areas without *C. odorata*. The exchangeable Na was high in the ruderals with old *C. odorata* invasion and decreased in the areas with a young *C. odorata* invasion. However, it was low in forests and very low in ruderal areas without *C. odorata*. Finally, humus was high in forests as in ruderal areas with invasion of *C. odorata*.

The results of the multiple factor analysis (AFM) of the floristic and physico-chemical properties of soil confirmed these results. The two principal axes explained 43% of the variation (Figure 3). This analysis showed the floristic and edaphic parameters best adapted to each biotope. As a result, the first axis was correlated with floristic diversity and soil mineral elements. It separated the forest zones from the ruderals. This axis described on the positive side the forests that were not linked to any locality and in its negative part the ruderal zones with old invasion of *C. odorata* which are generally found in the locality of N'dotre and the ruderal zones with and without young *C. odorata* founded in the localities of Ecotourism and Anonkoi. The second axis was correlated with the organic elements of the soil. He separated the ruderal areas with old invasion of *C. odorata* from other biotopes. The forests, the ruderals without *C. odorata* and the ruderals with a young *C. odorata* invasion are characterized by a good diversity but a poverty in chemical elements of the soil. The ruderal zones with old *C. odorata* invasion are characterized by a low floristic diversity but a richness in chemical elements of the soil. They were correlated with total N, CEC, exchangeable Mg, exchangeable Ca, P, exchangeable K, C/N ratio and exchangeable Na.

4 DISCUSSION

Research on the impact of invasive plants is crucial to guide decision-making to reduce the costs of invasions and, in some cases, to improve their benefits [70]. However, few studies have been conducted around the world on the impacts of invasions by simultaneously considering flora and soil [46], [42], [71], [43], [44]. In this study, we use vegetation and soil parameters to better understand the impacts of *C. odorata* in the Banco National Park. To our knowledge, this study is the first to be conducted in Côte d'Ivoire.

At the floristic level, ruderals zones are generally of very low interest because they are not very diversified in species [72]. Most of the species that grow there are considered "weeds". Moreover, these environments are often very open, disturbed by human activities [16]. We usually find heliophilous and colonizing species. Several authors confirm that these environments are used by invasive alien plants to invade natural ecosystems [17], [73]. In the Banco National Park, studies have shown that this park is subject to invasion [14], [15]. Among the most cited species we can cited: *Hopea odorata* (Dipterocarpaceae), *Chromolaena odorata* (Asteraceae), *Tithonia diversifolia* (Asteraceae), etc. In this study, we asked ourselves the question of the level of qualitative and quantitative diversity of the ruderal areas of the BNP? BNP is a protected area subject to intense anthropogenic pressures such as pollution, tourism, electricity lines, etc. [13], who participate in the increase of ruderal areas in this conservation area. Our study has shown that these ruderal areas are as floristically rich as forests. The diversity of the species encountered is certainly not the same because more heliophilous but quantitatively the two areas are very rich. There are even species with special status, of great importance for the Ivorian flora. This is probably due to the fact that unlike other ruderal open areas, this has the advantage of being located in a biological conservation area [72], [74]. Thus, several studies have shown that invasive plants reduce the floristic richness and diversity of native species [75], [76], [77], [78], [79], [80], [81], [82]. Our study confirms this trend. In this study, ruderal areas with an old invasion of *C. odorata* had a very low species richness compared to the other biotopes. We also found that the diversity of native species was negatively affected by the invasion of old *C. odorata*. This confirms the hypothesis that the invasion of by plant causes a change in the abundance of other species [83], [84] showed that high rates of *C. odorata* prevented enrichment of summer fallow flora. Then, [22] have shown that *C. odorata* reduces the abundance of native plants. Our study thus confirms that the presence of *C. odorata* in the ruderal zones modifies the richness and the floristic diversity of the native species by reducing their abundance.

Table 3. Summary statistics of different soil variables per biotope

	Forests				**Ruderals**				**Young *Chromolaena***				**Old *Chromolaena***			
Factor	Average	Sd	CV	Ran	Average	Sd	CV	Ran	Average	Sd	CV	Ran	Average	Sd	CV	Ran
P (mg/100g)	0.63a	0.74	1.17	2.4	0.42a	0.29	0.69	0.9	0.7a	0.5	0.71	1.8	4.37a	11.33	2.59	36.2
K (mg/100g)	0.91a	0.69	0.76	2	1.32a	0.58	0.44	2.3	1.21a	0.64	0.53	2	1.62a	0.62	0.38	2.4
Mg (mg/100g)	1.89a	0.76	0.4	2.2	1.61a	0.57	0.35	1.9	1.81a	1.58	0.87	5.6	3.15a	2.66	0.84	9.5
Ca (mg/100g)	5.22a	3.7	0.71	11.8	17.48a	18.68	1.07	63	28.97a	58	2	190.4	51.21a	101.57	1.98	333.7
pH KCl	3.59a	0.17	0.05	0.6	4.42a	0.6	0.14	2	4.3a	0.9	0.21	3	4.44a	0.77	0.17	2.5
Total N (mg/100g)	0.1a	0	0	0	0.1a	0	0	0	0.08a	0.04	0.5	0.1	0.1a	0.05	0.5	0.2
Organic C (g/kg)	14.36 ± 1.25b	1.03	0.07	2.35	8.91 ± 0.84a	0.69	0.08	1.67	9.88 ± 2.02ab	1.65	0.17	4.02	12.21 ± 2.69ab	2.2	0.18	4.79
pH (H2O)	4.39a	0.15	0.03	0.35	5.26a	0.2	0.04	0.5	5.29a	0.8	0.15	1.72	5.53a	0.71	0.13	1.6
CEC (méq/100)	2.33a	0.35	0.15	0.86	1.8a	0.34	0.19	0.8	2.46a	0.97	0.39	2.34	3.72a	2.96	0.79	6.82
C/N	13.54a	0.87	0.06	2.6	13.22a	0.94	0.07	2.6	13.93a	0.6	0.04	1.9	13.43a	1.3	0.1	4.5
Al 3+ (méq/100)	3.79a	0.23	0.06	0.7	3.67a	0.25	0.07	0.7	3.86a	0.16	0.04	0.5	3.74a	0.37	0.1	1.3
H+ (mg/100g)	0.74 ± 0.08b	0.14	0.19	0.5	0.35 ± 0.06a	0.08	0.23	0.3	0.41 ± 0.07a	0.11	0.27	0.3	0.41 ± 0.12a	0.14	0.34	0.5
K ech (mg/100g)	2.16 ± 0.93a	1.44	0.67	3.8	0.88 ± 0.42a	0.48	0.54	1.5	10.13 ± 1.48c	2.48	0.24	7.3	5.58 ± 0.65b	2.07	0.37	5.6
Mg ech (mg/100g)	3.18a	1.08	0.34	3.4	2.71a	0.6	0.22	2.3	2.3a	1.59	0.69	5.5	5.33a	4.64	0.87	16.3
Ca ech (mg/100g)	4.78a	6.33	1.32	15.9	12.75a	11.04	0.86	38.1	25.52a	51.1	2	171.3	49.15a	84.96	1.73	281.6
Na ech (mg/100g)	1.28 ± 0.17b	1.28	1	3.8	0.21 ± 0.03a	0.24	1.14	0.7	2.04 ± 0.38c	0.55	0.27	1.8	2.97 ± 0.26d	0.62	0.21	2
(%) Humus	2.87 ± 0.25b	0.21	0.07	0.47	1.78 ± 0.17a	0.14	0.08	0.34	1.97 ± 0.40ab	0.33	0.17	0.8	2.44 ± 0.54ab	0.44	0.18	0.96
(%) Clay	10.77a	1.7	0.16	4.11	8.79a	1.44	0.16	3.06	8.95a	2.18	0.24	4.68	8.67a	0.39	0.04	0.87
(%) Fine silt	2.03a	0.19	0.09	0.44	2.35a	0.46	0.19	1.11	1.99a	0.37	0.18	0.78	2.23a	0.31	0.14	0.76
(%) Coarse silt	1.27a	0.19	0.15	0.43	1.11a	0.31	0.28	0.75	0.99a	0.17	0.17	0.38	1.11a	0.01	0.01	0.01
(%) Total silt	3.29a	0.23	0.07	0.49	3.47a	0.36	0.1	0.77	2.98a	0.34	0.11	0.83	3.34a	0.31	0.1	0.77
(%) Fine sand	17.76a	2.68	0.15	6.51	18.13a	1.13	0.06	2.54	15.96a	2.72	0.17	5.97	14.75a	1.58	0.11	3.84
(%) Coarse sand	68.17a	4	0.06	8.51	69.62a	1.13	0.02	2.77	72.11a	4.69	0.06	11.48	73.23a	1.41	0.02	3.38
(%) Total sand	85.93a	1.88	0.02	2.63	87.74a	1.66	0.02	3.84	88.07a	2.48	0.03	5.51	87.98a	0.53	0.01	1.3
Index of battance	0.1a	0.01	0.1	0.01	0.16a	0.03	0.19	0.08	0.13a	0.01	0.08	0.03	0.13a	0.02	0.15	0.06

Sd : Standard deviation ; CV : coefficient of variation ; Ran: Range. The same superscript letter within a line indicates no significant difference between species. Comparisons between taxa were performed using one-way ANOVA followed by the Tukey-HSD test

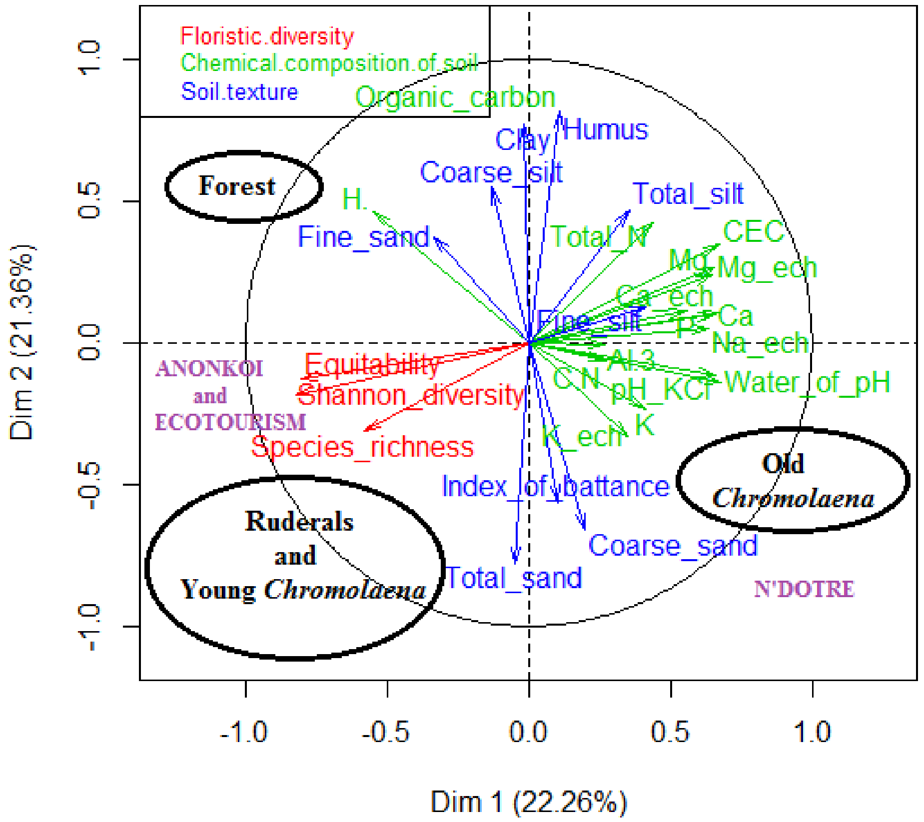


Fig. 3. Multiple Factorial Analysis (MFA) of the four biotopes of the Banco national park based on floristic and soil parameters. The qualitative variables include the modality (presence / absence of Chromolaena), the type of biotopes (forests, ruderals without C. odorata and ruderals with young and old C. odorata) and the sampling areas (Anonkoi, Ecotourism, N'dotre). The quantitative variables include the 25 chemical and granulometric soil parameters, the species richness, the Shannon and the equitability indices of each quadrat. This analyses was performed using R version 3.2. (R foundation).

At soil level, in this study, 5 soil variables were discriminated to separate the biotopes. The organic C content informs on the level of soil fertility [83]. It is therefore an important criterion. Our results showed that the ruderals areas without *C. odorata* were poor in organic C. But, the invaded zones by *C. odorata* were as rich in organic carbon as in forests. This means that *C. odorata* brings organic C to the soils they invade. [76], [38], and [39] demonstrated an increase in soil organic C in *C. odorata* fallows. Humus is the set of surface layers containing organic matter [86]. It is essential for the stability and fertility of a soil. Humus feeds plants with the nutrients they need, when they need them [87]. Our results also showed that ruderal areas without *C. odorata* were poor in humus. However, the areas invaded by *C. odorata* were as rich in humus as in the forests. We can also say that *C. odorata* brings humus to the soils they invade. Thus, our results are consistent with those of several authors who have demonstrated that *C. odorata* significantly improves the mineral and organic fertility of the upper horizons of poor soils [88], [89], [90]. Na provides an indication of soil salinity [91], [92]. Exchangeable Na was elevated in ruderal areas with old *C. odorata* invasion and decreased in ruderal areas with young *C. odorata* invasion. However, it was low in forests and very low in ruderal areas without *C. odorata*. This would mean that *C. odorata* brings Na to the soils they invade, or that soils invaded by *C. odorata* have a higher salinity. These results are corroborated by the work of [76] who found that soil invasion by *C. odorata* increased Na levels in these soils. Exchangeable K is the form easily accessible to plants [93]. It is a major mineral element for the development and growth of plants. Our results demonstrated that exchangeable potassium is high in ruderal areas with young *C. odorata* invasion and decreases in ruderal areas with old *C. odorata* invasion. However, it is low in forests and ruderal areas without *C. odorata*. This suggests that the areas invaded by *C. odorata* consume a lot of K from which there is a decrease of K in these environments. Contrary results have been found by other authors [76], [94]. Instead, they showed that *C. odorata* soil invasion increased K levels in the soil. Our results also showed that the ruderal zones with old *C. odorata* invasion were characterized by a richness in chemical minerals whereas the other biotopes were characterized by a poverty in these chemical minerals. These results are like those [37], [38] who demonstrated that soils invaded by *C. odorata* resulted in a significant improvement in nutrient availability and soil biological activity. Other studies have also shown that *C. odorata* can maintain and improve soil fertility ([95], [34], [96], [94]). Thus, we can say that *C. odorata* enriches the soil that it invades by making available in the soil several mineral elements.

Relationship between flora and soil of *C. odorata* invaded areas.

Our results showed that there was a correlation between flora and soil environments invaded by *C. odorata*. Indeed, *C. odorata* invaded areas had low floristic diversity while they were rich in chemical soil minerals. However, in addition to the role of other soil minerals, our results allow us to say that exchangeable K and exchangeable Na could play a significant role in the relationship between flora and soil of *C. odorata* invaded environments. The richness of the ruderal areas with young *C. odorata* invasion in exchangeable K and the high consumption of this mineral in the ruderal zones with old invasion of *C. odorata* make us say that a ruderal zone rich in exchangeable K could attract *C. odorata*. Exchangeable K has a major role in plant development because it allows them to resist induced stress, such as drought, frost, excess brightness and pest attack. Plants that are deficient in K are more sensitive to these forms of stress [97], [98]. This mineral could therefore play an important role in growth and colonization *C. odorata* to the detriment of native plants. Similarly, the exchangeable Na being higher in the ruderal zones with old invasion of *C. odorata*, it gives us an account of the increase of the salinity in the soil invaded by *C. odorata*. However, this increase in soil salinity could modify the physical and mechanical properties of soils, which could affect plant development [99]. The influence on the development of plants would be to the advantage of *C. odorata* plants and to the disadvantage of native plants, hence the low floristic richness and diversity in the areas invaded by *C. odorata*. Also, some authors who have tried to explain the low floristic richness and diversity in the invaded areas have rather talked about the mechanism of negative feedback exerted by the microbial community of the soil in the invaded areas which could have an essential role in the replacement of native species. An important regulator of community structure is the ability of plants to change the soil of microbial communities [100]. [101], reported that *C. odorata* can accumulate high soil concentrations which generates fungal pathogens (*Fusarium spp*.) responsible for creating negative feedback on native plant species and concluded that that the impact of *C. odorata* is due to the biotic interactions between native plants and the biotic community of the soil.

5 CONCLUSIONS

At the end of this study, we can say that the invasion of area by *C. odorata* causes negative consequences on the level of the flora which translate into a poverty in richness and floristic diversity. However, the invasion of area by *C. odorata* has positive consequences on the soil because *C. odorata* contributes to a significant improvement of the chemical properties of the soil. There is also a significant relationship between flora and soil environments invaded by *C. odorata*. Areas invaded by *C. odorata* consume exchangeable K while increasing exchangeable Na unlike other biotopes. These two minerals could therefore play an important role in the growth and colonization of environments by *C. odorata* to the detriment of native plants. Our study showed that invasion of ruderal areas with an old *C. odorata* invasion was very pronounced in N'dotre unlike other sampling sites. The N'dotre site is in the northern part of BNP. This site constitutes the most anthropized zone of the park, where the influence of the man is deeply exerted. This area could be a starting point for the control of this invasive species.

ACKNOWLEDGMENTS

This study was funded by the International Foundation for Science (IFS) through the Carolina Mac Gillavry Award for Dr. Marie-Solange Tiébré within the research project "Individual Grant Number J / 5728-1". We would like to thank the Water - Soil - Plant Exchanges and the Biodiversity and Landscape Unit of the Gembloux Agro-Bio Tech, University of Liege in Belgium, for the help for soil and plant analyses. Our thanks also go to the Ivorian Office of Parks and Reserves (OIPR) for permission to conduct this study in the Banco National Park (BNP).

REFERENCES

[1] C. M. D'Antonio and S. Kark, "Impacts and extent of biotic invasions in terrestrial ecosystems", *Tree*, no. 17, pp. 202-204, 2002.

[2] C. M. D'Antonio and L. A. Meyerson, "Exotic plant species as problems and solutions in ecological restoration: a synthesis", *Restoration Ecology*, vol. 10, no. 4, pp. 703–713, 2002.

[3] J. M. Levine, "Biological invasions", *Current Biology*, no. 18, pp. 57-60, 2008.

[4] D. G. Cory, R. Laflamme, E. Knill, L. Viola, T. F. Havel, N. Boulant and C. Negrevergne, NMR based quantum information processing: Achievements and prospects, arXiv preprint quant-ph/0004104, 2000.

[5] C. S. Kolar and D. M. Lodge, "Progress in invasion biology: predicting invaders", *Trends in Ecology & Evol*ution, no. 16, pp. 199-204, 2001.

[6] D. L. Pimentel, K. Lach, Zaniga and D. Morrison, “Environnemental and economic cost of nomardegenous species in the United States”, *Biosciences*, vol. 50, pp. 53-65, 2000.

[7] F. Selvi, E. Carrari and A. Coppi,” Impact of pine invasion on the taxonomic and phylogenetic diversity of a relict Mediterranean forest ecosystem”, *Forest Ecology Management*, no. 367, pp. 1–11, 2016.

[8] M. L. McKinney and J. L. Lockwood, “Biotic Homogeneization : a few winners replacing many losers in the next mass extinction”, *Trends in Ecology & Evolution*, no. 14, pp. 450-453, 1999.

[9] D. F. Sax and S. D. Gaines, “Species diversity: from global decreases to local increases”, *Trends in Ecology & Evolution*, pp. 561-566, 2003.

[10] D. J. Weidenhamer and M. R. Callaway,“Direct and Indirect effects of Invasive Plants on Soil Chemistry and Ecosystem Function”, *Chemical Ecology*, no. 36, pp. 59-69, 2010.

[11] E. A. Bitty, B. Kadjo, S. Gonedele Bi, O. M. Okon and K. P. Kouassi, "Inventaire de la faune mammalogique d’une forêt urbaine, le Parc National du Banco, Côte d’Ivoire”, *International Journal of Biological and Chemical Sciences*, vol. 7, no. 4, pp. 1678- 1687, 2013.

[12] J. D. Mèmèl, M. Karamoko, A. Otchoumou and D. K. Kouassi, "Abondance, taille et mortalité des escargots terrestres du Parc National du Banco (Côte d’Ivoire) : effet de la composition granulométrique et chimique du sol ", *Livestock Research for Rural Devolopment*, vol. 23, no. 9, pp. 6, 2011.

[13] N. Sako, G. Beltrando, K. L. Atta, N. H. Dibi and T. Brou "Dynamique forestière et pression urbaine dans le Parc National du Banco (Abidjan, Côte d’Ivoire)", *VertigO*, vol. 13, no. 2, PP. 12, 2013.

[14] M. S. Tiébré, K. Djaha, B. T. A. Vroh, K. D. N’Da and C. Y. Adou Yao, " Stratégies et potentiel d’invasion des massifs forestiers par *Hopea odorata* Roxb. (Dipterocarpaceae) : cas du Parc National du Banco en Côte d’Ivoire", *International Journal of Biological and Chemical Sciences*, vol. 8, no. 2, pp. 666-679, 2014.

[15] M. S. Tiébré, B. T. A. Vroh, D. Kouamé, K. D. N’Da and C. Y. Adou Yao, " Effets d’un arbre exotique envahissant *Hopea Odorata* Roxb. (Dipterocarpaceae) sur la diversité floristique et le stockage de carbone du Parc National du Banco en Côte d’Ivoire", *International Journal of Innovation and Applied Studies*, vol. 10, no. 1, pp. 207-278, 2015.

[16] C. Brun, Archéophytes et néophytes pour une nouvelle détermination des marqueurs polliniques de l’anthropisation. Le cas des milieux cultivés et rudéraux de Franche-Comté. Thèse de Doctorat de l’Université de Franche-Comté (France), pp. 430, 2007.

[17] H. Dietz and P. J. Edwards, " Recognition that causal processes change during plant invasion helps explain conflicts in evidence", *Ecology*, vol. 87, no. 6, pp. 1359-67, 2006.

[18] G. Ali-Amara, L’herbe, du Laos : *Chromolaena odorata* (l) R.M. King et H. Robinson (Asteraceae) en République Centrafricaine. Essais de lutte avec des herbicides. Thèse de Doctorat d’état, vétérinaire, Université Cheikh Anta Diop de Dakar (Sénégal), pp. 114, 1992.

[19] J. Audru, M. Berekoutou, M. Deat, G. De Wilspeare, F. Du Four, O. Kintz, A. Le masson, P. Menozu and O. Rojat, L'herbe du laos : *Chromolaena odorata* (L.) R. M. King et H. Robinson- Synthèse des connaissances et des acquis expérimentaux et établissement d'un programme d'intervention. Etude préparatoire.1. E. M.V.T, Ministère du Développement Rural de la République Centrafricaine, Alfort, pp. 268, 1988.

[20] B. Waterhouse, " Discovery of in Northern Queensland, Australia. *Chromolaena odorata*", *Newsletter*, vol. 9, pp. 12, 1994.

[21] J. Mouloungou and J. C. Sigrist, *Chromolaena odorata,* rapport de stage. CNEARC, France, pp. 30, 1993.

[22] R. T. Shackleton, A. B. R. Witt, W. Nunda and D. M. Richardson (2016) " *Chromolaena odorata* (Siam Weed) in Eastern Africa: Distribution and Socio-Ecological Impacts", *Biological Invasions*, pp. 1-14, 2016.

[23] K. Usha, R. Prasad, P. Muniappan, J. P. Ferrar, Aeschliman and H. De Foresta, Répartition, écologie et gestion de *Chromolaena odorata*. Comptes Rendus du Troisieme Atelier International sur *Chromolaena* Abidjan, Cote d'Ivoire, November 1993. Agricultural Experiment Station University of Guam, Mangilao, GUAM, USA Publication n° 202, pp. 213, 1996.

[24] T. I. Borokini and F. D. Babalola, " Management of invasive plant species in Nigeria through economic exploitation: lessons from other countries", *Management of Biological Invasions*, vol. 3, no. 1, pp. 45-55, 2012.

[25] S. Lowe, M. Browne, S. Boudjelas and M. De Poorter, 100 of the world’s worst invasive alien species: a selection from the global invasive species database. Vol. 12. Invasive Species Specialist Group Auckland, 2000.

[26] P. W. Michael, Review paper on weeds of concern to northern Australia. Unpublished Report to AQIS. Canberra, June, 1989.

[27] G. Achoundong, J. YoutaHappi, J. Bonvallot and B. Guillet, Formation et évolution des recrûs en savane. In Dynamique des Ecosystèmes Forestiers Intertropicaux. Ed Orstom-CNRS: Paris; pp. 115-119, 2000.

[28] B. Ngotta Biyon, M. Tchatat, E. S. Mokake and D. S. Dibong, " Origine et impact du chenal Tchad-Cameroun sur la propagation de *Chromolaena odorata* (L.) R. M. King and H. Robinson (Asteraceae) de Meiganga à Touboro", *International Journal of Biological and Chemical Science*, vol. 8, no. 1, pp. 57-65, 2014.

[29] A. K. Anning, K. Yeboah-Gyan, "Diversity and distribution of invasive Weeds in Ashanti Region, Ghana", *African Journal of Ecology*, vol. 45, no. 3, pp. 355-360, 2007.

[30] E. M. Lavabre, Le désherbage des cultures tropicales. Le technicien d'agriculture tropicale. ACCT et CTA, édition Maisonneuve et Larousse, Paris France, pp. 127, 1988.

[31] J. A. Timbilla, C. Zachariades and H. Braimah, Biological control and management of the alien invasive shrub, *Chromolaena odorata* in Africa. In: Neuenschwander P, Borgemeister C, Langewald J (eds) Biological control in IPM systems in Africa. CABI, London, pp 145-160, 2003.

[32] C. Zachariades, S. Janse van Rensburg and A. Witt, Recent spread and new records of *Chromolaena odorata* in Africa. In: Zachariades, C., Strathie, L.W., Day, M.D., Muniappan, R. (Eds.), Proceedings of the Eighth International Workshop on Biological Control and Management of *Chromolaena odorata* and other Eupatorieae. Nairobi, Kenya, 1–2 November 2010. ARC-PPRI, Pretoria, pp. 20-27, 2013.

[33] S. O. Dahunsi, S. Oranusi, J. B. Owolabi and V. E. Efeovbokhan, "Synergy of Siam weed (*Chromolaena odorata*) and poultry manure for energy generation: Effects of pretreatment methods, modeling and process optimization", *Bioresource Technology*, vol. 225, pp. 409-417, 2017.

[34] L. Gautier, "Taxonomy and distribution of a tropical weed: *Chromolaena odorata* (L.) R. King and Robinson", *Candollea*, vol. 47, pp. 645-662, 1992.

[35] K. Béné, D. Camara, N. B. Y. Fofie, Y. Kanga, A. B. Yapi, Y. C. Yapo, S. A. Ambe and G. N. Zirihi, "Étude ethnobotanique des plantes médicinales utilisées dans le Département de Transua, District du Zanzan (Côte d'Ivoire)", *Journal of Animal &Plant Sciences*, vol. 27, no. 2, pp. 4230-4250, 2016.

[36] K. N'Guessan, F. H. Tra Bi and M. W. Koné, "Étude ethnopharmacologique de plantes antipaludiques utilisées en médecine traditionnelle chez les Abbey et Krobou d'Agboville (Côte d'Ivoire)". *Ethnopharmacologia,* vol. 44, pp. 42-50, 2009.

[37] E. F. Edoukou, A. W. Koné and J. E. Tondoh, "Les jachères à base de *Chromolaena odorata* (Asteraceae) et de légumineuses ont-elles les mêmes potentialités agronomiques?", *Étude & Gestion des Sols*, vol. 20, no. 2, pp. 9-106, 2013.

[38] A. W. Koné, E. F. Edoukou, J. T. Gonnety, A. N. A. N'Dri, L. F. E. Assémien, P. K. T. Angui and J. E. Tondoh, "Can the shrub *Chromolaena odorata* (Asteraceae) be considered as improving soil biology and plant nutrient availability?", *Agroforestry System*, vol. 85, pp. 233-245, 2012.

[39] E. J. Tondoh, W. A. Koné, K. J. N'Dri, L. Tamene and D. Brunet "Changes in soil quality after subsequent establishment of *Chromolaena odorata* fallows in humid savannahs, Ivory Coast", *Catena*, vol. 101, pp. 99-107, 2013.

[40] K. H. Kouassi, K. N'Guessan, G. M. Gnahoua and D. Traore, "Dynamique de *Chromolaena odorata* (l.) r. m. king & h. rob. et évolution de la richesse floristique au cours de la reconstitution de la flore postculturale en zone de forêt semi-décidue de côte d'ivoire", *Agronomie Africaine*, vol. 20, no. 3, pp. 257-265, 2008.

[41] A. M. McCary, R. Mores, A. M. Farfan and H. D. Wise, "Invasive plants have different effects on trophic structure of green and brown food webs in terrestrial ecosystems: a meta-analysis", *Ecological Letters*, vol. 19, pp. 328-335, 2016.

[42] S. Medina-Villar, S. Rodríguez-Echeverría, P. Lorenzo, A. Alonso, E. Perez-Corona and P. Castro-Díez, "Impacts of the alien trees *Ailanthus altissima* (Mill.) Swingle and *Robinia pseudoacacia* L. on soil nutrients and microbial communities", *Soil Biology & Biochemistry*, vol. 96, pp. 65-73, 2016.

[43] S. Vanderhoeven, N. Dassonville and P. Meerts, "Increased topsoil mineral nutrient concentrations under exotic invasive plants in Belgium", *Plant & Soil*, vol. 275, no. 1-2, pp. 169-179, 2005.

[44] S. Vanderhoeven, N. Dassonville, L. Chapuis-Lardy, M. Hayez and P. Meerts, (2006) "Impact of the invasive alien plant *Solidago gigantea* on primary productivity, plant nutrient content and soil mineral nutrient concentrations", *Plant & Soil*, vol. 286, pp. 259-268, 2006.

[45] S. Constan-Nava, S. Santiago Soliveres, R. Torices, L. Serra and A. Bonet, "Direct and indirect effects of invasion by the alien tree *Ailanthus altissima* on riparian plant communities and ecosystem multifunctionality", *Biological Invasions*, pp. 1-14, 2014.

[46] L. I. Dong, H. W. Yu and W. M. He, "What determines positive, neutral, and negative impacts of *Solidago canadensis* invasion on native plant species richness?", *Scientific Report*, pp. 1-9, 2015.

[47] W. H. Khan, M. S. Khan, H. Ahmad, Z. Ahmad and S. Page, "Vegetation mapping and multivariate approach to indicator species of a forest ecosystem: A case study from the Thandiani sub Forests Division (TsFD) in the Western Himalayas", *Ecological Indicator*, vol. 71, pp. 336-351, 2016.

[48] L. Gamfeldt, H. Hillebrand and P. R. Jonsson, "Multiple functions increase the importance of biodiversity for overall ecosystem functioning", *Ecology*, vol. 89, pp. 1223–1231, 2008.

[49] A. Hector and R. Bagchi, "Biodiversity and ecosystem multifunctionality", *Nature*, vol. 448, pp. 188–190, 2007.

[50] F. T. Maestre, A. P. Castillo-Monroy, M. A. Bowker and R. Ochoa-Hueso, "Species richness effects on ecosystem multifunctionality depend on evenness, composition and spatial pattern", *Journal Ecology*, vol. 100, pp. 317–330, 2012a.

[51] E. S. Zavaleta, J. R. Pasari, K. B. Hulvey and D. G. Tilman, "Sustaining multiple ecosystem functions in grassland communities requires higher biodiversity", Proceedings of the National Academy of Sciences of USA, vol. 107, pp. 1443-1446, 2010.

[52] M. C. Peel, B. L. Finlayson and T. A. McMahon, "Updated world map of the Koppen-Geiger climate classification", *Hydrology and Earth System Sciences*, vol. 11, no. 5, pp. 1633-1644, 2007.

[53] M. Eldin, Le climat de la Côte d'Ivoire. In : Le milieu naturel de Côte d'Ivoire. Mémoires ORSTOM, 50, Paris (France), pp 73-108, 1971.

[54] F.A.O. World reference base for soil resources. Aframework for international classification, correlation and communication. World soil resources reports 103, p. 145, 2006.

[55] A. Perraud, Les sols. In : Le milieu naturel de la Côte d'Ivoire. Mémoire ORSTOM, 50, Paris (France), pp 157-263, 1971.

[56] E. A. Prasad, Impact of *Lantana camara*, a major invasive plant, on wild life habitat in Bandipur Tiger Reserve, southern India. The Rufford small grants (for nature conservation) of India, pp. 24, 2007.

[57] A. R. Slesak, T. B. Harrington and W. A. D'Amato, "Invasive scotch broom alters soil chemical properties in Douglas-fir forests of the Pacific Northwest, USA", *Plant & Soil*, vol. 98, pp. 281-289, 2016.

[58] E. Van Der Maarel, "Transformation of cover-abundance values in phytosociology and its effects on community similarity", Vegetatio, vol. 39, no. 2, pp. 97-114, 1979.

[59] A. McCauley, C. Jones and K. Olson-Rutz, "Soil pH and Organic Matter", *Nutrient management module*, vol. 8, pp. 16, 2017.

[60] J. Pauwels, E. Van Ranst, M. Verloo and Z. A. Mvondo, Manuel d'Analyses de sols et de plantes. Equipements, Gestion de stocks, de verrerie et produits chimiques. Publications agricoles-28, AGCD, Bruxelles, Belgique. p. 265, 1992.

[61] J. M. Bremner and C. S. Mulvaney, Methods of soils analysis. Part 2 2nd ed. Agron Monogr.9.ASA and SSSA, Madison WI p595-624 Hall. New Jersey, p. 539, 1982.

[62] B. Dabin, Étude d'une méthode d'extraction de la matière humique du sol. Ronéo O.R.S.T.O.M.*,* S.S.C. Bondy, pp 47-63, 1970.

[63] S. R. Olsen and L. E. Sommers, Phosphorus. In: Page AL, Miller RH, Keeney DR (eds) Methods of soils analysis, part 2, 2nd edn. American Society of Agronomy, Madison, pp. 403–430, 1982.

[64] Technicon Industrial Systems, Individual/simultaneous determination of nitrogen and/or phosphorus in BD acid digests. Technicon Industrial Systems, Tarrytown, 1977.

[65] C. E. Shannon and W. Weaver, The mathematic theory of communications. University Illinois Press, Urbana, p. 117, 1949.

[66] E. C. Pielou, "The measurement of diversity in different types of biological collections", *Journal of Theoretical Biology*, vol. 13, pp. 131-144, 1966.

[67] P. Pagès, "Analyse Factorielle Multiple appliquée aux variables qualitatives et aux données mixtes", *Revue de Statistiques Appliquées*, vol. 50, no. 4, pp. 5-37, 2002.

[68] L. Aké-Assi, "Impact de l'exploitation forestière et du développement agricole sur la conservation de la biodiversité biologique en Côte d'Ivoire", *Le flamboyant*, vol. 46, pp. 20-21, 1998.

[69] UICN, 2015. - IUCN Red List of Threatened Species, 2015. [Online] Available: http://www.iucnredlist.org (July 2, 2018).

[70] R. T. Shackleton, D. C. Le Maitre, D. M. Richardson and B. W. Van Wilgen, "Use of non-timber forest products from invasive alien Prosopis species (mesquite) and native trees in South Africa: implications for management", *Forest Ecosystem*, vol. 2, pp. 16, 2015.

[71] M. Séleck, J. P. Bizoux, G. Colinet, M. P. Faucon, A. Guillaume, P. Meerts, J. Piqueray and G. Mahy, "Chemical soil factors influencing plant assemblages along copper-cobalt gradients: implications for conservation and restoration", *Plant & soil*, vol. 373, no. 1-2, pp. 455-469, 2013.

[72] I. Kowarik, "Time lags in biological invasions with regard to the success and failure of alien species", *Plant Invasions*, pp. 15-38, 1995.

[73] R. W. Tyser and C. A. Worley, Alien flora in Usha K, Prasad R, Muniappan P, Ferrar JP, Aeschliman, H. De Foresta (1996) Répartition, écologie et gestion de *Chromolaena odorata*. Comptes Rendus du Troisieme Atelier International sur *Chromolaena* Abidjan, Cote d'Ivoire, November 1993. Agricultural Experiment Station University of Guam, Mangilao, GUAM, USA Publication n° 202, p. 213, 1992.

[74] M. L. McKinney, "Urbanization, Biodiversity and Conservation", *BioScience*, vol. 52, no. 10, pp. 883-890, 2002.

[75] B. A. Aboh, Phytosociologie, ecologie, potentialités et aménagement des pâturages naturels envahis par *Chromolaena odorata* et *Hyptis suaveolens* en Zone Soudano-guinéenne (Bénin). Thèse de Doctorat Unique de l'Université d'Abomey-Calavi (Bénin), p. 227, 2008.

[76] O. O. Agboola and T. A. Oyedele, "Effect of *Chromolaena odorata* on Species Diversity, Composition and Soil of the Invaded Vegetation in Ile-Ife, South-Western Nigeria", *Polytechnic Journal of Science Technologie*, vol. 7, pp. 1-16, 2012.

[77] M. Gaertner, A. D. Breeyen, C. Hui and D. M. Richardson, "Impacts of alien plant invasions on species richness in Mediterranean-type ecosystems: a meta-analysis", *Progress in Physical Geography*, vol. 33, pp. 319-338, 2009.

[78] S. Mangla, I. M. Callaway and R. M. Callaway, "Exotic invasive plant accumulates native soil pathogens which inhibit native plants", *Journal Ecology*, vol. 96, pp. 58-67, 2008.

[79] A. McWilliam, "A plague on your house? Some impacts of *Chromolaena odorata* on Timorese livelihoods", *Human Ecology*, vol. 28, pp. 451-469, 2000.

[80] E. Motard, A. Muratet, D. Clair-Maczulajtys and N. Machon, "Does the invasive species *Ailanthus altissima* threaten floristic diversity of temperate peri-urban forests?", *Comptes Rendus Biologies*, vol. 12, pp. 872-879, 2011.

[81] L. B. Thapa, K. Kaewchumnong, A. Sinkkonen and K. Sridith, "Impacts of invasive *Chromolaena odorata* on species richness, composition and seedling recruitment of Shorea robusta in a tropical Sal forest, Nepal", *Songklanakarin Journal Science Technology*, vol. 38, no. 6, pp. 683-689, 2016.

[82] M. Vila, M. Tessier and C. M. Sueh, "Local and regional assessment of the impacts of plant invaders on vegetation structure and soil properties of Mediterranean islands", *Journal of Biogeography*, vol. 33, pp. 853-861, 2006.

[83] M. R. Keane and J. M. Crawley, "Exotic plant invasions and the enemy release hypothesis", *Trends in Ecology & Evolution*, vol. 17, pp. 164-170, 2002.

[84] K. H. Kouassi, K. N'Guessan, G. M. Gnahoua and D. Traore, "Dynamique de *Chromolaena odorata* (l.) r. m. king & h. rob. et évolution de la richesse floristique au cours de la reconstitution de la flore postculturale en zone de forêt semi-décidue de côte d'ivoire", *Agronomie Africaine*, vol. 20, no. 3, pp. 257-265, 2008.

[85] R. Lal, "Soil carbon sequestration impacts on global climate change and food security", *Science*, vol. 304, pp. 1623-1627, 2004.

[86] F. Toutain, "Les humus forestiers structures et modes de fonctionnement", *Biologie et forêt*, pp. 449-477, 1981.

[87] J. Keilling, "Humus et civilisations : la querelle des deux agronomes. Les civilisations veulent des terres fertiles", *Faim et Soif*, vol. 20, pp. 31-32, 1957.

[88] N. N. Agbim, "Carbon cycling under *Chromolaena odorata* (L.) canopy", *Biological Agriculture and Horticulture*, vol. 4, pp. 203-212, 1987.

[89] H. De Foresta and D. Schwartz, "*Chromolaena odorata* and disturbance of natural succession after shifting cultivation: an example from Mayombe, Congo, Central Africa", *Biotrop Special Publication*, vol. 44, pp. 23-41, 1991.

[90] E. Mollard, Quelques déterminants techniques et sociaux de la jachère en Afrique de l'Ouest. In, Floret et Serpantié éds., La jachère en Afrique de l'Ouest. Paris, ORSTOM, Collection Colloques et Séminaires, pp. 171-177, 1993.

[91] D. Saidi, Y. Le Bissonnais, O. Duval, Y. Daoud and A. Halitim, "Effet du sodium échangeable et de la concentration saline sur les propriétés physiques des sols de la plaine du Cheliff (Algérie)", *Étude & Gestion des Sols*, vol. 11, no. 4, pp. 81-92, 2004.

[92] D. Tessier, Etude expérimentale de l'organisation des matériaux argileux. Hydratation, gonflement et saturation au cours de la dessiccation et de la réhumectation. Thèse Doctorat. ès-Sciences, Université de Paris, VII, p. 361, 1984.

[93] J. Boyer, Comportement du potassium dans les sols tropicaux cultivés. Compte Rendu du l0e Colloque de l'Institut International de la Potasse, Abidjan, Côte d'Ivoire. pp. 83-102, 1973.

[94] K. A. Tshinyangu, T. J. M. Mutombo, M. A. Kayombo, M. M. Nkongolo, N. G. Yalombe and M. J. Cibanda, "Effet comparé de *Chromolaena odorata* King et H.E. Robins, et *Tithonia diversifolia* A. Gray sur la culture du Maïs (*Zea mays* L) à Mbujimayi (RD. Congo)", *Journal of Applied Bioscience*, vol. 12, pp. 10996-11001, 2017.

[95] H. De Foresta, "*Chromolaena odorata* and disturbance of natural succession after shifting cultivation : an example from Mayombe, Congo, Central Africa. In : *R. Munniappan and P. Ferrar (Eds.)*. Ecology and Management of *Chromolaena odorata"*, *BIOTROP Special* Publication, vol. 44, pp. 23-41, 1991.

[96] J.J.P. Slaats, *Chromolaena odorata* fallow in food cropping systems. An agronomic assessment in South-West Ivory Coast. Doctoral thesis, Wageningen Agricultural University, Wageningen, The Netherlands, pp. 177, 1995.

[97] J. F. Dénis, La fertilisation de l'olivier en potassium et en magnésium. Association française interprofessionnelle de l'olive (AFIDOL), France, pp. 5, 2000.

[98] J. Magny and J. Baur, Pour comprendre les analyses de terre. Revue « Purpan », Laboratoire « Europe-Sol »,41-42 (nouveau tirage), Purpan, Toulouse, pp. 145-222, 1990.

[99] F. Sigala, J. C. Fies and R. Guennelon, Influence du sodium sur les propriétés physiques d'un sol aux niveaux textural et structural. In: Bouch et R. (ed.). Reuse of low quality water for irrigation. Bari: Ciheam, (Options Méditerranéennes : Série A. Séminaires Méditerranéens; no. 1, pp. 159-168, 1989.

[100] J. N. Klironomos, "Feedback with soil biota contributes to plant rarity and invasiveness in communities", *Nature*, vol. 417, pp. 67-70, 2002.

[101] S. Mangla, I. M. Callaway and R. M. Callaway, "Exotic invasive plant accumulates native soil pathogens which inhibit native plants", *Journal of Ecology*, vol. 96, pp. 58-67, 2008.

APPENDIX 1 GENERAL LIST OF INVENTORIED SPECIES IN OUR DIFFERENT STUDY SITES OF BANCO NATIONAL PARK

Species	Families	Biological types	Chorology
Acacia mangium Willd.	Fabaceae	mp	GC-SZ
Acacia pentagona (Schumach. &Tonn.) Hook.f.	Fabaceae	LmP	GC-SZ
Acridocarpus longifolius (D.Don) Hook.f.	Malpighiaceae	mp	GC
Acroceras zizanoides (Kunth) Dandy	Poaceae	np	GC-SZ
Adenia gracilis Harms	Passifloraceae	Lmp	GC
Adenia lobata (Jacq.) Engl.	Passifloraceae	Lmp	GC
Adenia mannii (Mast.) Engl.	Passifloraceae	Lnp	GC
Aframomum sceptrum (Oliv. & Hanb.) K. Schum.	Zingiberaceae	np	GC
Afzellia bella Harms var. _gracillor_ Keay	Fabaceae	mP	GCW
Agelaea pentagyna (Lam.) Baill.	Connaraceae	Lmp	GC
Ageratum conyzoides L.	Asteraceae	Th	GC-SZ
Albertisia cordifolia (Mangenot & Miège) Forman	Mennispermaceae	np	GCi
Albertisia scandens (Mangenot & Miège) Forman	Mennispermaceae	Lnp	GCW
Albizia adianthifolia (Schum.) W. F. Wright	Fabaceae	mP	GC
Albizia zygia (DC.) J. F. Macbr.	Fabaceae	mP	GC-SZ
Alchornea cordifolia (Schum. & Thonn.) Müll. Arg.	Euphorbiaceae	Lmp	GC-SZ
Alternanthera sessilis (L.) DC.	Amaranthaceae	Ch	GC-SZ
Ampelocissus leonensis (Hook. f.) Planch.	Vitaceae	Lmp	GC-SZ
Anchomanes difformis (Blume) Engl.	Araceae	G	GC
Aneilema beniniense (P. Beauv.) Kunth	Commelinaceae	Ch	GC
Angylocalyx oligophyllus (Bak.) Bak.f.	Fabaceae	np	GC
Annickia polycarpa (DC.) Engl. et Diels	Annonaceae	mP	GC
Anthonotha fragrans (Baker f.) Exell & Hillcoat	Fabaceae	MP	GC
Anthonotha macrophylla Pal. Beauv.	Fabaceae	mp	GC
Antiaris toxicaria Lesch. var. _africana_ Engl.	Moraceae	mP	GC-SZ
Antiaris toxicaria var. _welwitschii_ (Engl.) Corner	Moraceae	mP	GC
Asystasia gangetica (L.) T. Anders.	Acanthaceae	np	GC-SZ
Baphia bancoensis Aubrév.	Fabaceae	mp	GCi
Baphia capparidifolia Bak.	Fabaceae	Lmp	GC
Baphia nitida Lodd.	Fabaceae	mp	GC
Blighia welwitschii (Hiern) Radlk.	Sapindaceae	mP	GC
Breynia disticha J. R. & G. Forst	Euphorbiaceae	np	i
Buxus acutata Friis	Buxaceae	np	GC
Byrsocarpus coccineus Thonn. ex Schumach.	Connaraceae	Lmp	GC
Calycobolus africanus (G. Don) Heine	Convolvulaceae	LmP	GC
Ceiba pentandra (L.) Gaertn.	Malvaceae	MP	GC-SZ
Centrosema pubescens Benth.	Fabaceae	Lmp	GC
Cercestis afzelii Schott	Araceae	Lmp	GC
Chassalia afzelii (Hiern) K. Schum.	Rubiaceae	Lmp	GCW
Chromolaena odorata (L.) R. King & H. Robinson	Asteraceae	np	i
Cissus aralioides (Welw. ex Bak.) Planch.	Vitaceae	Lmp	GC-SZ
Cissus producta Afzel.	Vitaceae	Lmp	GC
Cnestis ferruginea Vahl ex DC.	Connaraceae	Lmp	GC
Cola heterophylla (P. Beauv.) Schott et Endl.	Malvaceae	mp	GC
Cola millenii K. Schum.	Malvaceae	mp	GC
Cola nitida (Vent.) Schott & Endl.	Malvaceae	mP	GC
Combretum dolichopetalum Engl. & Diels	Combretaceae	Lmp	GC
Combretum micranthum G. Don	Combretaceae	mp	SZ
Costus afer Ker-Gawl.	Costaceae	G	i
Croton hirtus L'Hérit.	Euphorbiaceae	np	GC
Culcasia dinklagei Engl.	Araceae	Ch	GC
Culcasia saxatilis A. Chev.	Araceae	np	GC

Culcasia scandens P. Beauv.	Araceae	Lmp	GC
Cyathula prostrata (L.) Blume	Amaranthaceae	np	GC-SZ
Cyclosorus dentatus (Forsk) Ching	Thelypteridaceae	H	GC
Cyperus rotondus L.	Cyperaceae	G	GC-SZ
Cyperus sphacelatus Rottb.	Cyperaceae	H	GC-SZ
Dacryodes klaineana (Pierre) Lam	Burseraceae	mP	GC
Dalbergia afzeliana G. Don	Fabaceae	LmP	GC
Desmodium adscendens (Sw.) DC. var. _adscendens_	Fabaceae	Ch	GC
Dichapetalum angolense Chodat	Chrysobalaceae	Lmp	GC
Dichapetalum cymulosum (Oliv.) Engl.	Dichapetalaceae	mp	GC
Dichapetalum heudelotii (Planch. ex Oliv.) Baill. var. _heudolotii_	Chrysobalanaceae	Lmp	GC
Dichapetalum pallidum (Oliv.) Engl.	Chrysobalaceae	LmP	GC
Diodia sarmentosa Sw.	Rubiaceae	Lnp	GC-SZ
Dioscorea minutiflora Engl.	Dioscoreaceae	G	GC
Diospyros sanza-minika A. Chev.	Ebenaceae	mP	GC
Drypetes gilgiana (Pax) Pax & Hoffm.	Putranjivaceae	mp	GC
Elaeis guineensis Jacq.	Arecaceae	mP	GC
Eleusine indica (L.) Gaertn.	Poaceae	H	GC-SZ
Eragrostis tenella (L.) Roem. & Schult. Var. tenella	Poaceae	Th	GC-SZ
Euadenia trifoliolata (Schum. & Thonn.) Oliv.	Capparidaceae	mp	GC
Ficus exasperata Vahl	Moraceae	mp	GC-SZ
Funtumia elastica (Preuss) Stapf	Apocynaceae	mP	GC
Geophila obvallata (Schumach.) F.Didr.	Rubiaceae	Ch	GC
Geophila repens (L.) I. M. Johnston	Rubiaceae	Ch	GC-SZ
Glyphaea brevis (Spreng.) Monachino	Malvaceae	mp	GC
Griffonia simplicifolia (Vahl ex DC.) Baillon	Fabaceae	Lmp	GC
Heterotis rotundifolia (Smith) Jac.-Fél.	Melastomataceae	Ch	GC
Hopea odorata Roxb.	Dipterocarpaceae	mP	i
Icacina mannii Oliv.	Icacinaceae	Lmp	GC
Ipomoea involucrata P. Beauv.	Convolvulaceae	Th	GC-SZ
Ipomoea mauritiana Jacq.	Convolvulaceae	Lmp	GC-SZ
Kyllinga erecta Schumach. var erecta	Cyperaceae	G	GC-SZ
Lantana camara L. var. camara	Verbenaceae	Lmp	GC
Laportea aestuans (L.) Chew	Urticaceae	Th	GC
Leptoderris miegei Aké Assi & Mangenot	Fabaceae	Lmp	GCi
Lycopodiella cernua (L.) Pic. Ser.	Lycopodiaceae	np	GC-SZ
Manihot esculenta Crantz	Euphorbiaceae	mp	i
Microdesmis keayana Léonard	Pandaceae	mp	GC
Mikania cordata (Brum. f.) B. L. Robinson	Asteraceae	Lmp	GC
Millettia zechiana Harms	Fabaceae	mp	GC
Mimosa invisa Mart. Ex Colla	Fabaceae	Lnp	i
Momordica cabrae (Cogn.) Jeffrey	Curcubitaceae	Lmp	GC
Monodora tenuifolia Benth.	Annonaceae	mp	GC
Myrianthus arboreus P. Beauv.	Moraceae	mp	GC
Myrianthus libericus Rendle	Moraceae	mp	GC
Napoleonaea vogelii Hook.& Planch.	Lecythidaceae	mp	GC
Nauclea latifolia Sm.	Rubiaceae	Lmp	GC-SZ
Nephrolepis biserata (Sw.) Schott	Oleandraceae	H	GC
Neuropeltis acuminata (P. Beauv) Benth.	Convolvulaceae	LMP	GC
Neuropeltis prevosteoides Mangenot	Convolvulaceae	LMP	GCW
Newbouldia laevis (P. Beauv.) seem. ex Bureau	Bignoniaceae	mp	GC
Oldenlandia corymbosa L. var. corymbosa	Rubiaceae	Ch	GC-SZ
Rhabdophyllum affine (Hook.f.) Engl.	Ochnaceae	np	GC
Palisota hirsuta (Thun.) Schum ex Engl.	Commelinaceae	np	GC
Panicum brevifolium L.	Poaceae	Ch	GC
Panicum laxum Sw.	Poaceae	Th	GC-SZ

Panicum maximum Jacq.	Poaceae	H	GC
Paspalum scobiculatum L. var. scrobiculatum	Poaceae	H	GC-SZ
Paspalum vaginatum Sw.	Poaceae	rh	GC
Pentaclethra macrophylla Benth.	Fabaceae	mP	GC
Petersianthus macrocarpus (P. Beauv.) Liben.	Lecythidaceae	MP	GC
Phyllanthus amarus Schum. & Thonn.	Euphorbiaceae	np	GC
Phyllanthus muellerianus (O. Ktze.) Exell	Phyllanthaceae	Lmp	GC-SZ
Piper guineense Schum. & Thonn.	Piperaceae	Lmp	GC
Platysepalum hirsutum (Dunn) Hepper	Fabaceae	LmP	GCW
_Polyalthia oliver_i Engl.	Annonaceae	mp	GC
Pteridium aquilinum (L.) Kuhn	Dennstaedtiaceae	G	GC
Pueraria phaseoloides (Roxb.) Benth.	Fabaceae	Lmp	i
Raphia hookeri G.Mann. & H. Wendl.	Arecaceae	mp	GC
Rauvolfia vomitoria Afzel.	Apocynaceae	mp	GC-SZ
Rhigiocarya peltata Miège	Mennispermaceae	Lmp	GCi
Rhigiocarya racemifera Miers	Menispermaceae	Lmp	GC
Salacia nitida (Benth.) N. E. Br.	Celastraceae	Lmp	GC
Scoparia dulcis L.	Plantaginaceae	np	GC-SZ
Setaria chevalieri Stapf	Poaceae	H	GC
Sida _acuta Brum_. f. subsp. _acuta_	Malvaceae	np	GC
Sida alba L.	Malvaceae	np	GC-SZ
Solanum rugosum Dunal	Solanaceae	mp	GC
Sphenocentrum jollyanum Pierre	Menispermaceae	np	GC
Stachytarpheta jamaicensis (L.) Vahl	Verbenaceae	np	GC
Stenotaphrum secundatum (Walt.) Kuntze	Poaceae	Sto	GC
Sterculia tragacantha Lindl.	Malvaceae	mP	GC-SZ
Strombosia pustulata Oliv. var. pustulata	Olacaceae	mP	GC
Strophanthus hispidus DC.	Apocynaceae	Lmp	GC-SZ
Tabernaemontana crassa Benth.	Apocynaceae	mp	GC
Tarenna corymbosa (Willd.) Pit.	Rubiaceae	mP	GC
Thaumatococcus daniellii (Bennet) Benth.	Marantaceae	Lmp	GC
Triumfetta rhomboidea Jacq.	Malvaceae	np	GC
Turraeanthus africanus (Welw. Ex C.DC.) Pellegr.	Meliaceae	H	i
Urera repens (Wedd.) Rendle	Urticaceae	H	i
Uvaria afzelii Sc. Elliot	Annonaceae	mP	GC
Uvariodendron angustifolium (Engl. & Diels) R.E. Fries	Annonaceae	np	GC
Xanthosoma sagittifolium _(L.) Schott_	Araceae	H	i
Xanthosoma wendlandii (Schott) Standl.	Araceae	H	i
Xylopia villosa Chipp	Annonaceae	mP	GC