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Full Length Research Paper

Species composition, seasonal abundance and distribution of avifauna in Lake Hawassa and part of the Eastern Wetland habitats, Southern Ethiopia

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This study was carried out in Lake Hawassa, Tikur wuha riverine habitat and Cheleleka wetland from August 2017 to February 2018. The study aims to investigate species composition, seasonal abundance and distribution of birds. Systematic random sampling techniques at an interval of 3 km were used to select sampling blocks. T-test and one way ANOVA were applied for analysis of the effect of season on the composition and abundance of species. The result showed a total of 103 avian species record belonging to 47 families and 14 orders during the wet and dry seasons. Of the species recorded, (71) bird species (68.93%) were residents, 29 Palaearctic migrants (28.16%) and 3 Intra-African migrants (2.91 %). The overall species composition of birds during the wet and dry seasons was not significantly different, but there was a significant difference within the study sites. There was no significant seasonal difference in the abundance of birds in Lake Hawassa and the riverine habitat. However, dry season had an effect on the avian abundance in Cheleleka wetland. Distributions of bird species were variable in the study areas. The results imply the need to conserve the avifauna of the whole study sites through the conservation of their habitats.

Key words: Wetland birds, abundance, endemic, migrant, resident.

INTRODUCTION

Birds, also known as Aves, are the best-known class of vertebrate animals that occur worldwide in nearly all habitats (Wenny et al., 2011; Sekercioglu, 2012). Most of the birds are useful to mankind. They play a useful role in the control of insect pests of agricultural crops, as predators of rodents, as scavengers, as seed dispersers, and as pollinating agents (Hadley et al., 2012; Ramchandra, 2013). The diversity of these organisms is one of the most important ecological indicators to evaluate the quality of habitats (Manjunath, 2012). Furthermore, they do add enjoyment to our lives, because of their distinctive colors, attractive display, unique songs and calls.

There are over 9,026 various species of birds (class Aves), grouped to 27 Orders and 155 families currently inhabit the earth (BLI, 2017, Nkwabi et al., 2018). Of these, 1,469 species are considered threatened with extinction, 1,017 species are near threatened, 62 species

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lack the data to determine their status, and 145 species are recorded as extinct. As the recent data from the IUCN shows, a total of 2,486 species or just under one quarter of all the world's birds are treated as global conservation priorities (BLI, 2018). According to Lepage (2017) there are 864 bird species in Ethiopia, of which 19 are endemics, 35 are globally threatened and 1 introduced species and a further 13 are shared only with Eritrea. Two-hundred-fourteen Palearctic migrants were also recorded in Ethiopia (Pol, 2006). Among these, 45 species have been found to over-summer within the boundaries of the country.

Birds have different spatial and temporal distributions in any wetland (Fletcher and Hutto, 2008). The diversity and distribution patterns depend on birds' mobility, food availability, habitat suitability, geo-physiological structure of a wetland and the size of the wetland (Akosim et al., 2008). Water bird communities represent a potentially useful group of organisms for monitoring changes to freshwater ecosystems. They may be ordered into functional groups representing a combination of diet and habitat use that allow assessment of changes to wetland habitats (Balapure et al., 2013). They are indicators and useful models for studying a variety of environmental changes (Green, 2004; Jamil, 2011).

The study area, Lake Hawassa and its part of the eastern catchment wetland habitat are part of the Ethiopian Central Rift Valley ecosystem. Lake Hawassa is a closed-catchment, which is fed both by a few temporary streams on the north-west and western side of the catchment and by the Tikur Wuha River, which is the only perennial river, that enters into Lake Hawassa draining the Cheleleka wetland on the north-east side. The terrestrial habitat adjoining the Lake Hawassa supports a rich diversity as compared to other Ethiopian Rift Valley lakes (Sairam, 2014). Chelekleka wetland is slightly acidic (humic acid) due to the large biomass degrading in the standing water (Zerihun Desta, 2003).

Assessment of diversity and distribution of ecosystem resources provides information on the resource that is contained in an ecosystem, resource relationships and the environmental factors that influence their distribution and diversity (Bibby et al., 2000; Thiollay, 2007). Characterizing community species composition and water bird dynamics are also important evaluation indicators that reflect habitat quality (Paillisson et al., 2002; Bishop et al., 2005; Nielsen et al., 2014).

However, a systematic bird species list and information on bird species diversity, relative abundance and their distributions across sites are lacking from this natural lake and part of the eastern wetland habitats.

MATERIALS AND METHODS

Description of the study area

Lake Hawassa and part of the eastern wetland habitats (Tikur wuha riverine habitat and Cheleleka wetland) were the specific sites where the present study was conducted (Figure 1). The area comprises parts of Oromya Regional State, and Southern Nations and Nationalities Peoples' Regional State. The Lake lies between 6˚45' 7" to 7˚6'37"N and 38˚23'30" to 38˚28' 48" E. The city of Hawassa, named after the Lake, is located at 275 km south of the capital city-Addis Ababa and is established in the very eastern shore of the lake (MoWR, 2010). The riverine habitat of Tikur Wuha River begins at Cheleleka wetland habitat towards Lake Hawassa to the west-south. It is a perennial river and the only tributary rivers that feed Lake Hawassa which drains from the Cheleleka wetland. The Cheleleka wetland habitat occurs between the geographical co-ordinates of 07˚00'13" to 07˚6'37"N and 38˚30'51" to 38˚34'44"E.

The annual average rainfall of Hawassa and its vicinities is 961 mm and distributed as 50% for Kiremt (June to September), 20% for Bega (October to February) and 30% for the Belg season (March to May) (Mulugeta, 2013). Mean monthly temperatures varied between 17 and 22°C with mean temperature of 17°C and low in July. The maximum temperature is 27°C and drops to 25.5°C from May to November. The night temperatures decline and sometimes come to zero °C between December and February and the relative humidity is close to 60% (Mulugeta, 2013).

Preliminary survey

A preliminary survey was conducted during the first two weeks of August, 2017. The physical features of the study area were assessed using ground survey. The coordinates of each study site were taken and their boundaries were delineated.

Sampling design

A systematic random sampling technique was used for selecting the actual sampling sites as described by Bibby et al. (1992). From the total area of Lake Hawassa (95.8 km^2), the following areas were sampled: 23.95 km^2, from Cheleleka wetland total area of which is 56.6 km^2, and also 14.15 km^2 and approximately 75% of the riverine habitat areas.

Then, a line transect method was employed for counting of birds on the shoreline of the Lake and the open wetland habitats at every 3 km interval. For the riverine habitat, four block observations were made by walking along the bank of the river (Rajashekara and Venkatesha, 2010).

A total of 26 transect lines were taken, including; 4 from the riverine habitat, 12 along the shoreline, 1 in the open area of Lake Hawassa and 9 from the open wetland habitat of Cheleleka wetland. A total of 25% of the study area was sampled from the Lake Hawassa and Cheleleka wetland habitats (Figure 2).

To count birds, a transect line of 2 km for the open wetland habitats and lake shoreline at 50 to 300 m sighting distance was selected. In the riverine habitat, a length of 1 km and a sighting distance ranging from 150 to 200 m in both sides perpendicular to the riverine buffer zone was followed (Bibby et al., 1998). The sighting distance varied on either side of transects depending on the species and habitat types as used by Pomeroy (1997) and Girma Mengesha et al. (2014). In the open area of the lake, one long transect line of 18 km length was laid projected from a south to north direction following Girma Mengesha et al. (2014). Counting of birds was carried out using a boat that was slowly driven along the transect line at a speed of between 5 and 10 km/hr to allow an easy detection of birds during surveys. Then birds within 300 m width on either side of the transects were counted.

Data collection

Data were collected from 6:30 a.m. to 10:00 a.m. in the morning

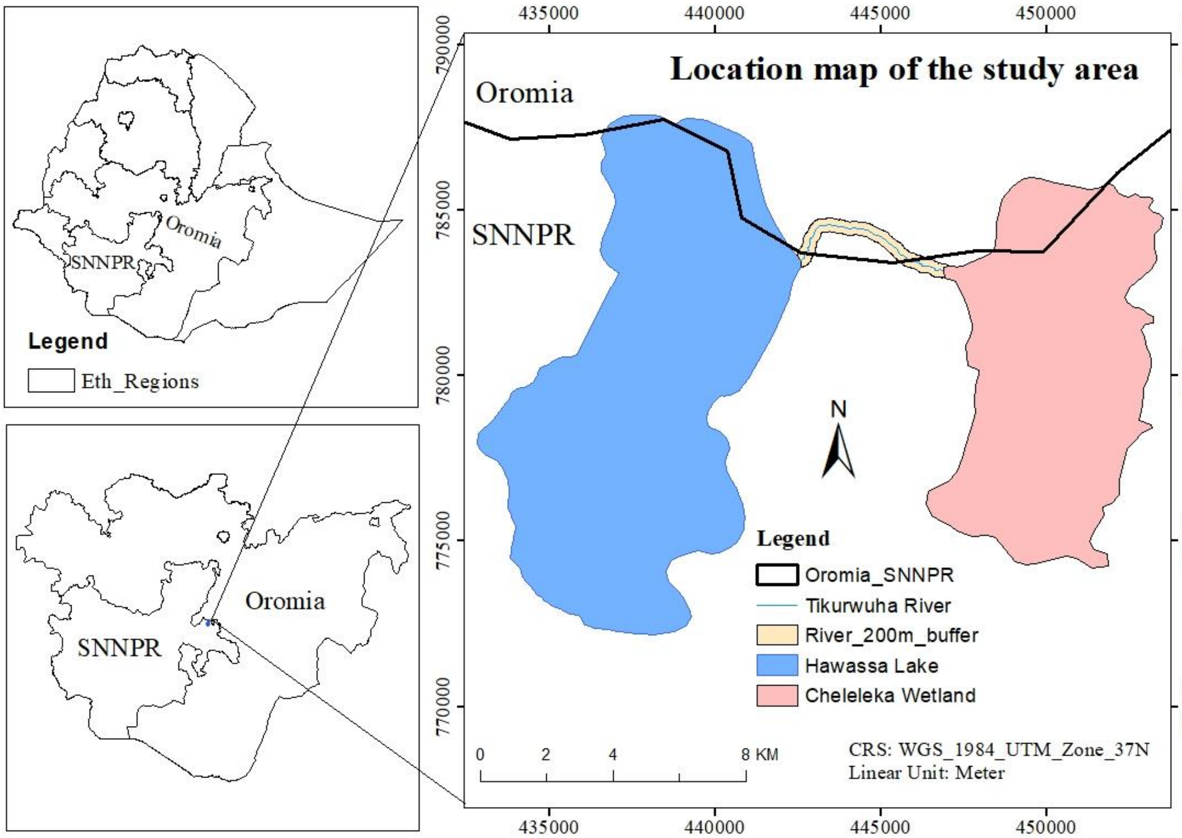

Figure 1. Location map of the study area.

Figure 2. Placements of sample points along transect lines.
Source: Google earth image (2016).

and from 3:00 p.m. to 6:00 p.m. in the afternoon, when bird activity was maxima and on days with good weather conditions (Centerbury et al., 2000). To minimize disturbance during counting, silent movement and appropriate distances from birds were taken into consideration (Bibby et al., 1992). Weekly visits to the site were made for six months during both wet and dry seasons. During the counting of birds, the start and end geographical coordinates of each transect were saved in Garmin 72 GPS unit to ensure the same transects were repeated during the dry season. The date (including starting and finishing time), bird species, number and survey site were recorded. To avoid repeated counting of birds, areas were divided, based on their distribution and habitat types (Datiko and Bekele, 2012).

Finally, a bird checklist was prepared on the basis of their scientific names, common names and IUCN status as per BirdLife International (2017) and (Redman et al., 2009).

Data analysis

The collected data were organized in an Excel spreadsheet for statistical analysis. Statistical Product Services and Solutions (SPSS) Version 20 software was used to do the statistical analysis. Before inferential statistics were performed, number of birds were transformed to $\log_{10}$ to improve homogeneity and normality test (Quinn and Keough, 2002; Skinner and Clark, 2008). The effect of seasons on species composition and abundance was analysed and compared using one-way ANOVA. Differences were considered statically significant at the 5% level. A pairwise t-Test was applied to test the difference in means in abundance of birds between the two seasons among the study sites and the level of significance was set at (p=0.05).

RESULTS

Species composition

A total of 103 species of birds, grouped under 47 families and 14 orders, were recorded during the two seasons, wet and dry from the three study sites (Appendix 1). Among the 14 orders Passeriformes was the highest with 24 species followed by Coliiformes (16), Ciconiifores (14) and Bucerotiformes (13). The least species was recorded in the order Accipitriformes, Charadriiformes, Columbiformes and Piciformes, with one species each (Appendix 1).

Out of the species recorded in the study area, Wattled Ibis (*Bostrychia carunculata*), Banded Barbet (*Lybius undatus)* and Black-winged lovebird (*Agapornis taranta*), were endemic to both Ethiopia and Eritrea. One endemic bird species Yellow-fronted Parrot (*Poicephalus flavifrons)* was also recorded (Appendix 1).

The analysis of data on migratory status revealed that out of 103 species, 29 Palaearctic Migrants (28.16%) and 3 Intra-African Migrants (2.91%) were recorded during the study period. The remaining (71) bird species (68.93 %) were residents including endemic species.

As per IUCN status (2017), 98 species were of least concern, and 2 species Ferruginous Duck (*Aythya nyroca*) and Black-tailed Godwit (*Limosa limosa)* were near threatened. A critically endangered species Hooded Vulture (*Necrosyrtes monachus)* was also recorded during the study period (Appendix 1).

During the wet and dry seasons, 90 and 96 bird species were recorded, respectively. Eighty three bird species were common to both seasons, but 13 and 7 species were exclusive to the wet and dry seasons, respectively.

The species composition of birds during the wet and dry seasons was not significantly different (ANOVA p = 0.23) but there was a significant difference within habitats between seasons. During both dry and wet seasons, Lake Hawassa (ANOVA p = 0.02) and Cheleleka wetland (ANOVA p = 0.01) show significant difference in the composition of avian species between seasons. However, in Tikur wuha riverine habitat (ANOVA p =0.07) did not show a significant difference.

Seasonal abundance

During both wet and dry seasons, Lake Hawassa (t = 0.32, P> 0.05) and Tikur wuha riverine habitat (t=1.35, P>0.05) did not show significant differences in the abundance of avian species. However, dry season had an effect on avian abundance in Cheleleka wetland (t=-1.13, P <0.05) (Table 1).

Spatial distribution of avian species

Birds showed variation in the distributions among the three habitat types. Charadriiformes, Ciconiifores and Anseriformes were more abundant and distributed in Lake Hawassa next to Passeriformes. Ciconiifores, Anseriformes and Passeriformes had greater distribution in the Cheleleka wetland habitat. Piciformes and Psittaciformes were distributed only in Tikur wuha riverine habitat (Figure 3). However, Passeriformes (Slender-billed Starling, Marsh warbler and little weaver), Coraciiformes (Silver-cheeked Hornbill and Northern carmine bee-eater), Columbiformes (doves), Anseriformes (Northern Pintail and Egyptian goose), Charadriiformes (little ringed plover and gull-billed tern, Ciconiifores (Hammer kop, Hadada ibis and Goliath heron) were well distributed across the three sites (Figure 3).

DISCUSSION

Species diversity

The present study shows that the lake and the associated wetland habitats are likely to have enough trees and vegetation covers to serve as a foraging site for a substantial number of bird species. The large size of the Lake, as compared to the other sites, might contribute to the highest richness and abundance of bird species. As

Table 1. Mean abundance values of birds in different study sites during wet and dry seasons (Mean ± SE).

Study sites	Season	M ± SE	T-value	P-value
Lake	Wet	32.22 ± 6.35	t=0.32	p=0.13
	Dry	32.11 ± 4.62		
Riverine	Wet	20.33 ±1.27	t=1.35	p=0.07
	Dry	18.58 ±1.06		
Swamp	Wet	24.06 ± 1.79	t=-1.13	p=0.02
	Dry	21.89 ± 1.91		

The t stands for a pair-wise t-test which is a statistical instrument to see the variations of abundance of birds between seasons; p is statistically significant/not significant effect of seasons on habitats.

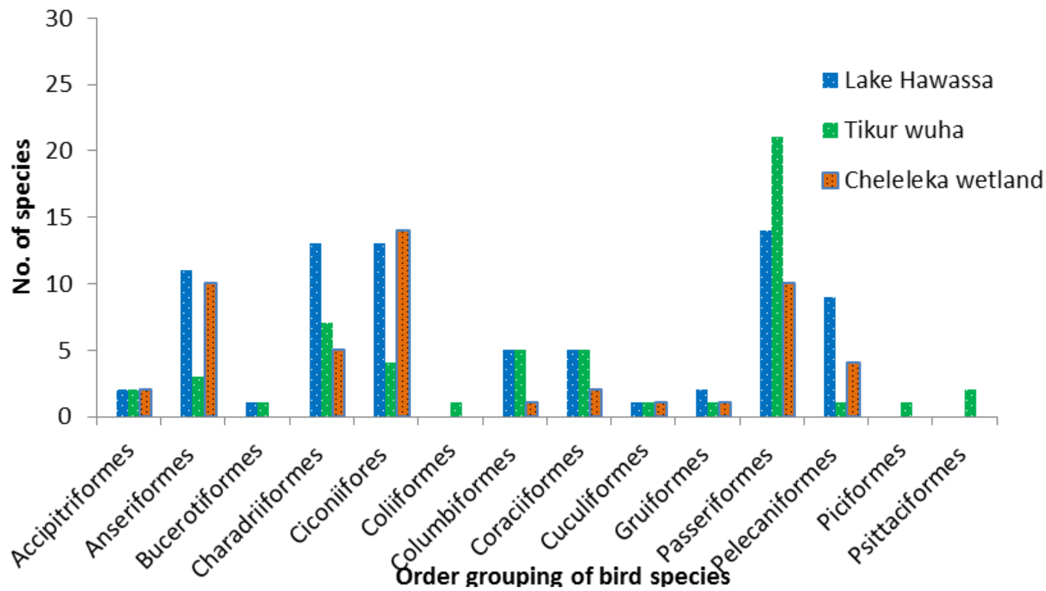

Figure 3. Bird orders and distributions among the three study sites.

reported by Nabaneeta and Gupta (2010), bird species richness and abundance are influenced by the size of habitat patches, local resource availability and vegetation composition. This is because of the availability of multiple, and varied, alternative feed sources for the birds; moreover, a large area is inaccessible for people contributing to a favorable condition for breeding, feeding and nesting sites (Aynalem and Bekele, 2008). It was also pointed out by Prakash and Manasvini (2013) that a higher abundance of birds in a habitat might be brought by the vegetation composition that forms the main element of their habitat, or it may be influenced by landscape, floral diversity, anthropogenic activities, as well as predation.

The significant seasonal variation of species composition in Lake Hawassa and Cheleleka wetland might be due to the seasonal availability of food for different bird species and nesting sites in the area. Other studies have also shown that seasonal variations in rainfall and food resources have led to seasonal changes in the species composition and abundance of birds (Bibi and Ali, 2013; Shitta et al., 2016). The abundance of bird species is determined by the composition of the vegetation that forms a major element of their habitats. There were high numbers of birds during the dry season in Lake Hawassa. This is in agreement with the work of Aynalem and Bekele (2008) on Lake Tana; and by Shitta et al. (2016) at Lake Marmai wetland in Nigeria. This could be partly due to the high number of Palearctic migrants that winter in this wetland of the study area. The emergent vegetation like *Typha* spp in the dry season may be making grounds for the winter migrant, which hampers the nesting and breeding sites for birds that breed in the early dry season.

The wet season shows a low species composition in Lake Hawassa. This could be due to the fact that summer migrants migrate back to their feeding grounds and resident birds move towards residential areas. Richardson (1990) had noted that migration greatly alters the bird population by changing both the number and composition. According to Kennedy et al. (2000), the distribution of birds is classified as migrant, resident, and endemic. Lake Hawassa and Cheleleka wetland are well known feeding grounds for winter migratory birds (EWNHS, 1996). The occurrence of winter birds in the area indicates that the area is important for migratory birds. This signifies the conservation importance of the area not only to common bird species, but also to birds of international concern.

Seasonal abundance

Individuals of most species were not distributed uniformly and most population exhibit fluctuations in abundance across study sites and seasons. Factors that may cause fluctuations include variation in water or food supply, the ability of individuals to disperse to new areas and species interactions such as predation or competition (Toms et al., 2002). Some of the bird species were observed in both wet and dry seasons. This was mainly due to the availability of resources that can attract the birds in all of the seasons. Migration to Africa to spend the winter also increased the population of some of the migrant bird species in the area.

There was no substantial significance difference in bird abundance in Lake Hawassa and the riverine habitat between seasons, though there was minimal variation in mean abundance of species. The lowest abundance and diversity of species was observed during the dry season in Cheleleka wetland. This might be attributed to high human disturbance and livestock grazing in the wetland. There was also sand extraction as observed during field visit. Intensive grazing of domestic livestock, primarily cattle, is correlated with the decreased structural complexity of vegetation; and this led to the decline and loss of a wide variety of avian species in the wetland (Scott et al., 2003). This has an effect on the number of birds that depend on such habitats. The impacts of habitat destruction and overgrazing on cover, nesting grounds and food accessibility to birds causes a dangerous situation for the survival of avian fauna (Jansen et al., 2007; Girma Mengesha et al., 2011).

Spatial distribution of avian species

The studied habitat types recorded 103 bird species which call attention for conservation. According to Storch et al. (2003) also Buckley and Freckleton (2010) the distribution patterns of bird species normally follows the spatial structure of the environment and habitat requirement of the bird species. This corresponds with the results of this study, whereby habitat specificity and generalization were observed. For example, Egyptian Goose (*Alopochen aegyptiacus*), Goliath Heron (*Ardea Goliath*), Hadada ibis (*Bostrychia hagedash*), Little Ringed Plover (*Charadrius dubius*), Marsh Warbler (*Acrocephalus alustris*), Northern Carmine Bee-eater (*Merops nubicus)*, Northern Pintail (*Anas acuta*), Red-eyed Dove (*Streptopelia semitorquata*) Silver-cheeked Hornbill (*Bycanistes brevis*) and Slender-billed Starling (*Onychognathus tenuirostris*) were recorded in all habitat types. On the contrary, Abdim's Stork (*Ciconia abdimii*), Black-crowned Night Heron (*Nycticorax nycticorax*), Black-headed Heron (*Ardea)*, Comb (Knob-billed) Duck (*Sarkidiomis*), Ruff (*Philomachus*) and Southern Pochard (*Netta erythrophthaima*) were recorded only in Cheleleka wetland.

The highland biome species such as the Yellow-fronted Parrot (*Poicephalus flavifrons*), Banded Barbet (*Lybius undatus*) and Black-winged Lovebird (*Agapornis taranta)* were recorded from the riverine habitat might be due the suitability of the habitat that supported the species. Furthermore, the availability of fruiting and flowering tree species observed during the study such as *Schefflera abyssinica*, *Ficus vast* and *Prunus Africana* could be the reason*.*

A similar finding also showed that flowering plants support a wide variety of birds as they feed on nectars, berry fruits and seeds (Mengesha and Bekele, 2008). Alviola et al. (2010) reported that birds are mainly dependent on the availability of food items for their life processes, choosing to stay in places where food is abundant. But Forest Oriole (*Oriolus monacha*) species, which was reported previously in the study area, was absent during this survey. This could be the lowest detectability of the species in the present study. But the additional endemic species, Wattled Ibis (*Bostrychia carunculata*), was recorded in this survey. Despite its small share from the total study area, the occurrence of highest number of endemic species in Tikur wuha riverine habitat might be due to the favorable environment of the habitat that supported the species in different ways. Sometimes food richness or the structure of surrounding landscape also made a favorable environment for the species (Whited et al., 2000; Barcena et al., 2004). However, Lake Hawassa which is the least disturbed habitat, and the highest disturbed habitat, Cheleleka wetland, also holds a considerable number of endemic species. This is evident to the present study sites significance in supporting important conservation concern birds in the country.

The globally threatened species, Ferruginous Duck and Black-tailed Godwit were recorded in Lake Hawassa during the wet and dry seasons respectively. Globally critically endangered species Hooded Vulture was also recorded from Tikur wuha riverine habitat. The occurrence of this critically endangered species is associated with the presence of river in the area, and this species appears to be dependent on riverside vegetation within plantations, selectively logged, and secondary forests (Achondo et al., 2011). Such bird categories together with other aforementioned criteria put the conservation status of this area under the IBA status.

CONCLUSION AND RECOMMENDATIONS

The record of high number of species in Lake Hawassa and part of the eastern wetland habitats during the wet and dry seasons shows a high representation of resident, highland biome and Palearctic species. The presence of endemic species as well as migrant and globally threatened species suggests that Lake Hawassa and part of the eastern wetland habitats are key conservation sites of birds. Moreover, the highest numbers of endemic species were recorded in Tikur wuha riverine habitat, indicating that the need for more conservation effort in this site. The seasonal variation in avian species and number of individuals in the study area was related to the differences in resource availability between habitats. During both seasons, the highest species richness and individuals of species were recorded in Lake Hawassa among other study sites. The three study sites support bird species at varying levels of abundance and distributions. While Lake Hawassa and Cheleleka wetland had complementary bird assemblages, some species were restricted to a specific site. Although, the study sites harbor diverse bird species, interferences with these habitats were observed. Therefore, conservation measures are needed to protect the biological diversity of the area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix 1. Systematic list of bird species at Lake Hawassa and part of the eastern wetland habitats (August. 2017 to February. 2018).

Order	Family/sub family	Common name	Scientific name	MS	2017 IUCN red List category
Ciconiifores	Ciconiinae	Abdim’s Stork	*Ciconia abdimii*	AM	LC
Accipitriformes	Milvinae	African Fish Eagle	*Haliaeetus vocifer*	R	LC
Charadriiformes	Jacanidae	African Jacana	*Actophilomis africanus*	R	LC
Bucerotiformes	Bucerotidae	African Grey Hornbill	*Lophoceros nasutus*	R	LC
Accipitriformes	Accipitridae	African Harrier-Hawk	*Polyboroides typus*	R	LC
Columbiformes	Columbinae	African Mourning Dove	*Streptopelia decipiens*	R	LC
Anseriformes	Anatinae	African pygmy Goose	*Nettapus auritus*	NM	LC
Gruiformes	Rallidae	Baillon's Crake	*Zapornia pusilla*	R	LC
Piciformes	Capitonidae	Banded Barbet	*Lybius undatus* [NE]	R	LC
Passeriformes	Hirundanida	Banded Martin	*Riparia cincta*	R	LC
Cuculiformes	Musophagidae	Bare-faced Go-away Bird	*Coryhaixoides personatus*	R	LC
Passeriformes	Nectariniidae	Beaufiful Sunbird	*Nectarinia pulchella*	R	LC
Gruiformes	Rallinae	Black Crake	*Amauromis flavirostris*	R	LC
Passeriformes	Corvidae	Black Crow	*Corvus capensis*	R	LC
Pelecaniformes	Ardeidae	Black Heron	*Egretta ardesiaca*	NM	LC
Ciconiifores	Ardeinae	Black-crowned Night Heron	*Nycticorax nycticorax*	R	LC
Ciconiifores	Ardeinae	Black-headed Heron	*Ardea melanoceephala*	R	LC
Charadriiformes	Scolopacinae	Black-tailed Godwit	*Limosa limosa*	NM	NT
Psittaciformes	Psittacidae	Black-winged Lovebird	*Agapornis taranta* [NE]	R	LC
Charadriiformes	Recurvirostidae	Black-winged Stilt	*Himantopus himantopus*	NM	LC
Cuculiformes	Cuculidae	Blue-headed Coucal	*entropus cupreicaudus*	R	LC
Columbiformes	Columbinae	Blue-spotted Wood Dove	*Turtur afer*	R	LC
Columbiformes	Treroninae	Bruce’s Green Pigeon	*Treron waalia*	R	LC
Passeriformes	Passerinae	Chestnut Sparrow	*Passer eminibey*	R	LC
Anseriformes	Anatinae	Comb (Knob-billed) Duck	*Sarkidiomis melanotos*	R	NR
Passeriformes	Pycnonotidae	Common Bulbul	*Pycnonotus barbatus*	R	LC
Gruiformes	Rallidae	Common Moorhen	*Gallinula Chloropus*	R	LC
Anseriformes	Anatinae	Egyptian Goose	*Alopochen aegyptiacus*	R	LC
Passeriformes	Sylviidae	Eurasian Reed Warbler	*Acrocephalus scirpaceus*	NM	LC
Anseriformes	Anatinae	Ferruginous Duck	*Aythya nyroca*	NM	NT
Anseriformes	Anatinae	Garganey	*Anas querquedula*	NM	LC
Ciconiifores	Threskiorbithinae	Glossy Ibis	*Plegadis falcinellus*	NM	LC
Ciconiifores	Ardeinae	Goliath Heron	*Ardea goliath*	R	LC
Pelicaniformes	Phalacrocoracidae	Great Carmmorant	*Phalacrocorax carbo*	R	LC
Pelecaniformes	Ardeidae	Great Egret	*Egretta alba*	R	NR
Passeriformes	Sylviidae	Great Reed Warbler	*Acrocephalu sarundinaceus*	NM	LC

Appendix 1. Contd.

Passeriformes	Sturnidae	Greater Blue-eared Starling	*Lamprotornis chalybaeus*	R	LC
Charadriiformes	Charadriidae	Greater Sand Plover	*Charadrius leschenaultia*	NM	LC
Anseriformes	Anatidae	Greater White-fronted Goose	*Anser albifrons*	NM	LC
Charadriiformes	Scolopacinae	Greenshank	*Tringa nebularia*	NM	LC
Charadriiformes	Larinae	Grey headed Gull	*Larus cirrocephalu*	R	LC
Pelecaniformes	Ardeidae	Grey Heron	*Ardea cinerea*	NM	LC
Coraciiformes	Alcedininae	Grey-headed Kingfisher	*Halcyon leucocephala*	AM	LC
Charadriiformes	Laridae	Gull-billed Tern	*Gelochelidon nilotica*	NM	LC
Ciconiifores	Threskiorbithinae	Hadada ibis	*Bostrychia hagedash*	R	LC
Ciconiifores	Scopidae	Hammer kop	*Scopus umbretta*	R	LC
Accipitriformes	Accipitridae	Hooded Vulture	*Necrosyrtes monachus*	R	CR
Anseriformes	Anatidae	Hottentot Teal	*Spatula hottentota*	NM	LC
Ciconiifores	Ardeinae	Intermediate egret	*Egretta intermediary*	R	LC
Columbiformes	Columbinae	Laughing Dove	*Streptopelia senegalensis*	R	LC
Charadriiformes	Jacanidae	Lesser Jacana	*Microparra capensis*	R	LC
Passeriformes	Sylviidae	Lesser Swamp Warbler	*Acrocephalus gracilirostris*	R	LC
Coraciiformes	Meropidae	Little Bee-eater	*Merops pusillus*	R	LC
Ciconiifores	Ardeinae	Little Egret	*Egretta garzetta*	R	LC
Charadriiformes	Charadriidae	Little Ringed Plover	*Charadrius dubius*	NM	LC
Passeriformes	Ploceinae	Little Weaver	*Ploceus luteolus*	R	LC
Coraciiformes	Alcedininae	Malachite Kingfisher	*Alcedo cristata*	R	LC
Ciconiifores	Ciconiinae	Marabou Stork	*Leptoptilos crumeniferus*	R	LC
Passeriformes	Sylviidae	Marsh Warbler	*Acrocephalus alustris*	NM	LC
Columbiformes	Columbidae	Mourning Collared-dove	*Streptopelia decipiens*	R	LC
Coraciiformes	Meropidae	Northern Carmine Bee-eater	*Merops nubicus*	R	LC
Anseriformes	Anatidae	Northern Pintail	*Anas acuta*	NM	LC
Anseriformes	Anatinae	Northern Shoveler	*Anas clypeata*	NM	LC
Charadriiformes	Recurvirostridae	Pied Avocet	*Recurvirostra avosetta*	NM	LC
Passeriformes	Corvidae	Pied Crow	*Corvus albus*	R	LC
Coraciiformes	Cerylinae	Pied Kingfisher	*Ceryle Rudis*	R	LC
Pelicaniformes	Pelecanidae	Pink-backed Pelican	*Pelecanus onocrofalus*	R	LC
Ciconiifores	Ardeidae	Purple Heron	*Ardea Purpurea*	R	LC
Columbiformes	Columbinae	Red-eyed Dove	*Streptopelia semitorquata*	R	LC
Passeriformes	Sturninae	Red-winged Starling	*Onychognathus morio*	R	LC
Pelicaniformes	Phalacrocoracidae	Reed (Long-tailed)Cormorant	*Phalacrocorax africanus*	R	LC
Charadriiformes	Caliditrinae	Ruff	*Philomachus pugnax*	NM	LC
Passeriformes	Sturninae	Ruppell’s Long-tailed Starling	*Lamprotornis purpuropterus*	R	LC

Appendix 1. Contd.

Passeriformes	Turdidae	Ruppell’s Robin-chat	*Cossypha semirufa*	R	LC
Passeriformes	Ploceinae	Ruppell’s Weaver	*Ploceus galbula*	R	LC
Passeriformes	Sturnidae	Rüppell's Starling	*Lamprotornis purpuroptera*	R	LC
Ciconiifores	Threskiorbithinae	Sacred Ibis	*Threskiomis aethiopicus*	R	LC
Ciconiifores	Ciconiinae	Saddle-billed Stork	*Ephippiorhynchus negalensis*	R	LC
Passeriformes	Sylviidae	Sedge Warbler	*Acrocephalus schoenobaenus*	NM	LC
Coraciiformes	Bucerotinae	Silver-cheeked Hornbill	*Bycanistes brevis*	R	LC
Passeriformes	Sturnidae	Slender-billed Starling	*Onychognathus tenuirostris*	R	LC
Anseriformes	Anatinae	Southern Pochard	*Netta erythrophthaima*	NM	LC
Coliiformes	Collidae	Speckled Mousebird	*Colius striatus*	R	LC
Passeriformes	Ploceinae	Spectacled Weaver	*Ploceus ocularis*	R	LC
Charadriiformes	Scolopacinae	Spotted Redshank	*Trunga erythropus*	NM	LC
Anseriformes	Anatinae	Spur-winged Goose	*Plectropterus gambensis*	AM	LC
Ciconiifores	Ardeinae	Squacco heron	*Ardeola ralloides*	NM	LC
Passeriformes	Sturninae	Superb Starling	*Lamprotornis superbus*	R	LC
Passeriformes	Ploceinae	Village Weaver	*Ploceus cucullatus*	R	LC
Ciconiifores	Threskiorbithinae	Wattled Ibis	*Bostrychia Carunculata* [NE]	R	LC
Passeriformes	Sturninae	Wattled Starling	*Creatophora cinerea*	R	LC
Pelecaniformes	Ardeidae	Western Cattle Egret	*Bubulcus ibis*	R	LC
Charadriiformes	Sterninae	Whiskered Tern	*Chlidonias hibridus*	NM	LC
Pelicaniformes	Pelecanidae	White great pelican	*Pelecanus onocrofalus*	R	LC
Ciconiifores	Ciconiinae	White Stork	*Ciconia ciconia*	NM	LC
Anseriformes	Anatinae	Whitebacked Duck	*Thalassomis leuconotus*	R	LC
Passeriformes	Timmallidae	White-rumped Babbler	*Turdoides leucopygius*	R	LC
Charadriiformes	Sterninae	White-winged Black Tern	*Childonias leucopetrus*	NM	LC
Coraciiformes	Alcedininae	Woodland Kingfisher	*Halcyon senegalensis*	R	LC
Anseriformes	Anatinae	Yellow-billed Duck	*Anas undulate*	NM	LC
Pelecaniformes	Ardeidae	Yellow-billed Egret	*Egretta intermedia*	R	LC
Ciconiifores	Mycteriinae	Yellow -billed storck	*Mycteria ibis*	R	LC
Psittaciformes	Psittacidae	Yellow-fronted Parrot	*Poicephalus flavifrons* [E]	R	LC

Description; Movement: MS=migratory status, PM=Palearctic Migrant, AM= Intra-African Migrant, R=resident; Endemism: E=endemic [E,] NE=near endemic [NE]; IUCN Conservation Status: NT=Near Threatened, LC=Least Concern, CR =Critically Endangered, NR= Not Recognized family names ends with …dae and subfamily …nae.

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Full Length Research Paper

Climate change study in Burkina Faso from 1987 to 2018: An online systematic review for future directions

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In this paper, we perform a bibliometric analysis of published climate change research in Burkina Faso for the period of 1987 to 2018. More specifically, this article aims at (1) revealing the temporal, and categorical patterns in climate change research; (2) summarizing the global research trends from multiple perspectives; and (3) providing an alternative demonstration of research advancements about climate change which may serve as a potential guide for future research in Burkina Faso. Scopus, ISI Web of Science, and Google Scholar were used to collect publications data. The initial search yielded five hundred and sixty-six publications. After removing duplicated documents and application of inclusion/exclusion criteria, 349 documents were retained for analysis. The study reveals that since the beginning of this century, the study on climate change is increasing in the scientific community, and publications are widely distributed in a large number of journals. Climate change has been studied in connection with other topics such as agriculture, health and diseases, water resources and wetlands. These results suggest that research productivity in the area of climate change in Burkina Faso has increased since the beginning of this century. However, there is a lack of studies connecting climate change and aquatic fauna in Burkina Faso. These results could help to orient the national research in the matter of climate change and its implications.

Key words: Climate change, bibliometrics, West Africa.

INTRODUCTION

Nowadays, the climate change concept is increasingly used in the scientific community over the world (Lukwale and Sife, 2017). Burkina Faso like many countries in Africa is vulnerable to the impacts of climate change (Ouédraogo et al., 2010). The country is a predominantly agricultural economy (Zougmoré et al., 2018). The sector contributes to 30% of GDP and occupies 90% of people (FAO, 2015). This implies that its economy and development depend mainly on natural resources that are vulnerable to climate variability and change (Sarr,

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2012). In a context that climate change poses a critical threat to the survival of our planet (Smith et al., 2012; IPCC et al., 2013) and occupies a central place in most environmental subjects (Epule-Epule et al., 2017), scientists are tackling a lot of questions about it (Marx et al., 2017). Policy-makers are also aware of climate change challenges (CCNUCC, 2009). Many studies already demonstrated that climate change affects water resource in Burkina Faso (Bambara et al., 2013; Bodian et al., 2013; Greimel et al., 2018) and food security (Clover, 2003; Vermeulen et al., 2012). Then, climate change has been approached in the literature in various ways. Nevertheless, information is sparse and there is a need to collect, analyze the structure and characteristics of scientific publications, and to synthesize them to orientate future research. Moreover, there are no bibliometric studies on the trends of research concerning the climate change area. Therefore, the present study, which is a knowledge synthesis analyses the climate change research trends by attempting to provide answers to questions about the structure and characteristics of climate change research in Burkina Faso by assessing the past and current state of knowledge on the subject of climate change in Burkina Faso using bibliometric research. Otherwise, National adaptation strategies should base on important scientific research (CCNUCC, 2012). The main questions are about (1) research that has been already done, (2) information need to be collected, and (3) future orientation of climate research in Burkina Faso. Bibliometric research is a branch of Bibliology widely used to analyze the products of scientific research contained in various types of journals (Perea-Moreno et al., 2018). It is a statistical method used for assessing trends in a specific subject (Mao et al., 2018) and a good tool to analyze the structure and characteristics of scientific publications, collect data and orientate future research (Barbosa and Schneck, 2015; Liang and Gong, 2017; Mao et al., 2018).

MATERIALS AND METHODS

Study area

Burkina Faso is located in the center of West Africa between latitudes 09°20'N and 15°N and longitudes 05°03'W and 02°30'E with an area of 274 200 km^2. It is a continental country without direct access to the sea. Its climate is the Sahelo-Sudanian type and is characterized by extremes of temperature oscillating between 15 and 40°C with an average of 28.8°C (Mouhamed et al., 2013) as well as considerable rainfall variations ranging from an average of 350 mm in the North (Sahelian climate) to 1200 mm in the South-West (Ouédraogo et al., 2010). This situation over the country has been characterized for several decades by a decrease, irregular rainfall, and a weakening of ecosystems (Ki et al., 2013).

Search strategy

The knowledge synthesis consists of two parts: a literature review and bibliometric analysis. For the literature review, the data were collected online for four weeks, from the 1st to the 28th of September 2018 at the University of Groningen. The data collection used three well-known bibliometric search engines to collect scientific publications from several journal databases. These were Web of Science (WoS), Elsevier Scopus (Scopus), and Google Scholar for relevant publications. These research engines provide comprehensive and standardized data and have been widely used by academia (Gao et al., 2016; Lukwale and Sife, 2017). The period of publications covered by the three-search engine during this research lasted from 1987 to 2018, for a total of 31 years. We did not use Google Scholar directly because it tended to include other items that are not useful for our study. So, Google Scholar has been only used when the document was not accessible on WoS or Scopus. These search engines were retained because of their accessibility to an important number of publications (Perea-Moreno et al., 2018; Tessier et al., 2016). Our search in WoS and Scopus focused on seven (07) keywords in two languages (English and French): 'Climate change', 'Changement climatique', 'Global change', 'Changement global', 'Global warming', 'Rechauffement global' and 'Burkina Faso'. The choice of these two languages is because Burkina Faso is a French-speaking country and then, the national language is French. Concerning English, it is since this language constitutes nowadays the main language used in the scientific community (Ferguson et al., 2011). Each keyword linked to climate change has been paired with the country name "Burkina Faso" and has been entered into the search box of each search engine and listed articles were downloaded. In the Web of Science search field, each of the keywords is linked with Burkina Faso using the "*" symbol. In Scopus and Google Scholar, the Boolean operator "AND" has been used for keyword matching. When the article is not accessible on these engines, we copy the title and launch the Google Scholar search. If access still not possible, we just copy the title, the abstract, the year of publication, the names of the authors and the name of the journal into a Word file. Article which summary is not accessible are discarded from analysis.

Inclusion and exclusion criteria

Inclusion

The search was restricted to studies conducted in Burkina Faso or a geographical area including Burkina Faso. After the raw data collection, only the publications having Burkina Faso, Africa, the world, or a part of the world including Burkina Faso as a field or subject of study were considered for the bibliometric analysis. The second criteria to include publication was the topic addressed.

Exclusion

The publications where Burkina Faso was not concerned by the study were excluded even if the author(s) are from Burkina Faso. The studies that had no publication date nor the author(s), nor journal name were also removed. We have also excluded the duplicated publications and only one of these documents was retained for analysis.

Data organization and analysis

After downloading, the publications are listed on an Excel sheet with the following information: Publication title, first author name and et al., document type, study area, research topics, journal name (where the paper has been published), keywords used, and search engine used. For the Bibliometric analysis, we first analyzed downloaded documents by type (article, poster, books, conference paper, etc), year of publication, and locality. Secondly, we analyzed

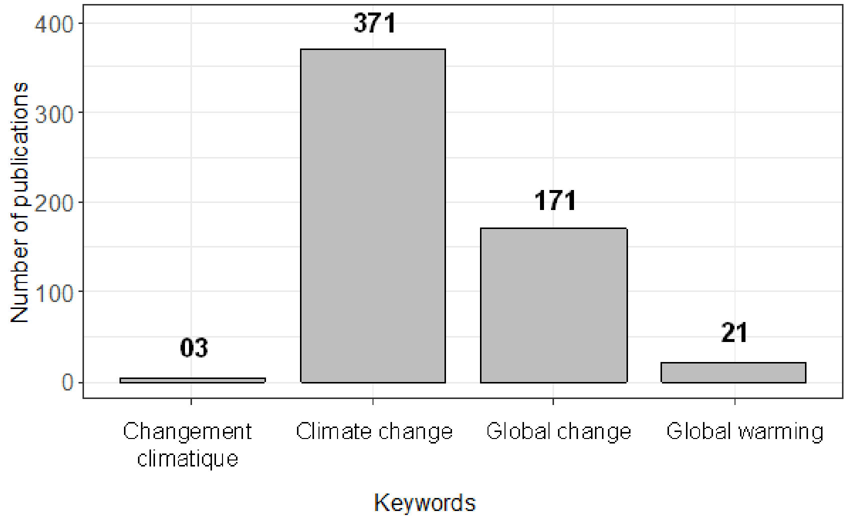

Figure 1. Number of publications by keywords.

the publications according to the research topic, to highlight favorite topics. We also determined the total number of published papers (TP) and growth index (GI) for each subject of the top 10 considering publications dating from 2000 to 2018. The delimitation of this period in the calculation of GI is because, during this period, the published papers are more homogenic than the period before where papers are sparse, minor, and which consideration could make bias in the result interpretation. The growth index shows, for 2 periods of the same duration, which period has an increase in the number of publications (Picard-Aitken et al., 2015). To do that, we first determined the date (year) of the first and last publications during this century as the global period of each top 10 main subjects. After that, we subdivided this period into two sub-periods with the same length when the number of years is paired and x+1 (for the first period) and x (for the second period), when the number is impaired. This formula has been used to determine growth index: $\mathrm{GI} = \frac{\sum_{P2(cd)} \text{Published papers}}{\sum_{P1(ab)} \text{Published papers}}$. Where P_2 means second sub-period beginning in c year and ending in d year; P_1 means first sub-period beginning in a year and ending b year. The relative growth rate (RGR) was calculated using this formula: $\mathrm{RGR} = (\ln N_2 - \ln N_1)/(t_2 - t_1)$ where, N_2 and N_1 are the cumulative number of publications in the years t_2 and t_1. The RGR is the increase in the number of publications per unit of time. For our analysis, we have just considered the period covering 2000 to 2018 as before that period, data are discontinuous. The software R version 4.0.2 was used to carry out statistical analysis.

RESULTS

Our initial search on WoS, Scopus, and Google Scholar databases yielded 566 publications. After application of exclusion criteria, only 349 publications have been submitted to bibliometric analysis.

Keywords research

According to keyword research, “climate change” has yielded the most publications with 371 documents (61.66%). No document has been downloaded by “Changement global” and “rechauffement global” (Figure 1). Then, only 3 documents were found using French word with “Changement climatique”.

Study areas

Six regions (study areas) were encountered in addition to Burkina Faso: Africa, Developing Countries, Sahel, Sub-Saharan Africa, West Africa, and World. Most papers are focused on Burkina Faso, up to 57%. About 17% of the documents deal with the West Africa region, 7% for Africa, 7% for World and 7% for the Sahel. Only 2-3% and of the studies concern respectively Sub-Saharan Africa and developing countries including Burkina Faso (Figure 2).

Types of publications

As part of the work done on climate change concerning Burkina Faso, most documents, up to 94%, were scientific articles. The remaining 6% are books, parts of books, conference papers and posters, or reports (Figure 3).

Trend of total publications

The analysis of publications per year revealed a rapid growth in research on climate change in Burkina Faso since the beginning of the 21st century (Figure 4). The histogram shows a fast growth that can be assimilated to exponential growth; going from above one publication per

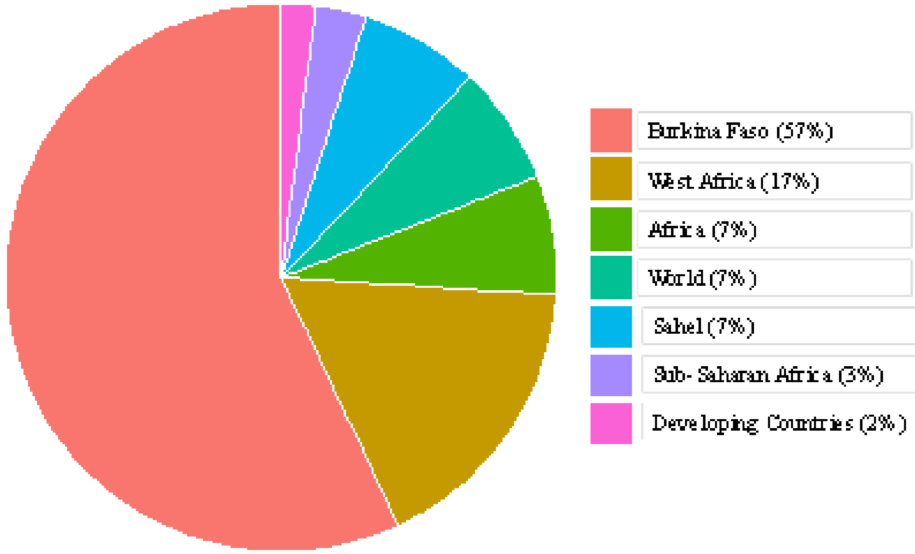

Figure 2. Proportion of publications according to the covered area.

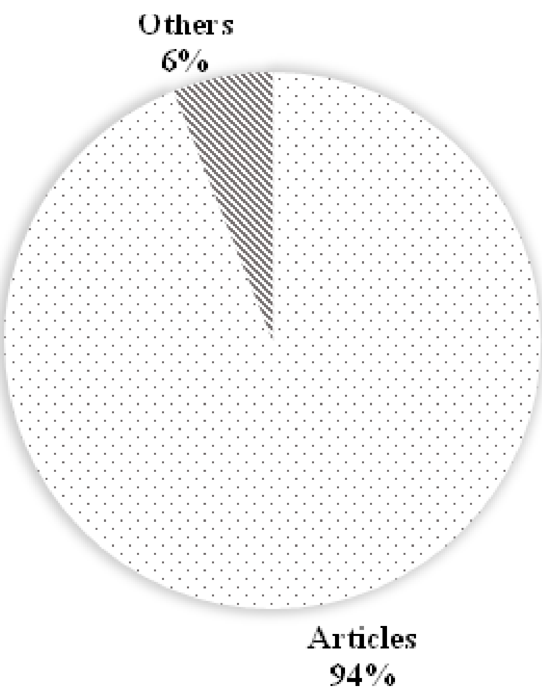

Figure 3. Proportion of publications according to the type of publication.

year to more than 35 publications after 2011.

Main topics of publications

The various themes discussed have been grouped into 23 topics according to their similarities (Figure 5). The most widely emerging topic is agriculture with 16% of publications. Around 80% (278) of publications are concerning the top ten topics: Agriculture, Health and Disease, Adaptation, Forest, Land use and Land change, Water resource and wetlands, drought and assimilate, Food and nutrition, Temperature-rainfall, and Animal and Livestock.

Relative growth rate

All publications output in the field of climate change collected are represented in Figure 6. It shows that the rate of publications decreases gradually from 2003 (RGR=1.012) to 2018 (RGR=0.109).

Growth index (GI)

The analysis of the top 10 main topics GI' shows that all of them have registered an increase during their second period, which explains the fact that GI is superior to 1. Except for 'Health and Disease which occupies third place, the six other themes that have been widely disseminated in research are closely linked to Agriculture. In order of importance, we have: 'Temperature and rainfall', 'Food and nutrition', 'Land use and land change', 'Forestry', 'Water resources and wetlands' and 'Drought, desertification…' (Figure 7).

The variation tendency of each main topic related to climate change is illustrated in Figure 8. This figure reveals that the discussion of 'Agriculture' and 'Food – Nutrition' register best-fitting exponential increasing. However, the publications related to 'Temperature and Rainfall' and 'Animal and Livestock' decrease slowly. The others are increasing slowly and linearly.

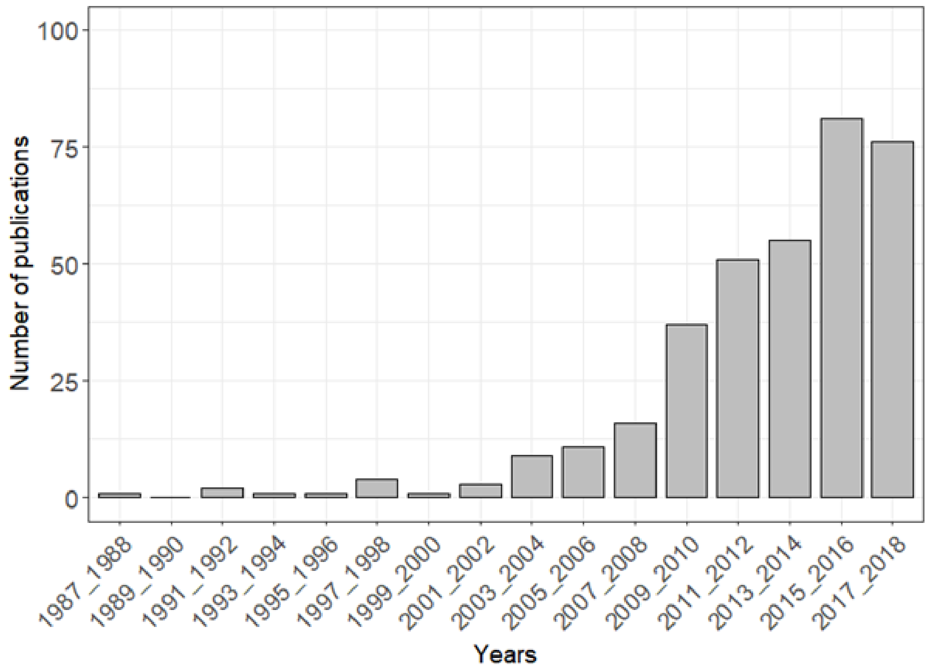

Figure 4. Trend of total publications according to the years.

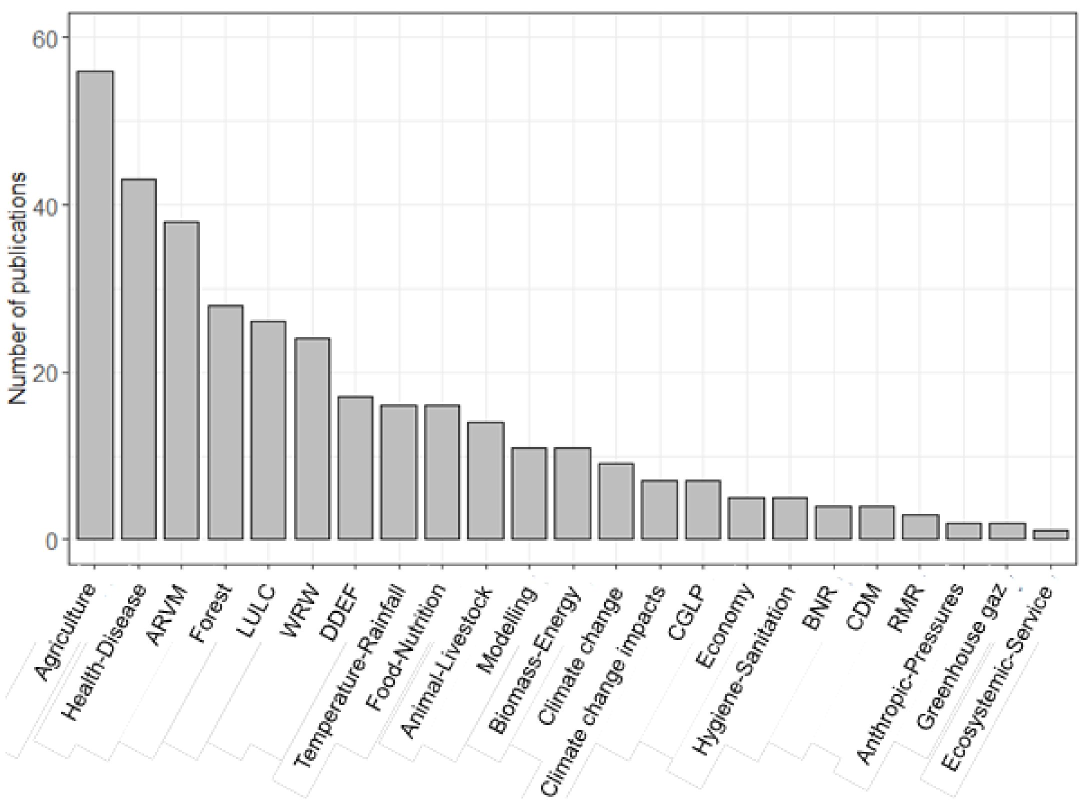

Figure 5. Number of publication per main topics.

Labels: BNR: Biodiversity and Natural Resources; CDM: Conflicts and Decision Makers; DDEF: Drought, Desertification, Evapotranspiration and Fire; CGLP: Culture, Gender and Local Perceptions; ARVM: Adaptation, Risks, Vulnerability and Migration; WRW: Water Resources and Wetlands; RMR: Research, Mercure and Relief; LULC: Land Use, Land Cover.

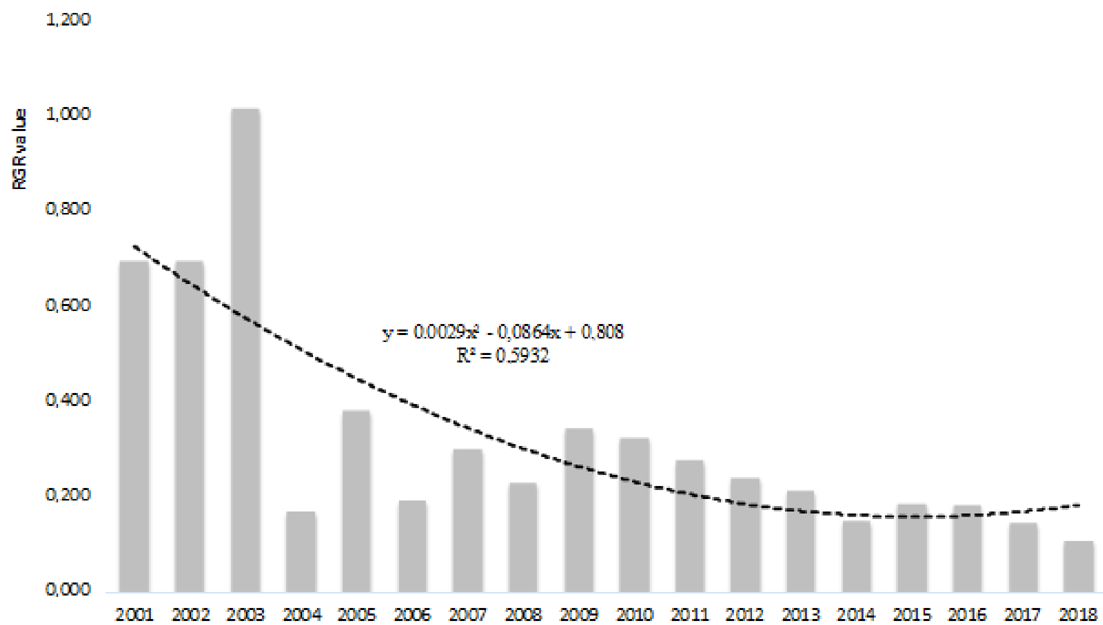

Figure 6. Relative growth rate of publications.

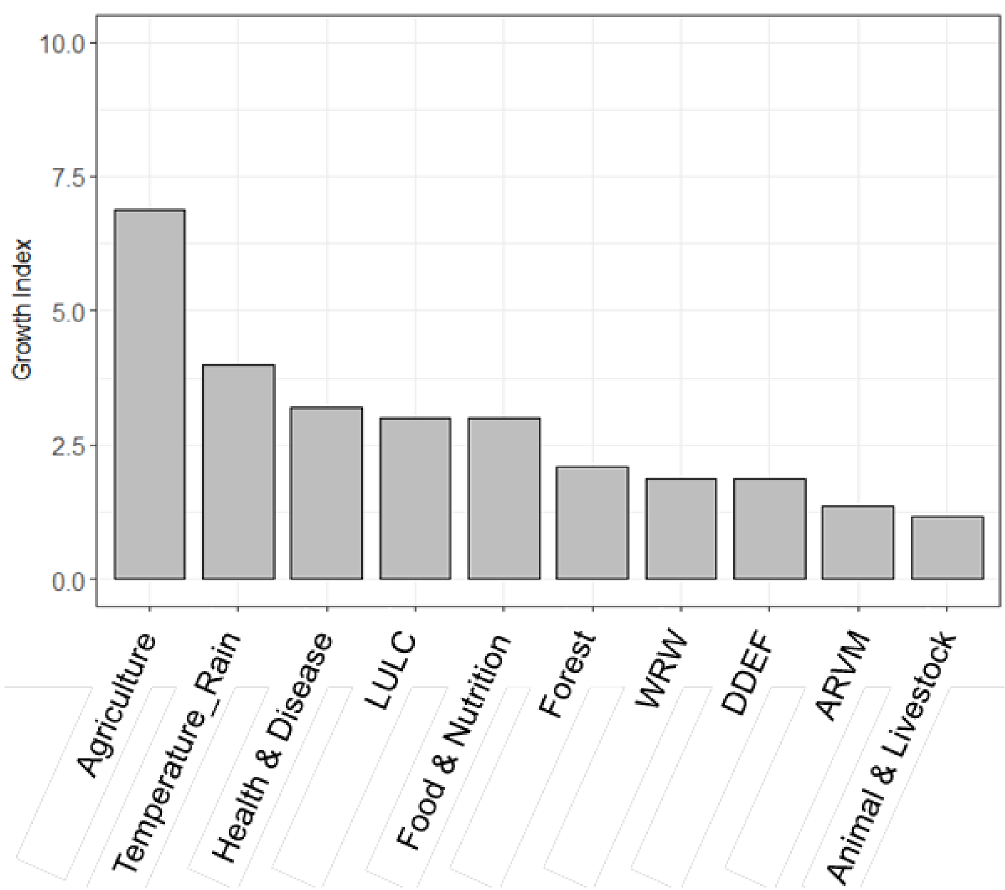

Figure 7. GI of top 10 main topics.
Labels: LULC: Land Use and Land Cover; WRW: Water Resources and Wetlands; ARVM: Adaptation, Risks, Vulnerability and Migration; DDEF: Drought, Desertification, Evapotranspiration and Fire.

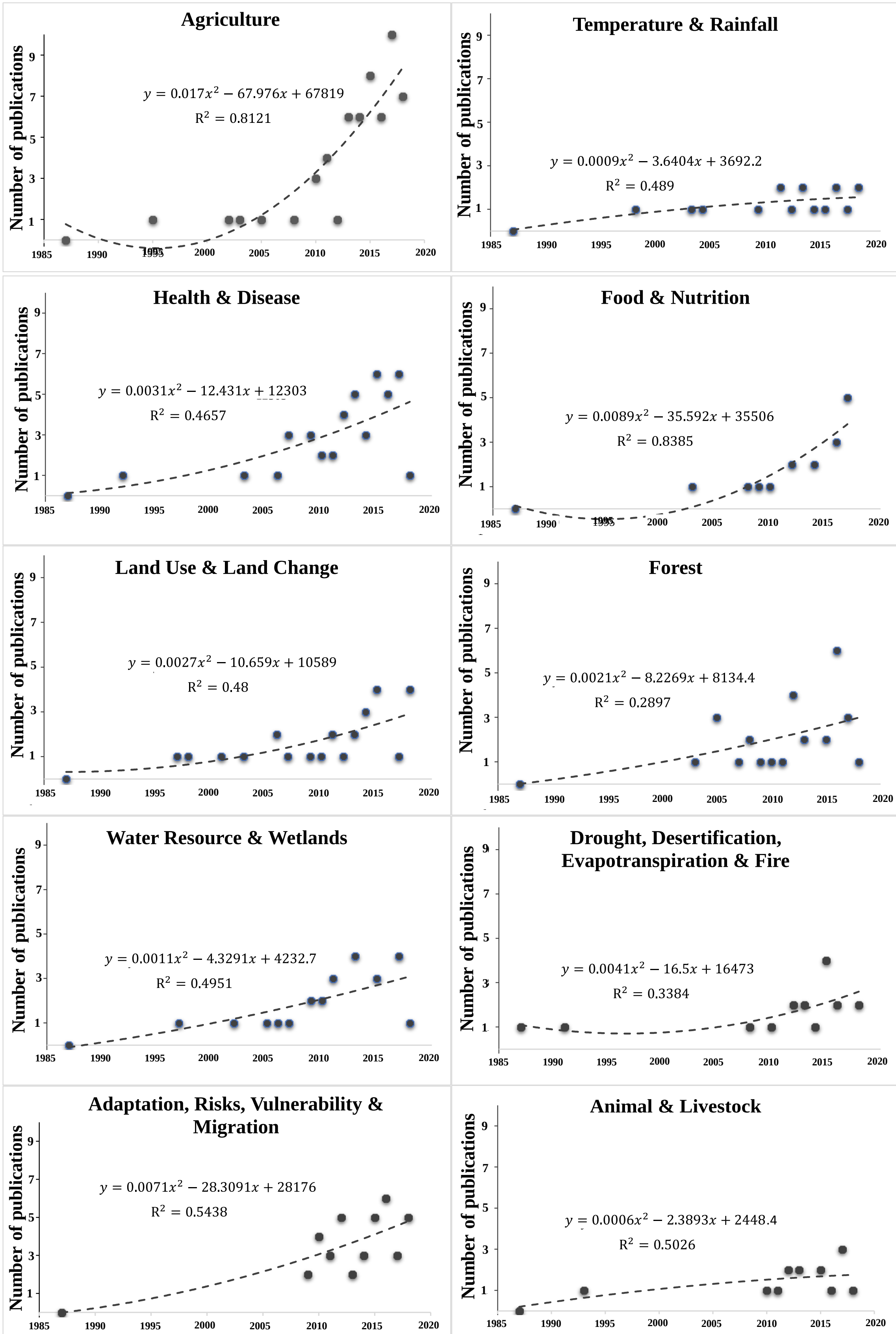

Figure 8. Trend of the number of publications per main topics.

DISCUSSION

The general results of this study indicate an exponential increase in the number of publications on climate change in Burkina Faso from 1987 to 2018.

Keywords research and types of publications

In general, the bibliometric research on climate change by keywords in Burkina Faso is more favorable by using the English term as most publications are in English. This means that English was by far, the dominant language in the field of climate change research. The bibliometric research on climate change conducted by Sangam and Savitha (2019) also showed a large predominance of publications in English, that is, 97.78%. This result is similar to those of Yevide et al. (2016) who have also found 97% of articles published in English. Although Burkina Faso uses French as the national language, scientists are aware that it is important to communicate the results of their researches in English. Indeed, it is now recognized that most scientists use English to publish their results (Ferguson et al., 2011). This fact can be an important gap to the vulgarization and the dissemination of the research results, as a policymaker in Burkina Faso are less use English. Tao et al. (2016) have also shown that the fact that most articles are published in one language constitutes a disadvantage in the development of worldwide academic research.

According to the types of publications, we observe a high number of scientific publications (articles) which represents 94% of documents downloaded. This proves that researchers are aware of the climate change reality in Burkina Faso and work to find the best conditions for people and decision-makers. The fact that there are few books compared to articles shows also that the concept of climate change has not yet reached a certain level of popularization. This could also constitute a gap in the dissemination of the results since the majority of Burkina Faso people are illiterate.

Study area and main topics

Studies regarding climate change have mainly focused on Agriculture and climate change Adaptation-Vulnerability-Resilience. Climate change will affect negatively agriculture and will increase from southern West Africa with -13% to northern West Africa with -18%. In the context of Burkina Faso, the fact that rainfed agriculture constitutes the source of economy in Burkina Faso (Zougmoré et al., 2018) with more than 85% of the population who are farmers (Roudier et al., 2014), and because of the vulnerability of this sector to climate change, could explain the importance of studies about climate change impact on agriculture. According to Challinor et al. (2007), climate change will negatively impact on crop productivity in Africa because its agrosystems are vulnerable to climate variability. In 2012, Ouédraogo also showed that climate change would influence crops and livestock systems in Burkina Faso. Besides, developing countries are more vulnerable to climate change. Sathaye and Ravindranath (1998) showed that climate change will highly affect energy and forestry in developing countries. Adaptation to climate change constitutes the third most topic already examined in the different climate change studies in Burkina Faso. Indeed, developing countries are more vulnerable to climate change and they need to make more efforts in climate change adaptation (Mertz et al., 2009). Furthermore, the vulnerability of households who are dependent on livestock in drier areas of developing countries could increase and induce poverty and inequity in these populations (Thornton, 2010). Some research conducted in Tanzania also showed the most publication on climate change adaptation, impacts/implication, and vulnerability (Lukwale and Sife, 2017). This means that these topics attracted increasing attention from scientific communities. Therefore, even if there were many studies on climate change's impact on agriculture, it would be important to analyze these impacts on fisheries whose products are the main source of animal protein for people of this country. Using Web of Science and Scopus does not allow to find scientific research on climate change impacts on fisheries in Burkina Faso which means that, even if it could exist some studies, there is probably a few. This bibliometric search, found only one reference about vulnerability of freshwater fisheries in West Africa to climate change (Carr and Hughes, 2014).

Trend of publications and growth index (GI)

The evolution of publications on themes related to climate change in Burkina Faso shows that the first publications concerned drought-desertification-evapotranspiration and bush fires in 1987 and 1992. Indeed, like many other countries of the sub-region, had just experienced the great droughts of the 1970s and 1980s, which led to famines can explain this fact. Considering global topics, we have noted an exponential increase of studies particularly since the beginning of this century. This trend is also approved by Theokritoff (2018) who has shown the commitment of the Burkina Faso Government to climate change over the past two decades. Many factors can explain this increase. Firstly, we noted that Burkina Faso signed the United Nations Framework Convention on Climate Change in 1993, before developing a National Strategy for the implementation of this Convention in 2001. Since then, the country has drafted several programs and policies to ensure a better adaptation of populations to climate change. Moreover, the RGR even if decreases along the time with some fluctuations, the value remains positive. This means a decrease in publications globally.

Climate change via global warming is recognized to drive temperature increase and disturb rainfall, particularly in tropical areas during this century (Deng et al., 2017). This situation leads many researchers to analyze their evolution.

While for all the themes, publications have progressed since 2000, it is not the same concerning 'Animals and Livestock' and 'Temperature and Rainfall' themes which, in addition to being the least addressed themes in the top 10, have also experienced a slight decrease in their publications, as shown by the negative slopes of their regression curve. However, the work of Kabore et al. (2017) showed high variability in rainfall in the North and Sahel of Burkina Faso. This therefore, highlights the need for research in this area to provide adaptation measures to local populations whose sectors of activity are highly dependent on climatic variables such as rainfall. The decrease in rainfall and temperature research is particularly contrary to the situation of the West African region. Indeed Sultan et al., 2015, showed an upward trend in research on these themes in the West African region over the last three decades. A lack of adequate financial support (Lukwale and Sife, 2017), a lack of data, or evidence of low interest in these areas could explain this decrease. Indeed, although agriculture occupies more than 80% of the population, uneducated farmers who are engaged in subsistence farming mostly practice it. As a result, there are hardly any statistical data available to provide a solid scientific basis. However, it is demonstrated that climate change will affect negatively agriculture (Döll et al., 2014). This agriculture occupies a central role in the economy of the country by providing employment (Belem and Saqalli, 2017).

The particular increase of the top 10 main topics is due to their implication in local population life. GI’ shows that all of them have registered an increase during their second period. The themes with an index greater than or equal to 3 are closely related. Indeed, the practice of agriculture (GI=6.87) which is the main source of food (GI=3) for the populations requires land occupation (GI=3). Consequently, the lack of adequate food could constitute public health problems (GI=4.2). This agriculture is unfortunately rainfed, which makes it vulnerable to climatic hazards such as temperature and rainfall (GI=4). Since the beginning of the 21st century, Burkina Faso has been engaged in the implementation of agricultural development policies that have led to the strong production of policy documents (Traoré et al., 2018). It is demonstrated since Conference of party (COP21) in 2015 that agriculture could be affected by climate change by modifying plants' growth and the abundance of some harmful and beneficial organisms associated with crops. Moreover, these results are also similar to those of Saguez et al. (2017) who showed that in recent years, changes have also been observed in certain plant and animal species with variations in temperature and precipitation, thus favoring the dissemination and spread of certain diseases. This observation reveals once again the need to pay special attention to these issues. The growing attention paid to these themes could also be explained by the demographic boom that the country has been experiencing since the beginning of the 21st century (Guengant et al., 2009), which has inevitably led to an increase in the number of researchers. In a nutshell, a greater number of published articles and a recent rapid increase in articles number related to climate change reveal the increased research focus on this topic.

Conclusion

This study based on the bibliometric research has highlighted the topics already discussed in Burkina Faso linked to climate change. It examined the trends of climate change research using a bibliometric approach based on 349 cited English and French publications from 1987 to 2018. The main themes addressed so far about climate change in Burkina Faso revolve around Agriculture, Health and Disease, Adaptation, and others themes associated with agriculture such as rainfall, temperature, food, land use and vegetation. This work revealed that very few studies have been interested in the impact of climate change on the biodiversity specifically in animal in Burkina Faso. This study revealed that there is no study by now in the field of climate change impact on fish fauna in Burkina Faso. Overall, this study could help to a better understanding of the past trajectory of climate change research in Burkina Faso. It could help researchers to identify research gaps in the current research as well as help them to guide them in establishing future research directions.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

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The effects of anthropogenic activities on the regeneration of flora in duekoué and scio forests in Southwestern Côte D'ivoire

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The aim of this study is to understand how the crop farms and forest plantations affect the regeneration of local flora. Ten plots of 10 m × 10 m size were established per vegetation type and all DBH categories of vascular plants were inventoried. The richness of adult plants (DBH ≥10 cm) was similar to those of juvenile plants (10 cm > DBH ≥1 cm), which was between 20 and 50 times lower than the richness of seedlings and herbaceous plants (DBH <1 cm). The undergrowth cleared forests showed the similar richness of adult and juvenile plants than the natural forest islands which was higher than those of the coffee and cocoa farms of both sites, the rubber and teak plantations at Duekoué site. But the richness of seedlings and herbaceous plants was variable according to the biotopes. Inside the DBH categories, the richness of adult plants was higher in both the patches of natural forest and forests with cleared undergrowth and, dropped drastically in the farms and the forest plantations. The juvenile plants were reduced to the crop species only in the farms while the seedlings and herbaceous plants showed an important richness in the farms and forest plantations. To avoid the decreasing of the richness for all DBH categories of vascular plants, the protected forest areas should not harbour any farms and, the forest plantations should not be single species planted.

Key words: Forest protection, cash crops, agroforestry, richness, adult plants, juvenile plants, seedlings, herbaceous.

INTRODUCTION

The high values of richness in vascular plants and floristic diversity are the main characteristics of dense tropical humid forests (Richards, 1996; Blanc, 2002; Parmentier et al., 2007; Ghazoul and Sheil, 2010; Parmentier et al., 2011). Indeed, this type of forest is far richer in vascular plant species (Myers et al., 2000; Spichiger et al., 2000; Ghazoul and Sheil, 2010) than the European and North American forests which are generally single species or poor species vegetation. Most of the hotspots (Myers et al., 2000; Pimm and Raven, 2000) including those of vascular plants are known from the tropical forests; moreover, the neotropical forests are considered to

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harbor the greatest total taxonomic diversity (Gaston and Williams, 1996; Ghazoul and Sheil, 2010).

The regeneration of the tropical forests proceeds by a natural and spontaneous process or by an artificial (induced or assisted) process (CTFT, 1989). Authors who studied the structure and composition of tropical forests showed that this vegetation type was naturally a veritable mosaic in eternal evolution (Richards, 1996; Ducrey and Labbe, 1985; CTFT, 1989; Baraloto, 2001; Dong, 2011; Ma et al., 2016). Species successions are always observable and, even if the study of a fairly large area showed a relatively stable character, a whole dynamic of population transformations takes place there every day. The mechanism that maintains this regeneration almost always calls for the presence of clearings or gaps (Whitmore, 1978) often caused by the presence of windfall (Oldeman, 1972).

Besides the forest regeneration by seed (Kouakou, 1989), the process of natural reconstitution of forests can be done by vegetative multiplication including rejection from stumps in the case of simple coppice or coppice under forest (CTFT, 1989). Multitudes of sylvicultural methods have been applied in the tropical forests, in general, and in the dense African humid forests, in particular (Martineau, 1929, 1930a, 1930b, 1932; Martinot-Lagarde, 1961; Maître, 1987, 1991, 1992). In West Africa, selective management and improvement of natural stands are methods which aim to assist natural regeneration while the tropical shelterwood system method aims to induce this natural regeneration (Ducrey and Labbe, 1985; CTFT, 1989). The regeneration of the tropical forests becomes artificial when plantations are established in the place of natural vegetation (CTFT, 1989). The methods of creating these forest plantations are diverse (CTFT, 1989) but are essentially based on the partial or full replacement of the original vegetation. They thus join the methods of creating cash or food crop plantations in dense tropical forest areas due to the devastating nature of the original vegetation and flora. Like natural regeneration, the artificial can be done either by seed or by vegetative propagation.

In the Upper Guinea sub-region (White, 1986) Côte d'Ivoire has the second largest West African humid rain forest area after Liberia (Poorter et al., 2004) and is known to be among the countries that have the highest tropical deforestation rate (Sayer et al., 1992; Chatelain et al., 2004) due to human activities despite a century policy of forest protection. There are two main categories of protected areas in Côte d'Ivoire which are the national parks banned of any human activities except management and research, and the classified (protected) forests whose purpose is the management for sustainable logging (Kouamé, 1998). The definition and delimitation of these protected forests began in 1924 by the conservation only (de Koning, 1983; Ahimin, 2006). After the Ivorian independence in 1960, their legal status has been created together with a national Forest Research Institute and a National Service of Forest Development. Many decades later, these proceedings could not stop the fast degradation of Ivorian forests (Dao, 1999; Chatelain et al., 2004; Ahimin, 2006). Due to rarefaction of wastelands in the rain forest area, the farmers crossed the limits of protected forests within which they establish their crops and live. The politico-military crisis in Côte d'Ivoire since 2002 led to increasing the illegal occupation of its South-western protected areas mainly the classified forests like Duekoué and Scio.

The aim of this manuscript is to analyze the regeneration of the flora in eight dominant vegetation types generated by human activities in the two most closed protected areas belonging each to a different sub-type of rain forest in Côte d'Ivoire. These vegetation types were the coffee and cocoa farms, the rubber and teak plantations, the undergrowth cleared forests and the natural forest islands (patches). The objective of this study is to compare the richness and diversity of the adult plants, of the juvenile plants and, of the seedlings and herbaceous plants in these vegetation types.

Hypotheses

Due to the natural distribution of plants in tropical forests and as both the National Service of Forest Development and the farmers remove several adult plants in the local vegetation during their activities in the study area, the first hypothesis was to find poorer richness and diversity of the adult plants. And as the loss flora depends on the intensity of the human activities on the local vegetation, the second hypothesis was to find different richness and diversity in these biotopes for each category of plants.

MATERIALS AND METHODS

The study biological material consists of the vascular plants accessed in the field while the technical material constitutes the tools used to collect and analyze the data.

Research site

The study was carried out in the classified forests of Duekoué (6°30'- 6° 45' N, 7° 00'- 7° 15' W) and Scio (6° 30'-7° 00' N, 7° 30'-8° 05'W) in South-West of Côte d'Ivoire (Figure 1). Climate in both areas is sub-equatorial with a long wet season from February to November and a short dry season from November to January. Annual rainfall varies from 1600-1700 mm in Duekoué forest to 1700-1800 mm in Scio forest. The average monthly temperature is 25°C while monthly and annual potential evapotranspiration of both areas are respectively 123.5 and 1482 mm (Eldin, 1971). The soils belong to the remould ferrallitic group (Perraud and de la Souchère, 1970). The natural vegetation of Duekoué forest consists of a moist semi-deciduous forest defined as a tropical rain forest type in which part of the higher trees shed their leaves during the 3-4 months dry season in a region of 1350-1600 mm annual rainfall (Trochain, 1957; ORSTOM and UNESCO, 1983) interrupted by savannas areas and inselbergs (Monnier, 1983). The original vegetation of

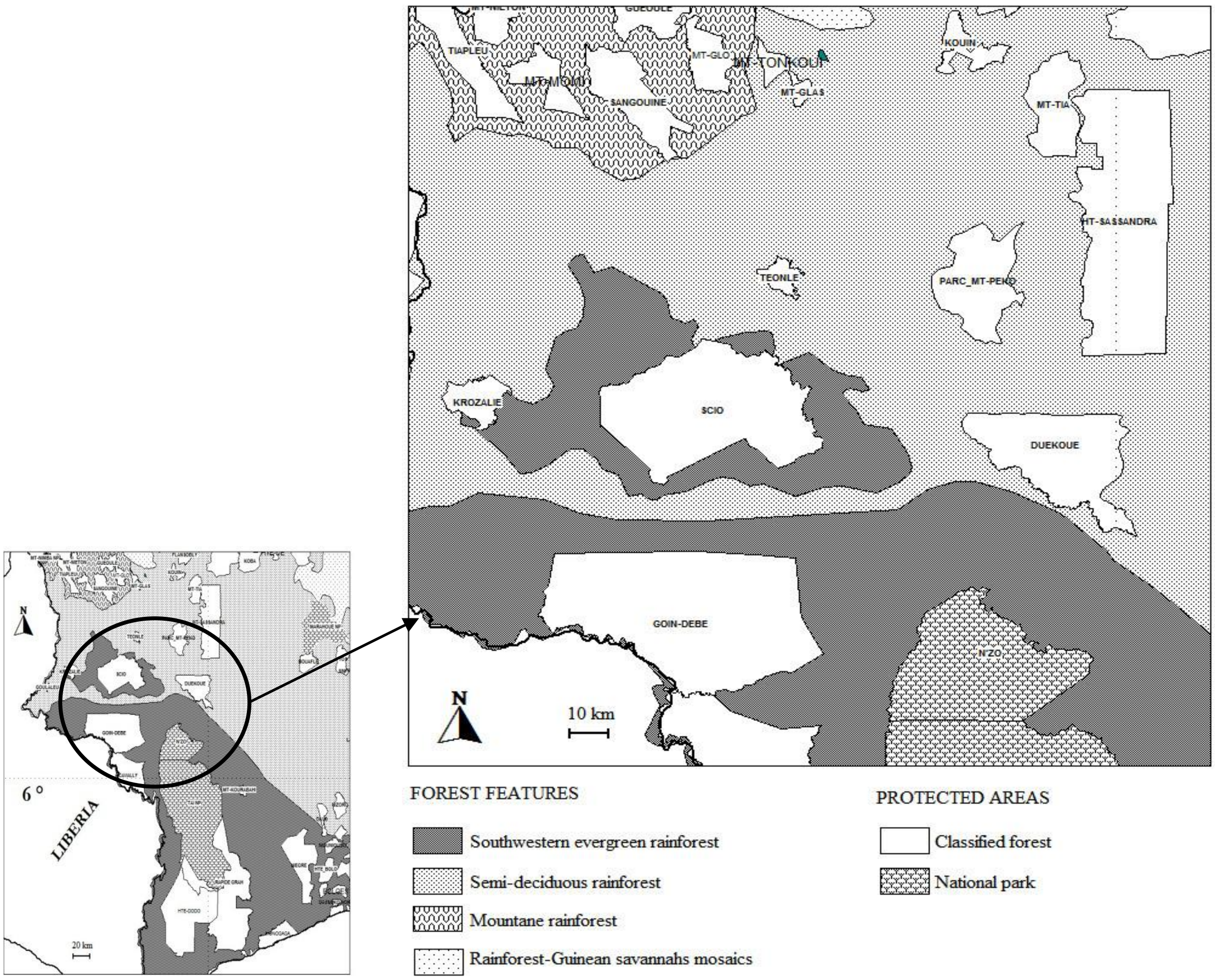

Figure 1. Localization with MapInfo 7.8 software of research sites on the map of protected areas.

Scio forest belongs to Ivorian South-Western evergreen forest type (Kouamé, 2010; Kouamé and Zoro Bi, 2010) that spreads in the wettest forest area.

Except the natural forest islands consisting of the remnant tropical rain forest, the other vegetation types plotted in the study were provided by human activities such as the preexistent natural forest fully or partially clearance and burning before the establishment of crops. Additionally, these farms and plantations were annually cleaned to avoid any competition between the crops and other vegetables. In the undergrowth cleared forests, just the herbaceous stratum was removed and the trees of the higher strata were alive and would be progressively eliminated until the crops become adults. This vegetation type was in fact the first step of the cocoa farms creating strategy for illegal population in the protected forests in Côte d'Ivoire.

Data collection

The eight vegetation types plotted in this study were the coffee farms, the cocoa farms, the rubber plantations and the teak plantations at Duekoué forest site, and the coffee farms, the cocoa farms, the undergrowth cleared forests and the natural forest patches at Scio forest site. Field data collection was carried out in eighty 100 m² (10 m × 10 m) plots, 10 per vegetation type. Homogeneity, size, repetition and availability of a vegetation type, and presence of plant individuals with DBH<10 cm were the criteria of these vegetation types selection. Within each plot, all plants individuals with diameter at 1.3 m (DBH) larger than 1 cm were named and measured for their DBH; those with a DBH smaller than 1 cm were simply named and registered. The lower limit to define regeneration varied considerably. For example, authors like Hawthorne (1993, 1994), who studied the regeneration of the tropical forest, used 5 cm DBH as the lower limit of his investigations. Vroh (2013) limited his studies to individuals with a minimum DBH of 2.5 cm while Tchouto (2004) and Kouamé (2016) used 1 cm as the lower limit of DBH which was also considered in his work.

Data analysis

The distribution of the data was first tested using the Shapiro Wilk's test (Bárány and Vu, 2007; Umarov et al., 2008), which concluded for normality (Kouamé, 2016). Afterwards, the Student t test for comparison of independent samples (Mead et al., 1993; Bar-Hen, 1998; Young and Young, 1998) was performed as recommended by Fowler et al. (1999) and Glèlè et al. (2006) and, the biotopes'

Table 1. Distribution of plot richness in different biotopes according to DBH categories.

Sites		Duekoué forest area				Scio forest area			
DBH classes	Variable	PCAFD	PCAOD	PHEVD	PTECD	PCAFS	PCAOS	FDEFS	FNBAS
DBH≥10 cm (adults)	Minimum	0	1	1	1	0	1	3	3
	Maximum	2	1	2	3	2	1	8	7
	General	2	1	2	4	2	1	17	22
	Mean	1.2^{a}	1.0^{a}	1.1^{a}	1.5^{a}	1.0^{a}	1.0^{a}	5.4^{b}	4.9^{b}
	St.-deviation	0.6	0.0	0.3	0.8	0.7	0.0	2.2	1.5
10 cm>DBH≥1 cm (juveniles)	Minimum	1	1	1	1	1	1	2	2
	Maximum	1	1	1	8	1	1	7	12
	General	1	1	1	19	1	1	10	25
	Mean	1.0^{a}	1.0^{a}	1.0^{a}	4.3^{b}	1.0^{a}	1.0^{a}	4.5^{b}	6.6^{b}
	St.-deviation	0.0	0.0	0.0	2.6	0.0	0.0	1.4	2.9
DBH<1 cm (seedlings and herbaceous)	Minimum	29	16	34	15	31	19	84	56
	Maximum	50	35	92	59	54	34	112	98
	General	82	75	122	116	124	100	201	239
	Mean	38.3^{ab}	28.5^{a}	44.9^{b}	31.5^{ab}	40.5^{b}	28.4^{a}	100.3^{d}	78.3^{c}
	St.-deviation	6.7	5.9	17.0	12.1	6.6	5.4	8.6	12.9

Biotopes in Duekoué forest area: PCAFD (Coffee farms), PCAOD (Cocoa farms), PHEVD (Rubber plantations), PTECD (Teak plantations). Biotopes in Scio forest area: PCAFS (Coffee farms), PCAOS (Cocoa farms), FDEFS (Undergrowth cleared forest), FNBAS (Natural forest). The richness is expressed in number of species. The mean values with the same letter are similar.

prospective correlations were analyzed throughout Pearson correlation with SPSS 27.0 software. Data of each category of DBH in plots were analyzed using a factorial analysis with Statistica 13.5 software to clarify the relationships between the plots by a² spatial distribution. The flora in the Coffee plantations and cocoa plantations that have been assessed in both research sites were analyzed with an ANOVA using Statistica 13.5 software for checking prospective impacts of site and/or crop nature on plot flora and their richness. Bonferroni's Post Hoc test with Statistica 13.5 software led to segregate impacts of site and crop nature as the ANOVA showed their effects on plot richness.

RESULTS

General data

In all biotopes, the richness of adult plants with DBH ≥10 cm was similar to those juvenile plants with 10 cm > DBH ≥1 cm. And the richness of seedlings and herbaceous plants with DBH <1 cm was very far higher than the last two categories of DBH (Table 1). Indeed, the richness of plants with DBH <1 cm was between 20 and 50 times higher than that of other categories of DBH.

Adult plants

The richness was higher (P <0.05) in the patches of natural forest and forests with cleared undergrowth (Table 2), which presented, respectively between 17 ± 2 species and 22 ± 2 species (Table 1 and Figure 2). This richness dropped drastically in all the plantations where it fluctuated between 1 species, in the cocoa farms of both sites, and 4 ± 1 species, in the teak plantation at Duekoué forest area (Table 1 and Figure 2). Also, all the plantations expressed the same (P≥0.05) richness. The richness for this category of DBH also exhibits greater inter-plot variability in patches of natural forest and in forests with cleared undergrowth and very low variability in plantations; it is constant in the cocoa farms of both sites. The plots were arranged in three groups (Figure 3) among which the largest, in terms of the number of plots, gathered the plots of natural forest islands, cleared undergrowth forests, teak plantations and rubber plantations, in conditions of poor opening in the vegetation. The coffee farms of both sites constituted group II, also under conditions of low opening in the vegetation while the cocoa farms gathered in a third group, under conditions of large openings in the vegetation (Figure 3). Openness in vegetation expresses 20.10% while the nature of the crop is responsible for 13.90% of the variability of the factorial analysis.

Juvenile plants

The richness was higher in the natural forest patches, forests with cleared undergrowth and Duekoué teak plantations which showed similar value (Figure 2 and

Table 2. Comparison matrix of the mean richness for adult plants.

	PCAFD	PCAOD	PHEVD	PTECD	PCAFS	PCAOS	FDEFS	FNBAS
PCAFD								
PCAOD	ns							
PHEVD	ns	ns						
PTECD	ns	ns	ns					
PCAFS	ns	ns	ns	ns				
PCAOS	ns	ns	ns	ns	ns			
FDEFS	**	***	**	*	***	***		
FNBAS	*	**	**	ns	**	**	ns	

Test of Levene (F = 15.95, P < 0.001); test of Kruskal-Wallis: H (7, N = 80) = 57.44, P < 0.001. ns: no significant test (P≥0.05); *: significant test (P<0.05); **: highly significant test(P<0.01); ***: very highly significant test (P<0.001).

Tables 1 and 3). In the coffee and cocoa plantations of both sites and in the rubber plantations of Duekoué, the richness was reduced to the cash crops only (Table 1); therefore this category of DBH showed no inter-plot variability (Figure 2) in these biotopes. The plot richness showed greater variability in the natural forest islands, in the under-cleared forests and teak plantations. All the biotopes were dispersed within three groups formed by the coffee plants of both sites (group I), in the lowest values of the opening in the vegetation (Figure 4,); the cocoa farms of both sites appeared in the highest values of the opening of the vegetation while all the other biotopes grouped together under the conditions of medium opening of the vegetation to form the largest group (Group II and Figure 4).

Seedlings and herbaceous plants

For this category of vascular plants including seedlings and herbaceous plants, the highest values of richness were obtained in forests with cleared undergrowth, while patches of natural forest were placed in second place (Figure 2 and Tables 1 and 4). With very significantly different richness (P> 0.01) between them, these two biotopes did not show any similarity with the richness of any plantation (Table 4). In contrast, cocoa farms from both sites showed the same (P≥0.05) richness; the rubber plantations exhibited the same richness with coffee farms from both sites while the teak plantations exhibited the same richness as all cash crops (Table 4). Although more amplified in islands of natural forest and forests with cleared undergrowth, inter-plot variability within biotopes is also significant in plantations (Figure 2). Four groups of equal importance, in terms of the number of plots composing them, were revealed by the analysis in principal components of the richness of this category of vascular plants in the plots of regeneration study (Figure 5). Indeed, the coffee Openness in vegetation expresses 20.42% while the nature of the crop is responsible for 19.75% of the variability of the factorial analysis.

Plants of the two sites constituted the first group (Group I and Figure 5) which appeared in the weakest conditions of the vegetation closure; following them are the teak plantations and rubber plantations which formed group II, then the cocoa trees constituting the third group, under average conditions of vegetation closure (Figure 5). Finally, islands of natural forest and forests with cleared undergrowth gave rise to group IV, in the highest values of vegetation closure (Figure 5). At the level of seedlings and herbaceous plants with DBH <1 cm, it was established a very important crop effect (P <0.001) on the plot richness. But no effect was identified neither for the site nor for the site-crop combination (Table 5). The Bonferronni's Post-Hoc test showed no difference between the richness of vascular plants with DBH <1 cm in the coffee farms of both sites, and in the cocoa farms of both sites (Table 6). Openness in vegetation expresses 20.42% while the nature of the crop is responsible for 19.77% of the variability of the factorial analysis.

DISCUSSION

The similar richness in the coffee and cocoa farms, and in the rubber and teak plantations for plants of both DBH ≥10 cm and 10 cm> DBH ≥ 1 cm could be explained by the similarity of impacts of the antropogenic activities for these categories of plants. During the establishement of these agrosystems, many local preexisting species with DBH ≥ 1 cm were removed (Tondoh et al., 2015; Kouamé, 2016; Delewron et al., 2019a, b) to avoid any competition with the cultivated species. This competition could be for the nutrient resource (Veenendaal et al., 1996; Delissio and Primack, 2003), for the spatial occupancy (Moeur, 1997; Boyden et al., 2005; Brūmelis et al., 2009) or for the available sunlight (Poorter , 2001; Baraloto, 2003; Yedmel, 2014).

The richness of plants with DBH <1 cm between 20 and

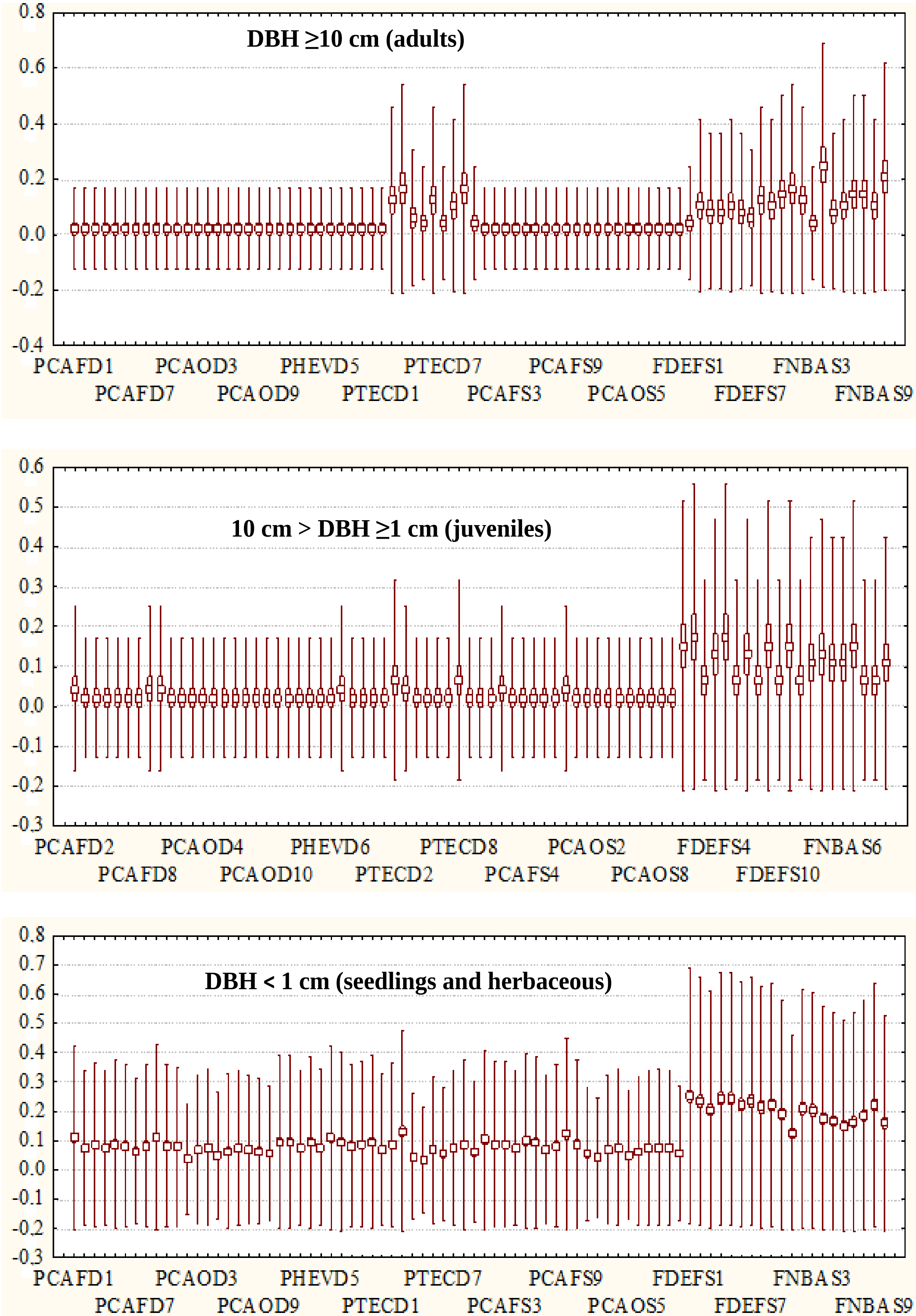

Figure 2. Boxplots of the plot richness according to the DBH categories.

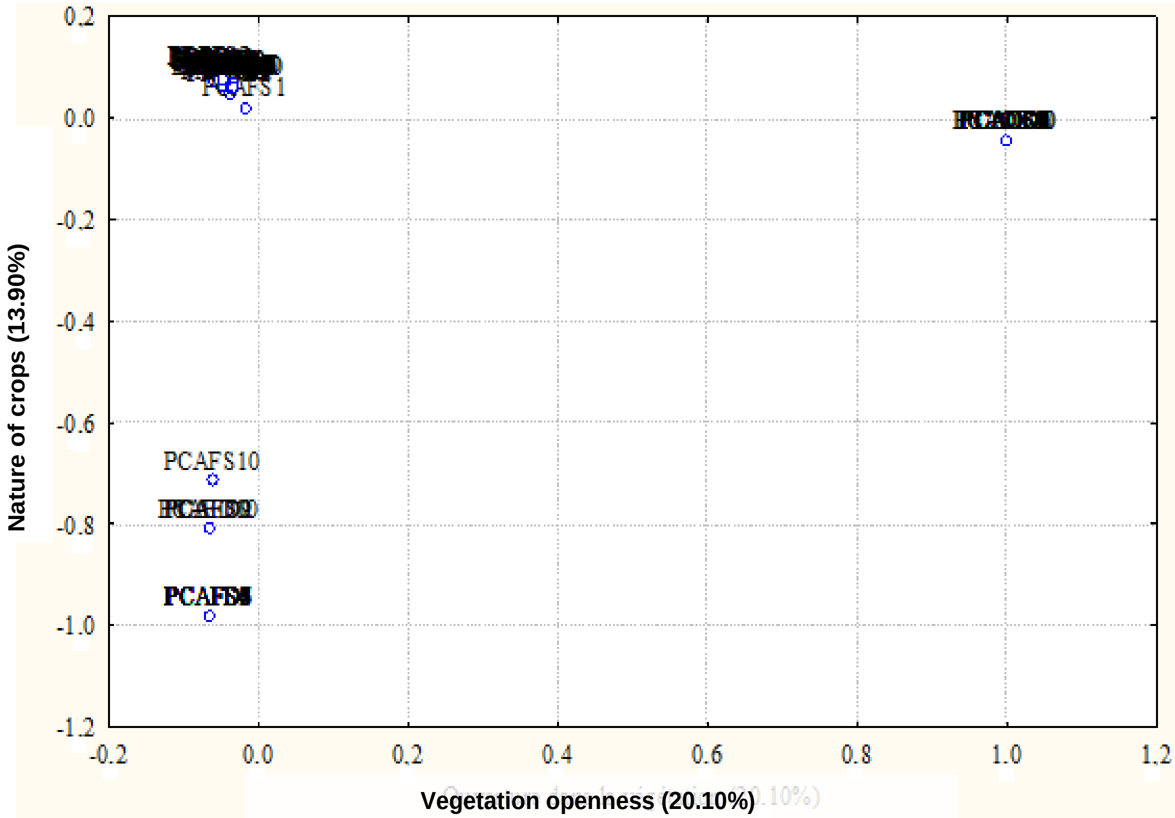

Figure 3. Representation of plots in the component plan 1-2 of the factorial analysis with Statistica 13.5 as a function of plot richness for adult plants.

Table 3. Comparison matrix of the means of the biotope richness for juvenile plants.

	PCAFD	PCAOD	PHEVD	PTECD	PCAFS	PCAOS	FDEFS	FNBAS
PCAFD								
PCAOD	ns							
PHEVD	ns	ns						
PTECD	*	*	*					
PCAFS	ns	ns	ns	*				
PCAOS	ns	ns	ns	*	ns			
FDEFS	**	**	**	ns	**	**		
FNBAS	***	***	***	ns	***	***	ns	

Test of Levene (F = 17. 05, P < 0.001); test of Kruskal-Wallis: H (7, N = 80) = 72.32, P < 0.001.
ns : no significant test (P≥0.05); * : significant test (P<0.05); ** : highly significant test(P<0.01); *** : very highly significant test (P<0.001).

50 times higher than that of of both DBH ≥10 cm and 10 cm> DBH ≥ 1 cm (Table 1) could be explained by the explosion of seeds germination in opened vegetation as usually shown in tropical forest area (Kahn, 1978a; 1978b, 1982; Brokaw, 1985; Chazdon and Fetcher, 1988; Kouakou, 1989; Kouamé, 1998; Baraloto, 2003). The extension of this highest richness of plants with DBH <1 cm category to the undergrowth cleared forest and the islands of natural forest demonstrates that the plants for this DBH category belong to several species. Thus, in natural and anthropized environments, several species coexist in the form of even higher amounts of plants of DBH <1 cm; but there are fewer species in anthropized environments. In addition, the species of these anthropized environments are essentially pioneers (Kouamé et al., 2015a; Kouamé, 2016). The presence of

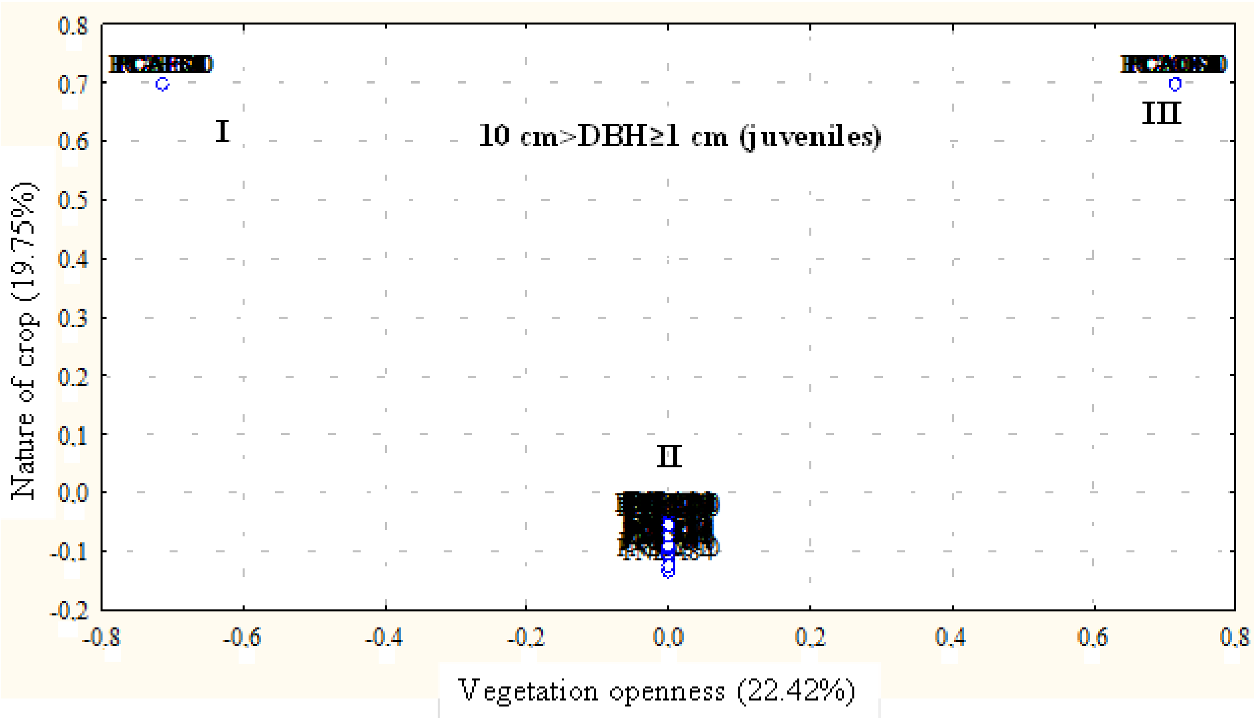

Figure 4. Representation of plots in the component plan 1-2 of the factorial analysis with Statistica 13.5 as a function of plot richness for juvenile plants.

Table 4. Comparison matrix of the means of the biotope richness for seedlings and herbaceous plants.

	PCAFD	PCAOD	PHEVD	PTECD	PCAFS	PCAOS	FDEFS	FNBAS
PCAFD								
PCAOD	*							
PHEVD	ns	*						
PTECD	ns	ns	ns					
PCAFS	ns	*	ns	ns				
PCAOS	*	ns	*	ns	*			
FDEFS	***	***	***	***	***	***	***	
FNBAS	***	***	***	***	***	***	***	

Test of Levene (F = 1.98, P = 0.07); test of Newman-Keuls, df = 72. ns : no significant test (P≥0.05) ; * : significant test (P<0.05) ; ** : highly significant test(P<0.01) ; *** : very highly significant test (P<0.001).

certain species of the natural forest undergrowth such as *Geophila obvallata* (Schumach.) F.Didr. in the cocoa farms of both sites (Kouamé, 2016) testifies to the similarity of shade between the patches of natural forest, the undergrowth cleared forests and the cocoa farms. And the presence of other species such as *Chromolaena odorata* (L.) R.King & H.Robyns., which is a pioneer plant, in the islands of natural forest shows that these islets present discontinuities in the canopy of their vegetation.

The values of richness in the biotopes (Table 1) showed that, if the patches of natural forest, forests with cleared undergrowth, rubber plantations and teak plantations could be together in the same group for the category of plants with a DBH ≥10 cm, on the basis of their density values (Kouamé et al., 2015b; Kouamé, 2016), these biotopes were very divergent for their floristic compositions (Kouamé et al., 2015a). Indeed, on the basis of their richness values (Table 2), the islands of natural forest and the undergrowth cleared forests could not be associated with plantations which were the poorest among the biotopes. The decrease in richness in the undergrowth cleared forests showed that this type of clearing mainly eliminates species in the 10 cm > DBH ≥1

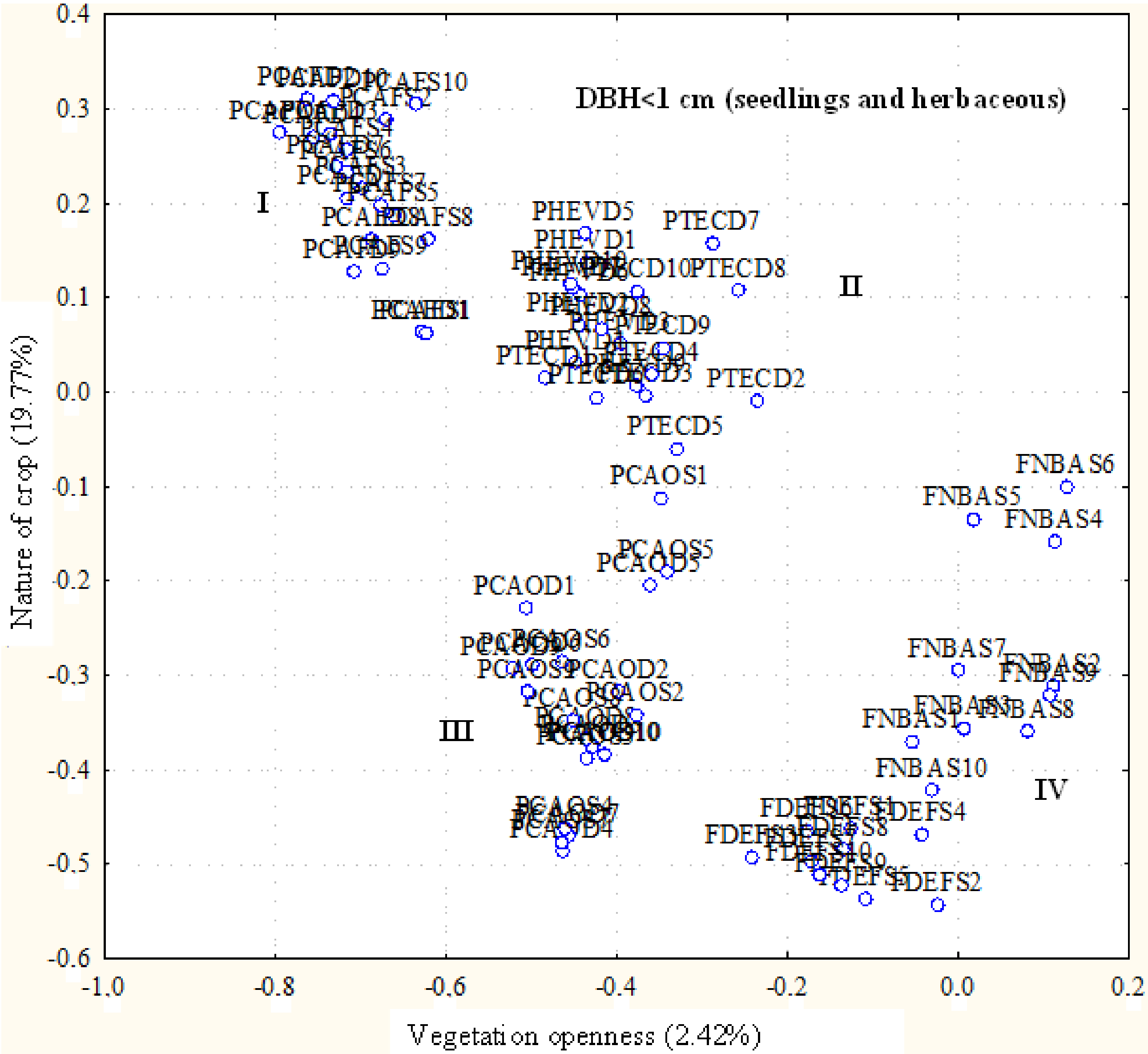

Figure 5. Representation of plots in the component plan 1-2 of the factorial analysis with Statistica 13.5 as a function of plot richness for plants.

cm category. In the teak plantations, the presence of species other than *Tectona grandis* L.f. in this category of DBH increased the richness in comparison to the rubber plantations, and the coffee and cocoa farms.

The regeneration of the tropical dense forest, whether natural or artificial, by seeds or by vegetative propagation, is a long process and under the influence of several factors whose outcome is the obtaining of adult plants (Baraloto, 2003). Indeed, out of tens of thousands of seeds produced each season by a few mature trees in the fruiting phase, very few will survive and reach the adult tree stage, after an average time estimated at over 150 years (Clark and Clark, 1992, Kouamé, 1998). Already, for most tropical trees, less than 1% of all germinated seeds will reach the juvenile stage (De la Mensbruge, 1966; Alexandre, 1982; Baskin and Baskin, 1998; Kouamé, 1998; Baraloto, 2003). Then, a large number of factors including pathogenic fungi infect the apical meristem until the death of the plant (Augspurger, 1983; Gilbert et al., 2001). In addition to fungi, insects and vertebrates feed on the leaves or stems of young plants (Sandoval and Aide, 2000). More surprisingly, the mortality due to the fall of plant debris (branches, large fruits, epiphytes, lianas) and that due to excavations and turning of soil by vertebrates are also very high (Clark and Clark, 1991). The passage from the seedling stage to that of young stem requires not only survival but also consistent growth. And the resource that most limits this

Table 5. Effects of the site and the nature of the crops on the richness of vascular plants with DBH<1 cm in coffee and cocoa farms using a Factorial ANOVA.

Effect	SC	df	MF	F	P
Ord origin	46036.22	1	46036.22	1210.153	***
Site	11.02	1	11.02	0.29	ns
Crops	1199.02	1	1199.02	31.519	***
Site*crops	13.23	1	13.23	0.348	ns
Error	1369.5	36	38.04		

ns : test no significant (P≥0.05) ; *** : test very highly significant (P<0.001).

Table 6. Separation of the effects of the site and the nature of the crops on the richness of vascular plants with DBH<1 cm in coffee and cocoa farms using Bonferroni's Post Hoc test.

	Cocoa Duekoué	Coffee Duekoué	Cocoa Scio	Coffee Scio
Cocoa Duekoué		**	ns	***
Coffee Duekoué	**		**	ns
Cocoa Scio	ns	**		***
Coffee Scio	***	ns	***	

Error: MC Inter is about 38.042. ns: test no significant (P≥0.05); ** : test highly significant (P<0.01) ; *** : test very highly significant (P<0.001). df = 36.

growth of young plants is undoubtedly sunlight, less than 1% of that reaching above the canopy is available in the undergrowth (Alexandre, 1979a, 1979b; Chazdon and Fetcher, 1988). However, most tropical tree species appear to maximize photosynthetic activity with rates of around 15-25% of incident light (Kitajima, 1994; Poorter, 1999). It is assumed, therefore, that the growth of the vast majority of seedlings is clearly controlled by the light of the undergrowth (Jans and Poorter, 1991a, b; Poorter, 1999, 2001) and that, therefore, most species depend on windthrow to release their growth and proceed to subsequent stages (Brokaw, 1985), the only situation proving sufficient lighting in the primary forest. For shade-tolerant species capable of surviving and even growing in shady undergrowth, it is assumed that they also respond to a certain opening of the canopy, a condition allowing them to pass to the next stage (Whitmore, 1989). But it should be noted that a significant proportion of woody species will not reach the canopy as an adult and therefore will remain in the shade in the undergrowth all their lives. The availability of water in the soil also plays a role in the survival of young plants and their growth. And, in seasonal tropical rainforests, which experience dry seasons where monthly rainfall is less than 100 mm over several successive months, water also becomes a limiting factor for the development of young plants (Wright, 1992).

In the plantations studied in this work, the stands of the different crops behave like the dense humid natural forest under which the different factors of regeneration maintain their respective importance. In the early stages of plantation establishment, many other than crops, usually sun-loving (pioneer), compete with crops for all nutrient resources (Burslem et al., 1995; Huante et al., 1995) and space (Moeur, 1997; Ma et al., 2016). It is through regular maintenance actions that the peasants gradually eliminate this competition in favour of crops. When these maintenance actions are not carried out until the maturity of crops or are lacking in even old plantations, we witness mosaics made up of crops and a larger floral procession of pioneer species gradually transforming into thickets or fallow (Kouamé, 2016). But when plantations are regularly maintained, crops exhibit their optimum development and the survival of species other than crops depends on their ability or not to withstand the ecological conditions prevailing below crops. Thus, in addition to the classic factors of regeneration in natural dense forest (Baraloto, 2003), the human factor plays a decisive role in the regeneration process in cash crop plantations and forest plantations. The different groups obtained by the factorial analysis of the floristic richness of plants in the DBH <1 cm category (Figure 5) find their explanations in the functional groups of species living in the undergrowth of the different biotopes. Cocoa farms, teak plantations and rubber plantations, which provide more shade than coffee farms, are closer to islands of natural forest and undergrowth cleared forests; this is the translation of the presence in their undergrowth of an important floral procession supporting the shade that prevails there. In coffee farms, the crowns of coffee trees and other shrubs and trees let in more solar light (Perfecto et al., 1996, 2003, 2005); therefore, it is much more the pioneer species that thrive in the undergrowth. The crop effect on the richness of plants in the DBH category <1 cm in cocoa and coffee farms of both sites revealed by the ANOVA and the Bonferroni's Post Hoc test (Tables 5 and 6) results from this difference in the shade of these two cultures and by ricochet of that of the groups of species of this category of DBH which live there.

Conclusion

The studied biotopes showed various richness according to the DBH categories. The undergrowth cleared forests and the islands of natural forest presented the same richness for the plants with DBH ≥ 1 cm which was higher than those in all other biotopes. Adult plants showed similar richness with juvenile plants in all the biotopes. Therefore, the hypothesis to find poorer richness of adult plants than both the juvenile plants and the seedlings and herbaceous plants was rejected. And the richness of the seedlings and herbaceous plants (DBH < 1 cm) was between 20 and 50 times higher than that of the other plants in all the biotopes. At this level of plants of the DBH <1 cm category, it was established a very important crop effect on the richness of coffee and cocoa farms. But no effect was identified neither for the site nor for the site-crop combination. Moreover, the biotopes were shared between 3 and 4 groups according to the DBH category. Therefore, the hypothesis to find various richness in the studied biotopes was accepted.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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