Altenburg & Wymenga
ECOLOGISCH ONDERZOEK

Tree preference of insectivorous birds in the *Vitellaria* zone, West Africa

A&W-report 2152

commissioned by

Vogelbescherming
NEDERLAND

BirdLife International in The Netherlands

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L. Zwarts

Cover photograph
Vitellaria parkland with solely *Vitellaria* trees, after the entire low woody vegetation of mainly *Guiera senegalensis* has been removed (12 January 2012; southern Mali). Photo: Leo Zwarts

L. Zwarts**, ,** Fout! Verwijzingsbron niet gevonden.**,** Fout! Verwijzingsbron niet gevonden.**,** Fout! Verwijzingsbron niet gevonden. **2015**
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Altenburg & Wymenga ecologisch onderzoek, Feanwâlden, The Netherlands

Commissioned by
Birdlife International in The Netherlands
Vogelbescherming Nederland
Boulevard 12
3707 BM Zeist
The Netherlands
Tel. +31 30 6967799

Realised by
Altenburg & Wymenga ecologisch onderzoek bv
P.O.box 32
9269 ZR Feanwâlden,
The Netherlands
Tel +31 511 47 47 64
info@altwym.nl
www.altwym.nl

Project number	**Project leader**	**Status**
2438vit	E. Wymenga	Final

Authorisation	**Autograph**	**Date**
Approved	E. Wymenga	8-10-2015

Contents

1 Introduction

The shea tree *Vitellaria paradoxa*, karité in French, is very common and has a wide distribution in northern sub-Saharan Africa. The project “Birds, bees and butter” of BirdLife International (funded by Lush Ltd, VBN and RSPB) deals with the *Vitellaria* parkland zone and aims to determine the relationships between tree, bird and pollinator diversity, to conserve and restore ecosystem services and enable management for ecologically and economically sustainable production of shea fruits. Its long-term goal is more resilient and rural livelihoods, a healthy shea value chain and restoration and conservation of habitat for migratory birds through sustainable management of the shea parkland.

Vitellaria *agroforestry parkland is intensively exploited as wood- and cropland but in the dry season also as pastureland.*

This analysis provides the ‘bird’ part of the “Birds, bees and butter project”; the report summarises what we have learned about the habitat selection of the migratory birds within the distribution area of *Vitellaria* in West Africa, and also identifies knowledge gaps. The analysis is based on data collected during field work (2011-2015) funded by the Living on the Edge project of Vogelbescherming Nederland (VBN) - BirdLife in The Netherlands.

2 Methods

All data were collected in West Africa, between 10° and 18°N and 0° and 17°W, in 2007-2015 during the dry season, in October-March. Study plots of 300 x 50 m (usually three per site) were selected beforehand, using three criteria: (1) availability of high resolution satellite images on which individual trees are detectable, (2) roads or tracks should intersect latitudes at exactly 15.000˚N, 15.050˚N, 15.100˚N and so on (successive distances between sites at least 5.5 km), and (3) avoidance of no-go areas. Along these routes, sites were situated alternately to the left or right side of the track or road. In addition to 1733 pre-selected plots, we visited 321 other sites that were selected because of a specific habitat or the presence of specific tree species (Fig. 1). The average annual rainfall recorded at the different sites varied between 110 and 2200 mm with a gradual transition from desert and heavily grazed grassland with scrubs and sparse trees into cropland with scattered trees, scrubland and a mosaic of crop- and woodland.

All trees and scrubs (for brevity, trees and scrubs are hereafter referred to as trees) in the plots were identified, measured and searched for birds. Methods are described in detail in Zwarts & Bijlsma (2015). We recorded 182 tree species (Arbonnier 2007). Tree height and crown width were measured in all 307,914 trees. Crown width was used to calculate canopy surface (Zwarts & Bijlsma 2015). All trees within plots were carefully searched for birds, the latter noted per individual tree. As explained in Zwarts & Bijlsma (2015), our search effort was high and sufficiently validated to confidently equate bird density with absolute bird density. In this report ***all densities are given as bird numbers per canopy surface***.

We did not encounter shea trees in plots with less than 488 mm rain. Hence for the present study we selected data collected in plots with an average, annual rainfall of 500 mm or more. We also left out the (few) data collected in October and November. The remaining data set is still large with 168,146 trees, but nevertheless too small for the majority of the tree species encountered. We made a further selection for tree species of which we measured at least 2000 m^2 canopy surface in at least 100 trees, all common and widespread species within the distribution area of *Vitellaria*, in total 48 species. This data set is used to describe the tree preference, but the entire data set, thus covering also the arid and semi-arid region, is used to show the distribution of the trees and the birds in West Africa.

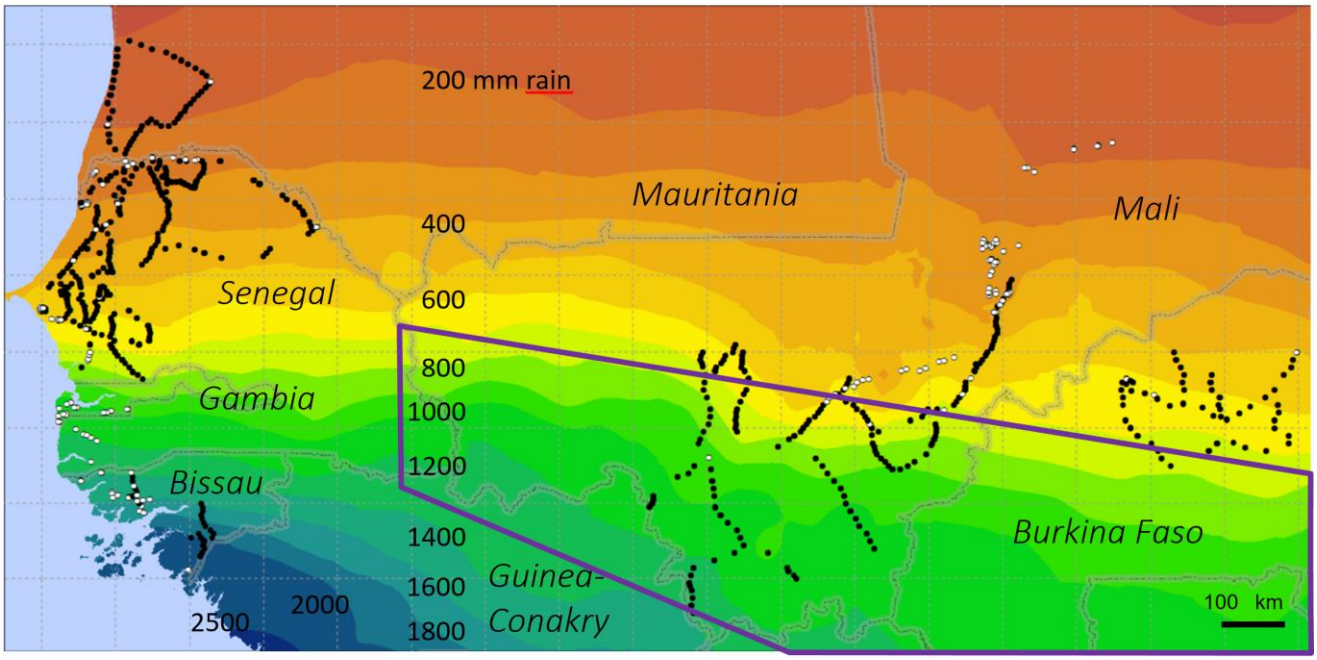


Fig. 1. The stratified random (black dot) and non-random (white dot) sampling sites in West Africa, with average annual rainfall (in mm) as background. The purple pentagon shows the outer limits of the distribution area of *Vitellaria.*

For the present analysis we selected insectivorous birds feeding in trees, including sunbirds and Little Weaver, the only weaver we recorded eating insects in trees. Doves, weavers and other ground-feeding birds using trees as a roost are ignored in the present study. We summate densities separately for Palearctic, long-distance migrants (hereafter referred to as migrants) and African species (hereafter referred to as residents, disregarding the fact that some may move short distances in response to rainfall and desiccation), and on the species level for the 13 and 14 most common migrants and residents,

respectively. Unlike migrants, which were routinely recorded from the beginning of the study, residents have been disregarded during the first years of observation, hence the smaller sample sizes than for migrants (details shown in Appendix 2 and 3).

Bird names are used according to the BirdLife Checklist version 7.0. Scientific names of all birds mentioned in the text are given in Appendix 1. We were unable to always identify Chiffchaffs as either Iberian or Common, but the few Chiffchaffs we heard and the many we could observe well were all Iberian Chiffchaffs, so the species is noted as (Iberian) Chiffchaff. Of the birds recognized as Olivaceous Warbler, 6 were noted as Eastern Olivaceous Warbler and 43 as Western Olivaceous Warbler, depending on whether they were regularly dipping their tail while feeding or not. Since we usually did not pay attention to this behaviour, they are lumped as Olivaceous Warbler.

Vitellaria: *beautiful tree, but hardly insectivorous birds.*

3 Results

3.1 Distribution in the Sahel-Sudan zone

Due to the large contrast in the yearly rainfall (Fig. 1), the West-African landscape gradually changes from north to south, within a distance of 600-700 km from Sahara desert to humid woodland, with a concomitant change in species composition of the woody vegetation (Fig. 2). The gradual change can be described as a latitudinal shift, but it is more informative to relate the distribution to the average annual rainfall. This section describes the distribution of birds and trees along the rain-gradient between 100 and 2200 mm.

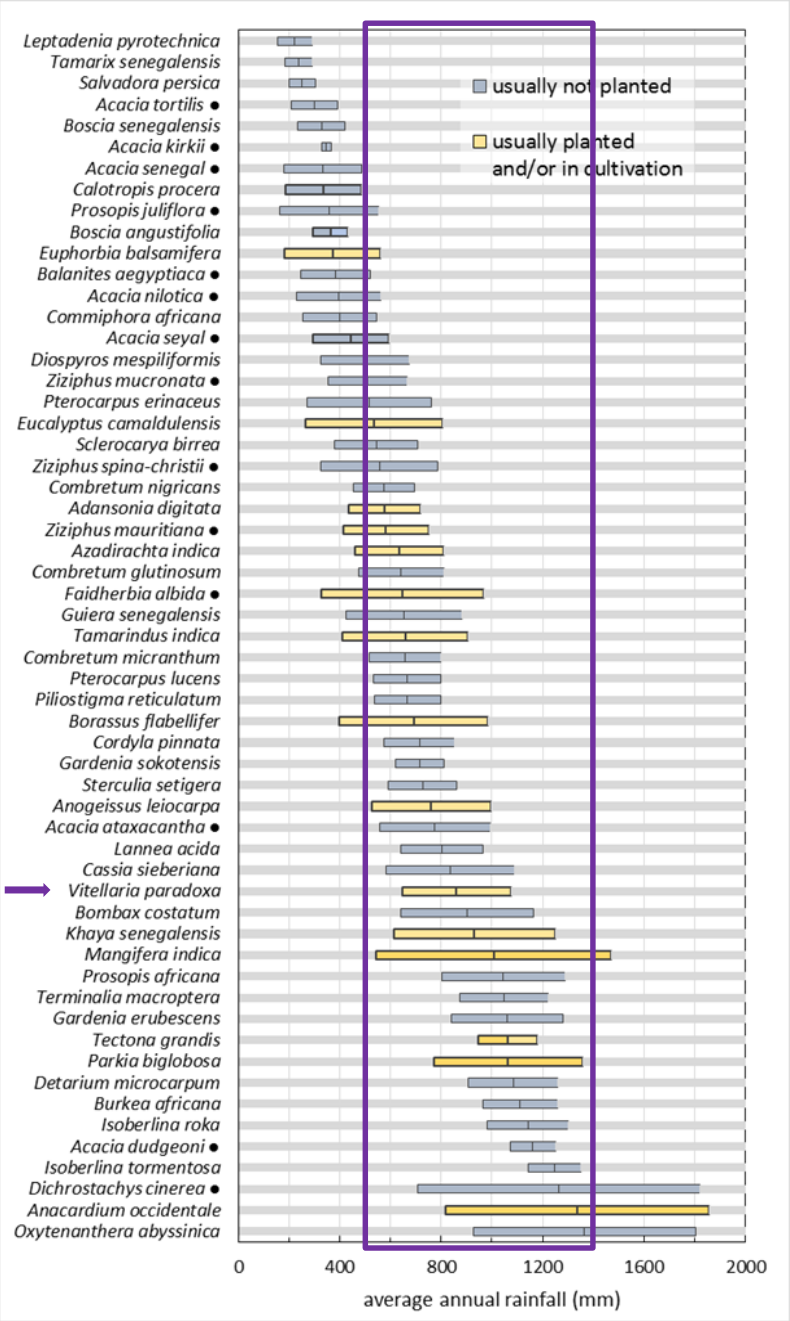


Fig. 2. Distribution of *Vitellaria paradoxa* (⟶) and 56 other tree species in West Africa as a function of annual rainfall. The 14 thorny tree species are marked (●).The average rainfall (± SD) for tree species was calculated for all data collected in the plots shown in Fig. 1. Range covered by plots: 110-2200 mm. The purple square indicates the distribution of *Vitellaria* (500-1300 mm rain).

Sample size per species varied between 101 and 74,762 trees. One-way analyses of variance revealed that the distribution along the rainfall gradient differed significantly for the 57 tree species (R^2=0.66; P=0.000, N=278,978).

Planted tree species have a wider distribution than tree species with a natural distribution. Since 1970 much woodland in regions with more than 1400 mm rain has been converted into cashew *Anacardium occidentale* plantations, a trend even extending to drier areas in recent years. Also mango *Mangifera indica* has been planted across a wide range. The wider distribution of the 15 planted trees and trees cultivated by farmers can be illustrated by the larger average standard deviation (SD) of 258 mm rainfall compared to 156 mm for tree species having a natural distribution (Fig. 2).

It is not rainfall sec but rather the ground water table, determined by rainfall and local conditions linked to relief, which determines the distribution of the trees. For example, riparian tree species, such as *Acacia kirkii*, *A. nilotica* and *A. seyal*, occur in the semi-arid Sahelian zone where the large riverine floodplains are located. On the other hand, *Vitellaria* is never found in areas being temporary flooded. Beside rainfall and ground water table, sediment is another important factor determining the local distribution of tree species. For instance, parklands with *Vitellaria* have sandy soils and are usually not found on laterite grounds or rocky soils. Moreover, *Vitellaria* does not occur in Guinea-Bissau and in Senegal (beside the most eastern part of the country). Thus, our own observations on *Vitellaria* are restricted to southern Mali (488-1385 mm rain) and central Burkina Faso (564-771 mm rain) (Fig. 1).

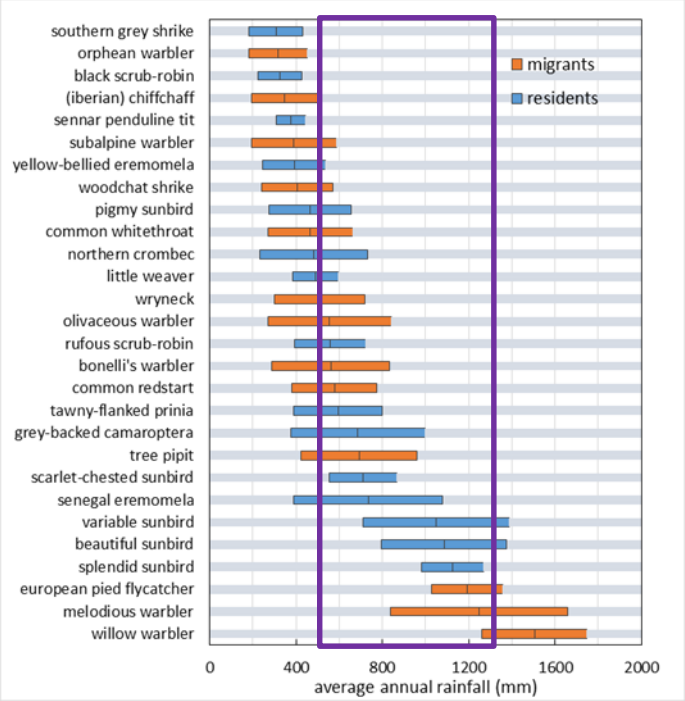


Fig. 3. Distribution of 28 bird species in West Africa as a function of annual rainfall. The purple square indicates the distribution of *Vitellaria* (500-1300 mm rain).The average rainfall (± SD) was calculated for all data collected in the plots shown in Fig. 1. Range covered by plots: 110-2200 mm.

Sample size per species varied between 8 and 1346 birds. One-way analyses of variance revealed that the distribution along the rainfall gradient differed significantly for the bird species (R^2=0.38, P=0.000, N=5338). Only birds observed between early December and mid-March were selected in order to exclude migratory species wintering further south and staging in the Sahel during migration.

The bird species, migrants as well as residents, show a species-specific distribution along the rainfall gradient (Fig. 3). The actual differences in distribution among bird species is even larger than shown. For example, Southern Grey Shrike and Orphean Warbler also occur in still drier areas north of our most northerly plot, while the majority of Tree Pipits, European Pied Flycatchers, Melodious Warblers and Willow Warblers winter further south than our plots. Consequently, had the entire range of their wintering areas been covered, northern species on average would have wintered in somewhat drier habitats and southern species in slightly wetter areas than suggested by Fig. 3.

The limited distribution of bird species within West Africa, as evident from the average SD of 208 mm of rainfall (Fig. 3), shows that many tree species listed in Fig. 3 will be out of bounds for the majority of bird species. However, as most bird species are found in the latitudinal zone with an annual rainfall of 200 to 800 mm rainfall (Fig. 3), the potential overlap in usage of tree species within this narrow distributional range by the various bird species is extensive. Fig. 3 also shows which bird species may be expected within the *Vitellaria* zone (purple square): Olivaceous and Bonelli's Warbler as well as Common Whitethroat and Common Redstart in the northern half of the *Vitellaria* zone and European Pied Flycatcher, Melodious and Willow Warbler in the southern half.

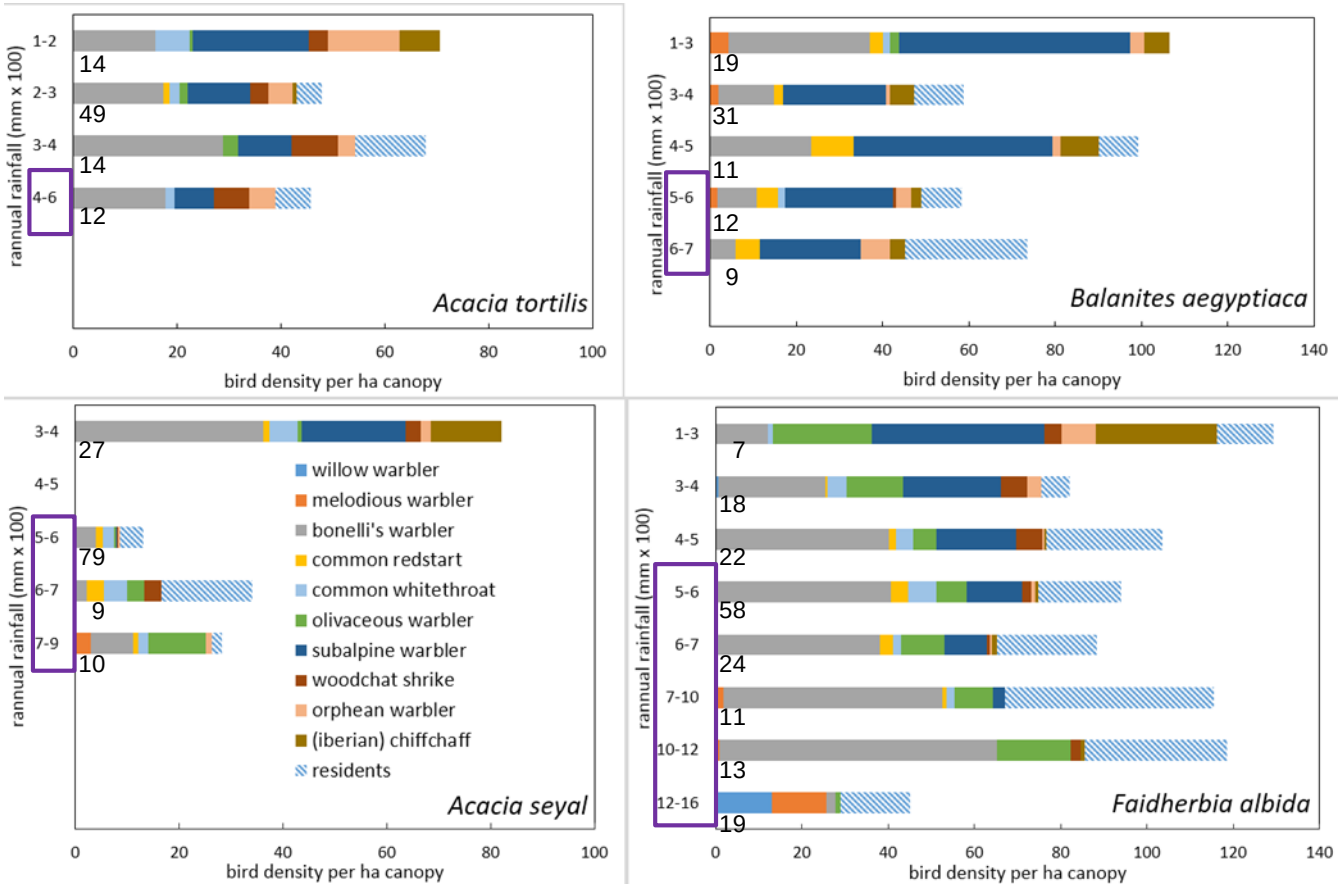


Fig. 4. The average bird density of 10 migrant species and of residents in four tree species as a function of average rainfall. The categories with the lowest and highest rainfall were lumped due to small sample sizes. The total canopy surface area of the investigated trees (*1000 m^2) is shown below the bars. The overlap with the *Vitellaria* zone (500-1300 mm rain) is indicated with the purple square along the y-axis.
We performed multinomial logistic regression analyses for the 10 bird species in the four tree species, with canopy surface as covariate, rain (same categories as shown in Fig. 4) and month as factors and individual trees as measure, to test whether the presence of one (or more) bird in a tree differed for the different rain zones (no analyses for Melodious Warbler and Orphean Warbler in *A. seyal*, since present in one category only). Number of trees: 16,991 for *A. seyal*, 19,748 for *A. tortilis*, 14,625 for *Balanites* and 4869 for *Faidherbia*, In all analyses, P = 0.000, except for Common Whitethroat in *Faidherbia* (P=0.001), Melodious Warbler in *A. tortilis* (P=0.001), Orphean Warbler in *A. tortilis* (P=0.017) and Olivaceous Warbler in *Balanites* (P=0.299).

Within tree species, birds show similar shifts in species composition and density, with (Iberian) Chiffchaff, Orphean Warbler and Woodchat Shrike being more common in the drier regions (100-400 mm rain), Subalpine Warbler and Bonelli's Warbler extending further into the more humid regions (100-700 mm and 100-1200 mm, respectively) and Melodious Warbler and Willow Warbler only found in regions with >1200 mm of rainfall. Throughout, residents are less common than migrants, but even so scarcer in the drier north than in the more humid south. The shift in species composition within each tree species closely resemble the zoning as shown in Figure 3, based on the occurrence in woody vegetation for all tree species combined. Evidently, part of the observed tree selection is determined by the rainfall-related, latitudinal selection of their wintering area.

3.2 Tree preference

The previous section clearly shows that some bird species are restricted to the dry Sahelian savanna (e.g. Orphean Warbler) and others or to more humid woodland 600 km further south (e.g. Willow Warbler). This latitudinal constraint also applies for each tree species (Fig. 4). Hence to describe the tree preference of the bird species it is necessary to restrict the analysis to the trees actually investigated within the distribution area of *Vitellaria*. Appendix 2 gives the average density per ha canopy reached by 13 migratory bird species in 48 tree species, based on data collected in the plots (Fig. 1) where the average annual rainfall was above 500 mm.

Vitellaria is not attractive for migrants: in 2965 trees (in total covering a total canopy surface of 10.8 ha): we saw only three migratory birds: 1 Woodchat Shrike, 1 Common Redstart and 1 European Pied Flycatcher.

Woodchat Shrikes usually use a tree only as perch, Common Redstarts (and to a lesser degree also Pied Flycatcher) usually forage on bare ground beneath a tree (pouncing from low branches). Hence we saw not any arboreal (leaf-gleaning), insectivorous migrant in a large sample of *Vitellaria* trees. In contrast, we noted 963 migrants in even less *Faidherbia* trees (2457 trees, with a summated canopy surface of 12.4 ha).

The relationship between the number of birds detected and the summated canopy of the selected 48 tree species is given in Fig. 5. The graph plots the total number of birds seen (in this case only migrants) against the total canopy surface of the same 48 tree species. We can plot both straightforward because the birds were noted per individual tree and for each individual tree we know the canopy surface (and by adding both per tree species, we get the data shown here).

The average bird density in the 48 tree species (rainfall > 500 mm) is 6.8 migrants/ha canopy. The blue line in the graph shows the expected total number of birds at this average density. The grey line gives the expected number of birds x 10 and the yellow line expected number x 0.1. Obviously, tree species deviate very much from each other regarding the number of feeding birds. Note I used a log-scale for both axis (and for the y-axis n+1, because we had no birds at all in some tree species).

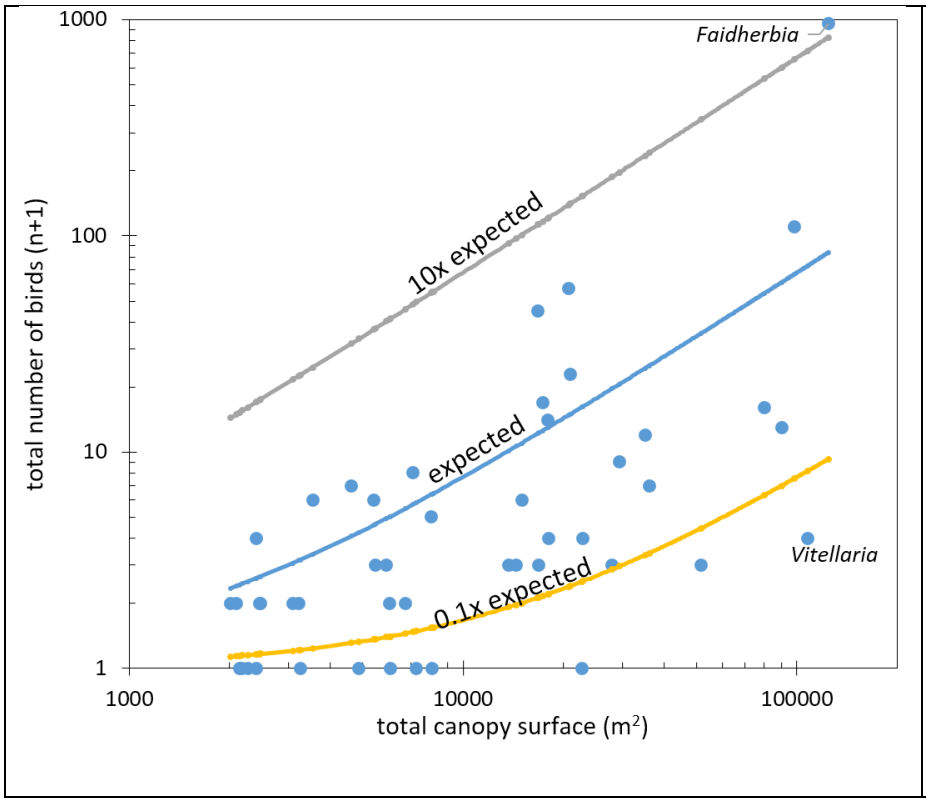


Fig. 5. Number of migrants detected in 48 trees species as a function of the summated canopy cover of all investigated trees.

The blue line gives the expected relationship at an average bird density of 6.8 birds/ha canopy. The grey and yellow line shows the expected number of birds if the density would be 10 times larger (68 birds/ha canopy) or smaller (0.68 birds/ha canopy) than average.

No bird was seen in 11 tree species. That is why the y-axis gives y+1, which is also the reason that the line showing the 0.1-expectation is curvilinear.

Fig. 6, based on Appendix 2, shows the significance of the different tree species for the migrants. Evidently, migrants reach their highest densities per ha canopy predominantly in thorny tree species (marked with a bullet).

Fig. 6. Density (n per ha canopy) of Bonelli's Warbler, Subalpine Warbler, Olivaceous Warbler, Common Whitethroat and Common Redstart and eight other migratory bird species in 48 tree species; data extracted from Appendix 1, but ranked here according to the density of all migrants together. Thorny species are marked (●).

Fig. 7 and appendix 3, give the same information as Fig. 6 and appendix 2, but now for residents. Grey-backed Camaroptera and Senegal Eremomela were the most common insectivorous residents. The sunbirds have been taken together as one category in Fig. 7 (but see the information per species in Appendix 3).

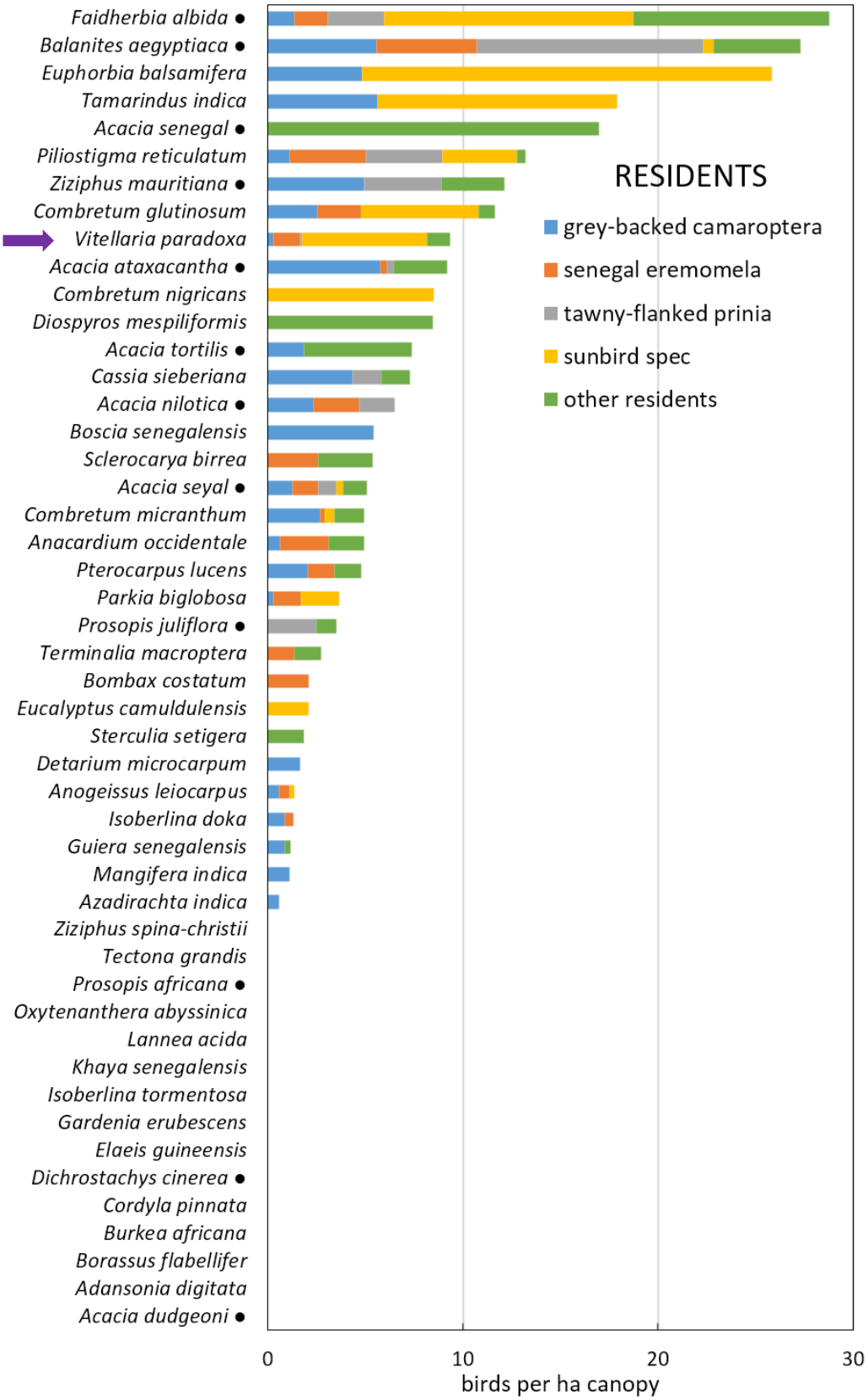


Fig. 7. Density (n per ha canopy) of Grey-backed Camaroptera, Senegal Eremomela, five sunbird species combined and seven other residents in 48 tree species; data extracted from appendix 3, but ranked here according to the density of all residents combined. Thorny species are marked (●).

There is much overlap in the tree preference of migrants and residents (Fig. 8). The densities of both categories of birds in the 48 selected tree species are significantly correlated (R=+0.60, N=48, P=0.000). There are, however, some differences. Migrants are concentrated in fewer tree species, especially in thorny ones. Relatively many migrants compared to residents are found in *Faidherbia*, *Acacia nilotica*, *A. tortilis* and *A. seyal*. We saw even no residents in *Ziziphys spina-cristii.* In contrast, relatively many residents were recorded in *Balanites*, *Tamarindus*, *A. senegal*, *Ziziphus mauritiana*, *Combretum nigricans*, *C. glutinosum* and *Vitellaria*.

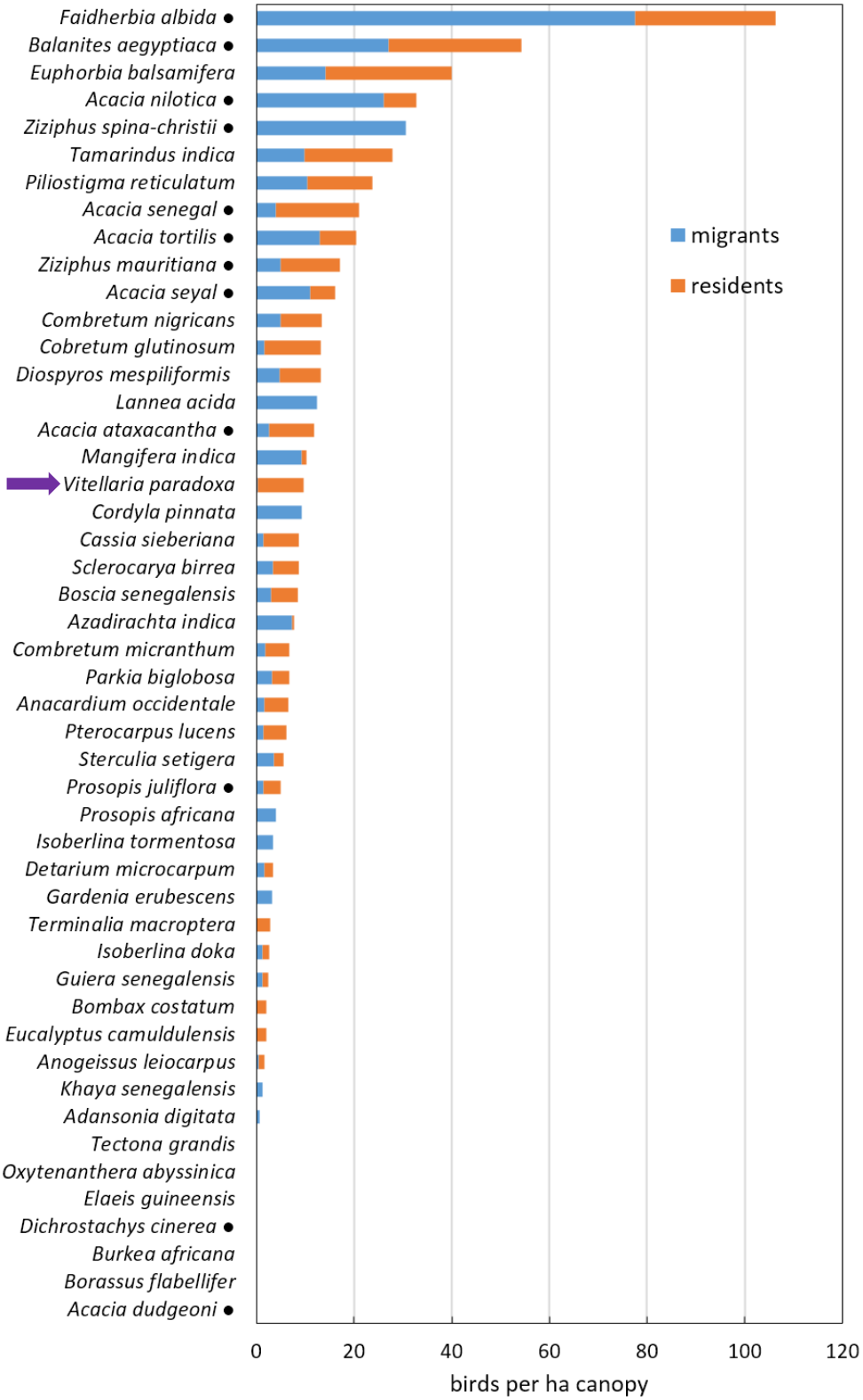


Fig. 8. Density (n per ha canopy) of migrants (data from Fig. 6 and appendix 2) and residents (data from Fig. 7 and appendix 3) in 48 tree species. Thorny species are marked (●).

Although most bird species reached a high density in *Faidherbia*, they differ regarding their choice in other tree species: Common Redstart reached its highest density in *Z. spina-christii* var. *spina-christii* (the variety bound to riverbanks and pond edges) and Common Whitethroat in living hedges of *Euphorbia balsamifera*. Olivaceous Warbler, for instance, was remarkably common in Neem *Azadirachta indica* and Mango *Mangifera indica*. One might also expect many European Pied Flycatcher in *Anogeissus leiocarpus*; it was the tree species preferred by the Pied Flycatchers studied by Janne Ouwehand and Rob Bijlsma in northern Ghana (Rob Bijlsma, pers. comm.). We saw none for two reasons. Most of our *Anogeissus* trees were north of the winter distribution area of this bird species, whereas it so happened that we saw no Pied Flycatchers in southern Mali in 176 large *Anogeissus* trees selected by us, while several were present in surrounding trees.

We saw relatively many sunbirds in *Vitellaria* trees, but they were only interested in the flowers of the semi-parasite *Tapinanthus* spec. Not any sunbird was noted in *Vitellaria* trees without flowering *Tapinanthus*.

Vitellaria *trees in full bloom (left) did not attract more birds than trees without flowers. The sunbirds we saw in* Vitellaria *trees, visited the flowers of the semi-parasite Tapinanthus (right).*

A selection was made for 48 tree species of which we had investigated at least 100 trees and a total canopy surface of more than 2000 m^2. In most tree species left out of the analysis, we never saw an insectivorous bird, so likely they are also of no importance of them, except for two species, which may be found within the distribution area of *Vitellaria*:

- *Mimosa pigra*, at least if flooded or with still humid ground, harbour many birds (192 birds/ha; Zwarts et al. 2015).
- *Zanthoxylum zanthoxyloides*, a species with thorns on its branches, twigs and leaves, attracts many birds if there are berries (Zwarts & Bijlsma 2015).

Néré or African locust bean tree *Parkia biglobosa* is not attractive for residents (3.68 birds/ha) and even less for migrants (3.12 birds/ha canopy). All data refer to the period early December – mid- March. Later in the season (when the tree starts to flower) it attracts more birds, among which Willow Warblers, at least in Ghana (pers. comm. Rob Bijlsma). What is true for *Parkia*, may also be true for other species. We would need comparable data before December and after mid-March to know whether the ecological ranking, as shown in Figs. 6, 7 and 8, differs seasonally.

Unlike migrants, which were routinely recorded from the beginning of the study, residents have been disregarded during the first years of observation, hence the smaller sample sizes than for migrants. Appendix 2 and 3 give the sample size (in the second and third row). For nearly all tree species, the difference is small, but for one tree species, *Ziziphus spina-christii*, the sample size has become very low for the migrants. It is a pity we do not know the density of residents for this species, because *Z. spina-christii* var. *spina-christii* (the variety bound to riverbanks and pond edges) is highly attractive for migrants; in not any tree we have seen so many Common Redstart (Appendix 2).

4 Discussion and conclusions

Birds are highly selective in their tree choice. An explanation is given elsewhere (Zwarts *et al*. 2015 and literature given in that paper): In short: migratory birds in the Sahel and Sudan vegetation zone prefer acacias and other thorny over non-thorny tree species, because thorny species invest in mechanical defence with spines and thorns to reduce the grazing pressure of large herbivores, rather than in chemical defence against arthropods feeding on foliage. Moreover, savanna trees are mostly deciduous, while most trees in tropical forests are evergreen. Deciduous trees are not attractive for birds if leafless, but when in leave they have more insects than evergreen trees, because trees with a shorter leaf life invest less in chemical and structural defence against herbivores, a trait that is conducive to higher numbers of arthropods.

Although the data set is still incomplete, we may arrive at the following four conclusions:

1. *Faidherbia* is the tree species with most birds, migrants as well as residents. From a bird's point of view, *Faidherbia* trees would be an ideal tree species to plant between *Vitellaria*. This tree is also popular among (northern) farmers for several reasons. Although the *Faidherbia* parkland zone is situated north of the *Vitellaria* zone, there is large overlap in the present distribution of both tree species. *Faidherbia* even grows where the annual rainfall amounts to 1200-1600 mm (Guinea-Bissau, northern Ivory Coast).
2. Other acacia trees (*A. seyal*, *A. nilotica*) also attract many birds; *A. tortilis* and *A. senegal* are also rich in birds, but their northerly distribution makes these species less suitable;
3. The bird density is also relatively high in other thorny species such as *Balanites* and *Z. spina-christii* var. *spina-christii*.
4. If riparian zones or other temporary flooded areas are available nearby *Vitellaria* parkland, planting the following tree species would result in maximal number of birds: *Faidherbia*, *Z. spina-christii*, *A. seyal* , *A. nilotica* and *Piliostigma reticulatum.* The impenetrable, thorny thickets of *Mimosa pigra* would attract many birds too, but this exotic species is invasive and considered by local farmers as a pest.

There still four important gaps in our knowledge:

1. The given densities referred to the sites shown in Fig.1 as far as situated in areas with an average rainfall above 500 mm. The larger part of the *Vitellaria* zone is situated further south (Ghana) and east (Togo, Benin, Nigeria). We do not know whether our measurements from the northwestern part of the *Vitellaria* zone (and also further west) is representative for the entire *Vitellaria* belt.
2. We presented bird densities for the period December-mid March, of which most data were collected in January and the first half of February. We still do not know whether the tree preference varies seasonally. Most Sahelian trees are more or less deciduous and several species even leafless for several months in the dry season. Hence it is conceivable that (bare) trees ranking low in Figs. 6-8, may attract foliage-gleaning birds some months earlier or later. The same is to be expected for trees flowering before or after the dry season; the example of *Parkia* was already mentioned.
3. Fruit is probably an essential food resource when birds fat up in the premigratory period. For that reason, *Salvadora persica* is such an important woody plant for migratory birds, at least for *Sylvia* species, in the northern Sahel. Woody plants with eatable fruit in March-April must be very rare in the Sudan zone. We still have to find out whether the berries of *Zanthoxylum zanthoxyloides* are indeed an important food resource for migratory woodland birds (as some preliminary observations suggest).
4. Would an isolated *Faidherbia* tree surrounded by a monoculture of birdless *Vitellaria* be as attractive for birds as the same tree if surrounded by many other *Faidherbia* trees? That is important to know if decisions have to be made where to plant *Faidherbia* trees and how many per site. We still have to analyse our data set to answer this question, but we expect that no, or hardly any, "island effect". In *Faidherbia,* we measured the highest bird densities in single *Faidherbia* trees without any (for birds attractive) tree within some kilometres. The relationship between the bird density in trees being attractive for birds and the degree of isolation still needs a quantitative analysis.

5 Cited references

Arbonnier M. 2007. Trees, shrubs and lianas of West African dry zones. Markgraf, Weikersheim.

Zwarts L. & Bijlsma R.G. 2015. Measuring absolute bird densities in trees. Ardea 103 (submitted).

Zwarts L., Bijlsma R.G., van der Kamp J., Sikkema M. & Wymenga E. 2015. Moreau's paradox reversed, or why insectivorous birds reach high densities in savanna trees. Ardea (submitted).

An extensive list of relevant literature is given in both Ardea-papers.

6 Appendix

Appendix 1. List of English and scientific names of bird species mentioned in the paper, based on BirdLife Checklist version 7.0 (except for Southern Grey Shrike which is *L. excubitor meridionalis* in BirdLife's list).

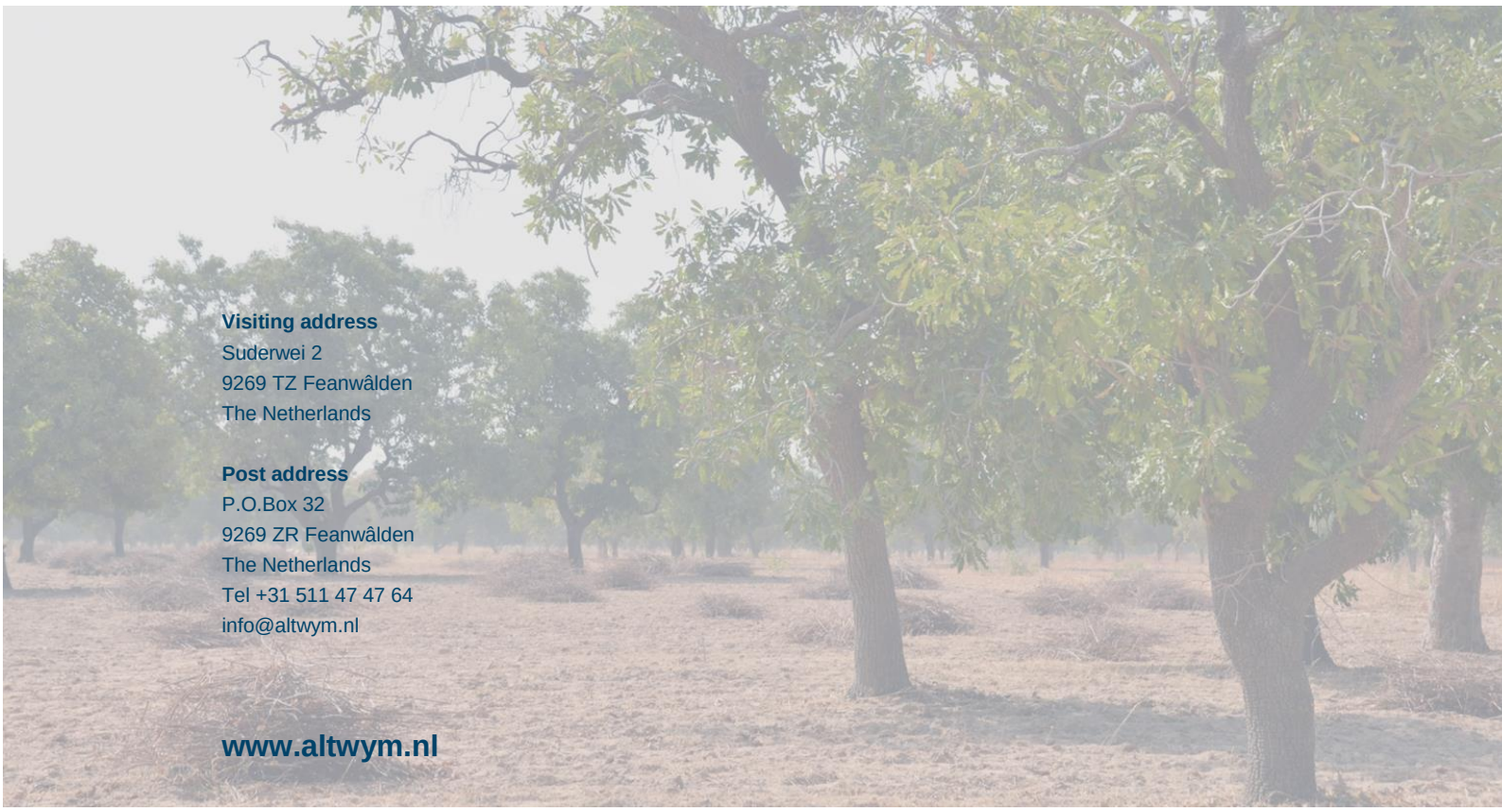
Beautiful Sunbird *Nectarinia pulchella*
Black Scrub-robin *Cercotrichas podobe*
Bluethroat *Luscinia svecica*
Bonelli's Warbler Phylloscopus bonelli
Common Chiffchaff *Phylloscopus collybita*
Common Redstart *Phoenicurus phoenicurus*
Cricket Longtails *Spiloptila clamans*
Eastern Olivaceous Warbler *Hippolais pallida*
Eurasian Wryneck *Jynx torquilla*
European Pied Flycatcher *Ficedula hypoleuca*
Common Whitethroat *Sylvia communis*
Grey-backed Camaroptera *Camaroptera brachyura*
Grey Woodpecker *Dendropicos goertae*
Iberian Chiffchaff *Phylloscopus ibericus*
Little Weaver *Ploceus luteolus*
Melodious Warbler *Hippolais polyglotta*
Northern Crombec *Sylvietta brachyura*
Orphean Warbler *Sylvia hortensis*
Pygmy Sunbird *Anthreptes platurus*
Rufous-tailed Scrub-robin *Erythropygia galactotes*
Scarlet-chested Sunbird *Nectarinia senegalensis*
Sedge Warbler *Acrocephalus schoenobaenus*
Senegal Eremomela *Eremomela pusilla*
Sennar Penduline-tit *Anthoscopus punctifrons*
Southern Grey Shrike *Lanius meridionalis*
Splendid Sunbird *Cinnyris coccinigastrus*
Subalpine Warbler *Sylvia cantillans*
Tawny-flanked Prinia *Prinia subflava*
Tree Pipit *Anthus trivialis*
Variable Sunbird *Nectarinia venusta*
Western Olivaceous Warbler *Hippolais opaca*
Willow Warbler *Phylloscopus trochilus*
Wood Warbler *Phylloscopus sibilatrix*
Woodchat Shrike *Lanius senator*
Yellow-bellied Eremomela *Eremomela icteropygialis*

Appendix 2. Density of 13 migratory birds species (n per ha canopy) in 48 tree species (alphabetic order). n= number of trees, m^2 = total surface of the canopy surface of the investigated trees. Five selection criteria: (1) 13 most common migratory bird species, (2) rainfall > 500 mm, (3) December-March, (4) n > 100, (5) m^2 > 2000 m^2 canopy.

Tree species	number of trees	total canopy, m^2	subalpine warbler	bonelli's warbler	tree pipit	wryneck	willow warbler	common redstart	common whitethroat	orphean warbler	melodious warbler	woodchat shrike	(Iberian) chiffchaff	olivaceous warbler	pied flycatcher	SUM
Acacia ataxacantha ●	4686	29585	0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00	0.00	0.70	0.00	0.00	0.00	2.82
Acacia ataxacantha ●	4670	29398	0.00	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	0.68	0.00	0.00	0.00	2.72
Acacia dudgeoni ●	434	2185	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acacia dudgeoni ●	434	2185	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acacia nilotica ●	1350	17881	1.82	8.49	0.00	0.00	0.00	7.27	1.21	0.61	0.00	0.00	6.06	0.00	1.21	26.67
Acacia nilotica ●	1246	16790	1.79	8.34	0.00	0.00	0.00	7.15	4.11	0.60	0.00	0.00	5.96	0.00	1.19	26.21
Acacia senegal ●	296	2847	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acacia senegal ●	265	2458	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acacia seyal ●	14339	103023	0.14	5.28	0.00	0.00	0.00	1.43	2.86	0.43	0.43	0.57	0.14	2.43	0.00	13.71
Acacia seyal ●	13312	98145	0.10	4.18	0.00	0.00	0.00	1.53	2.34	0.41	0.31	0.41	0.10	1.73	0.00	11.11
Acacia tortilis ●	659	4620	2.16	10.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.99
Anacardium occidentale	730	18475	0.00	0.56	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.56	0.00	1.69
Anogeissus leiocarpus	2378	53205	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Anogeissus leiocarpus	2268	51739	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.19	0.39
Azadirachta indica	1528	18976	0.56	1.12	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.56	0.56	3.93	0.00	7.29
Azadirachta indica	1361	17936	0.56	1.12	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.56	0.56	3.90	0.00	7.25
Balanites aegyptiaca ●	3813	27560	8.27	6.72	0.00	0.52	0.00	1.03	5.69	1.03	0.52	3.10	0.00	0.52	0.00	27.40
Balanites aegyptiaca ●	3417	26329	8.68	6.75	0.00	0.48	0.00	0.96	5.31	0.96	0.48	2.89	0.00	0.48	0.00	27.02
Bombax costatum	257	4886	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Borassus flabellifer	281	2403	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bossia senegalensis	2935	32227	0.00	0.00	0.00	1.00	0.00	0.00	3.10	0.00	0.00	0.00	0.00	1.00	0.00	5.10
Burkea africana	132	2142	0.00	0.00	0.00	0.00	0.00	4.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.97
Cassia sieberiana	5096	13755	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.73	0.00	1.46
Cassia sieberiana	5094	13732	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.73	0.00	1.46
Cobretum glutinosum	12990	38607	0.00	0.00	0.00	0.00	0.00	0.28	0.83	0.00	0.00	0.00	0.00	0.00	0.55	1.66
Combretum glutinosum	12261	36150	0.00	0.00	0.00	0.00	0.00	0.28	0.83	0.00	0.00	0.00	0.00	0.00	0.55	1.66
Combretum micranthum	18263	82274	0.00	0.00	0.00	0.13	0.00	0.76	0.89	0.00	0.00	0.00	0.00	0.13	0.00	1.91
Combretum nigricans	761	2074	0.00	0.00	0.00	0.00	0.00	4.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.97
Cordyla pinnata	167	5410	0.00	5.54	0.00	0.00	0.00	0.00	1.85	0.00	0.00	1.85	0.00	0.00	0.00	9.24
Detarium microcarpum	2480	6012	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00	0.00	1.66
Dichrostachys cinerea ●	928	3254	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diospyros mespiliformis	17844	26800	0.00	0.00	0.00	0.12	0.00	0.75	0.87	0.00	0.00	0.00	0.00	4.82	0.00	4.87
Elaeis guineensis	189	6052	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eucalyptus camaldulensis	2548	25435	0.00	0.54	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.85	0.00	0.00	0.00	0.24
Euphorbia balsamifera	2072	46415	0.00	0.00	0.00	0.00	0.00	3.15	6.30	0.00	0.00	3.15	0.00	3.15	0.00	15.75
Faidherbia albida ●	3257	168734	14.16	36.63	2.18	0.10	2.48	2.28	2.08	0.69	3.56	0.99	1.09	9.60	0.20	76.03
Gardenia erubescens ●	1161	3095	0.00	0.00	0.00	0.00	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23
Guiera senegalensis	68552	989486	0.11	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.22	0.00	0.78	0.00	1.33
Isoberlina roka	3032	22850	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31	1.31
Isoberlina tomentosa	347	5905	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.39	3.39
Khaya senegalensis	1197	17035	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	1.18
Lannea acida	101	2403	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.16	0.00	8.32	0.00	12.49
Mangifera indica	352	18223	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	8.07	0.58	9.23
Oxytenanthera abyssinica	328	8099	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parkia biglobosa	442	35293	0.28	0.57	0.57	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.85	0.00	0.28	3.13
Piliostigma reticulatum	10541	21279	0.95	0.48	0.00	1.91	0.00	1.91	2.86	0.00	0.00	0.00	1.43	0.95	0.00	10.48
Prosopis africana	397	2479	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.03	4.03
Prosopis juliflora ●	6634	9728	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	0.00	0.00	1.49
Pterocarpus lucens	798	14567	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38
Sclerocarya birrea	606	15601	0.00	1.33	0.00	0.00	0.00	0.00	0.67	0.00	0.00	1.33	0.00	0.00	0.00	3.34
Sterculia setigera	278	5465	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.66	0.00	0.00	0.00	3.66
Tamarindus indica	1731	84794	0.00	4.42	0.00	0.00	0.00	1.47	0.00	0.00	0.00	1.47	1.47	1.47	0.00	10.30
Tectona grandis	296	2265	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Terminalia macroptera	2672	7262	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitellaria paradoxa	3072	108071	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.09	0.00	0.00	0.09	0.26
Ziziphus mauritiana ●	2743	10389	0.00	0.00	0.00	0.00	0.00	1.25	3.76	0.00	0.00	0.00	0.00	0.00	0.00	5.02
Ziziphus spina-christi ●	445	8152	1.23	1.23	0.00	0.00	0.00	11.04	0.00	2.45	1.23	0.00	2.45	11.04	0.00	30.67
Prosopis africana	397	2479	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.03	4.03
Prosopis juliflora ●	485	6716	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	0.00	0.00	1.49
Pterocarpus lucens	797	14472	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38
Sclerocarya birrea	585	14982	0.00	1.33	0.00	0.00	0.00	0.00	0.67	0.00	0.00	1.33	0.00	0.00	0.00	3.34
Sterculia setigera	278	5465	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.66	0.00	0.00	0.00	3.66
Tamarindus indica	154	7978	0.00	4.34	0.00	0.00	0.00	1.41	0.00	0.00	0.00	1.41	1.41	1.41	0.00	9.89

Appendix 3. Density of 14 residents (n per ha canopy) in 48 tree species(alphabetic order). n= number of trees, m^2 = total surface of the canopy surface of the investigated trees. Five selection criteria: (1) 14 most common resident bird species, (2) rainfall > 500 mm, (3) December-March, (4) n > 100, (5) m^2 > 2000 m^2 canopy.

tree species	number of trees	total canopy, m2	rufous-tailed scrub-robin	green-backed camaroptera	northern crombec	senegal eremomela	tawny-flanked prinia	black scrub-robin	beautiful sunbird	pygmy sunbird	scarlet-chested sunbird	splendid sunbird	variable sunbird	cricket warbler	little weaver	grey woodpecker	SUM
Acacia ataxacantha ●	4662	29303	1.01	5.79	0.00	0.34	0.34	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.21
Acacia dudgeoni ●	434	2185	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acacia nilotica ●	1167	16099	0.00	2.35	0.00	2.35	1.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.48
Acacia senegal ●	265	2458	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.96	0.00	0.00	16.96
Acacia seyal ●	12877	91565	0.39	1.25	0.62	1.35	0.93	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.22	0.00	5.09
Acacia tortilis ●	642	4626	0.00	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.57	0.00	0.00	7.40
Adansonia digitata	234	27212	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Anacardium occidentale	671	15949	0.54	0.63	1.25	2.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.93
Anogeissus leiocarpus	2308	52524	0.00	0.56	0.00	0.56	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35
Azadirachta indica	1276	17051	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56
Balanites aegyptiaca ●	2652	19930	0.36	5.58	0.46	5.11	11.62	0.52	0.00	0.52	0.00	0.00	0.00	1.04	1.56	0.00	27.30
Bombax costatum	245	4749	0.00	0.00	0.00	2.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.11
Borassus flabellifer	571	4834	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boscia senegalensis	2965	3251	0.00	5.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.41
Burkea africana	132	2142	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cassia sieberiana	5095	13752	1.45	4.36	0.00	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.27
Cobretum glutinosum	11132	34693	0.26	2.52	0.56	2.24	0.00	0.00	4.02	0.00	2.01	0.00	0.00	0.00	0.00	0.00	11.62
Combretum micranthum	17807	80259	1.09	2.69	0.00	0.24	0.00	0.46	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.96
Combretum nigricans	749	2014	0.00	0.00	0.00	0.00	0.00	0.00	8.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.52
Cordyla pinnata	108	1843	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Detarium microcarpum	2480	6012	0.00	1.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.66
Dichrostachys cinerea ●	928	3254	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diospyros mespiliformis	127	1218	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.46
Elaeis guineensis	188	6052	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eucalyptus camuldulensis	1338	3730	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.09	0.00	0.00	0.00	0.00	0.00	0.00	2.09
Euphorbia balsamifera	2285	23667	0.00	4.83	0.00	0.00	0.00	0.00	0.00	0.00	21.02	0.00	0.00	0.00	0.00	0.00	25.85
Faidherbia albida ●	2457	142600	0.00	1.35	0.96	1.73	2.89	0.00	8.41	1.27	0.40	0.63	2.06	0.00	7.22	0.16	28.75
Gardenia erubescens	1161	3095	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guiera senegalensis	45549	67355	0.30	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18
Isoberlina roka	3032	22850	0.00	0.88	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31
Isoberlina tormentosa	347	5905	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Khaya senegalensis	109	15930	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lannea acida	101	2403	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangifera indica	348	18083	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10
Oxytenanthera abyssinica	328	8099	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parkia biglobosa	440	34939	0.00	0.28	0.00	1.42	0.00	0.00	0.00	0.00	1.97	0.00	0.00	0.00	0.00	0.00	3.68
Piliostigma reticulatum	9227	17648	0.47	1.12	0.00	3.92	3.92	0.00	3.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.21
Prosopis africana	390	1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prosopis juliflora ●	126	1498	1.03	0.00	0.00	0.00	2.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.50
Pterocarpus lucens	797	14472	1.37	2.06	0.00	1.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.81
Sclerocarya birrea	573	15014	0.00	0.00	0.00	2.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.35
Sterculia setigera	277	5427	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.83
Tamarindus indica	145	6613	0.00	5.64	0.00	0.00	0.00	0.00	2.46	9.83	0.00	0.00	0.00	0.00	0.00	0.00	17.93
Tectona grandis	296	2265	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Terminalia macroptera	2672	7262	0.00	0.00	1.38	1.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75
Vitellaria paradoxa	2952	102436	0.00	0.29	0.10	1.36	0.10	0.00	1.07	4.26	1.07	0.00	0.00	0.00	0.00	0.00	9.31
Ziziphus mauritiana ●	2619	9777	0.94	4.94	0.00	0.00	3.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.31	0.00	12.14
Ziziphus spina-christii ●	28	37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



Visiting address
Suderwei 2
9269 TZ Feanwâlden
The Netherlands

Post address
P.O.Box 32
9269 ZR Feanwâlden
The Netherlands
Tel +31 511 47 47 64
info@altwym.nl

www.altwym.nl