Altenburg & Wymenga ECOLOGICAL CONSULTANTS

Birds and trees in the Sahel:
Progress report 2012

A&W-report 1809

commissioned by

Vogelbescherming Nederland

Nationale Postcode Loterij

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Photograph front page
Most Palearctic woodland bird species in the Sahel were recorded on farmer's land. Photo: Leo Zwarts

L. Zwarts, J. van der Kamp, M. Sikkema, E. Wymenga 2012
Birds and trees in the Sahel: Progress report 2012. A&W-report 1809
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This study has been carried out in the framework of *Living on the Edge*, a project of *Vogelbescherming Nederland* and *BirdLife International* partners in the Sahel. The project aims to conserve and restore bird habitat in the Sahel and improve rural livelihoods by designing and promoting sustainable land use.
Living on the Edge is funded by the Dutch *Nationale Postcodeloterij*.

Project number	Project leader	Status
1785ltr.11	E. Wymenga	Final

Autorisation	Autograph	Date
Goedgekeurd	E. Wymenga	30-7-2012

Contents

The same wooded savanna in central Senegal on 14 October 1983 (left) and 31 January 1994 (right), showing loss of Acacia trees from cutting.

1 Introduction

Migratory birds spending the northern winter in the Sahel are in trouble. What might have changed in their African habitat to explain the on-going decline? Thanks to the financial support of *Vogelbescherming Nederland*, we were able to do a pilot study in 2011 aiming at optimisation of methods to describe (1) the zoning of woodland bird species from the Sahara desert to the tropical forests 800 km further south and (2) the tree preference of different bird species, - information necessary to understand why these woodland bird species are in decline. The methods such as elaborated beforehand, but also the adaptations made in the field, have been described in detail by Zwarts *et al*. (2011).

During this pilot study, we counted 57900 trees and 1002 Palearctic birds in 487 transects on 113 sites, covering a total surface area of 656 ha. The data allowed us to determine the preference of the Palearctic bird species for different tree species and for trees having a certain width and height. The collected data were also used to calculate the densities of the trees and birds per latitude and estimate the total number of birds wintering in SW Mauritania and W Senegal between 13 and 18°N and 13 and 17°W. Although this is a large area of 500 x 400 km, it is not more than 12% of the entire western Sahel and Sudan zone (extending from 10 to 18°N and from 10°E to 17°W, an area of 880 by 2800 km, nearly 2.5 million km^2). Are the data collected in SW Mauritania and W Senegal representative for the entire western Sahel-Sudan zone? Probably not.

Again thanks to the support of *Vogelbescherming Nederland*, we were able to continue the field work in 2012 using the same methods as developed during the pilot study and to collect the same kind of field data 1000 km more to the east in Mali. Moreover, the data from 2011 were only from the northern Sahel (13.2-18.0°N). In Mali we extended the range of sampling sites southward to 10° N (Fig. 1). Unfortunately, due to safety reasons, we had to skip the region north of 15.2°N. However, data in Mali were already available from the range 14.5-16.7°N due to preliminary field work done in, and around, the Inner Niger Delta in 2007-2010. Hence the Mali data may be considered as a nice replication test for the zone 14-17°N.

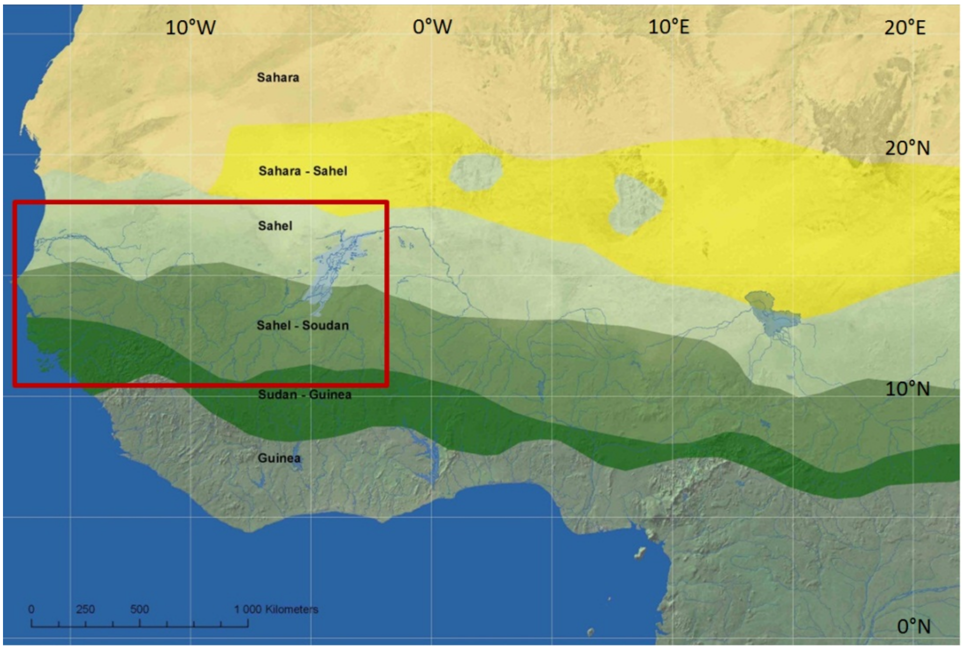


Fig. 1. West Africa divided into six climatic zones (simplified after Arbonnier 2002). The red square indicates the area (880 x 1400 km) where tree and bird densities were measured.

This report describes the latitudinal zoning of trees and birds. It also shows the tree preference of the birds, not only for certain species but also, within each tree species, for larger trees and for shrubs and trees with a relatively dense foliage or for trees and shrubs with flowers or berries. The data are used to do an improved estimate of the total numbers of birds present in the Western Sahel.

Acknowledgements

Dramane Camara was our driver but much more than that. Since he took care of us so well, we could fully focus on our field work every day from sunrise to sunset. Bakary Kone (Wetlands International) prevented many (potential) problems by giving us an official *ordre de mission*. He worried a lot about us when during our mission the (political) insecurity took a sudden turn for the worse. Without the support of Bernd de Bruijn (Vogelbescherming Nederland) this work would not have been performed. Lucien Davids (A&W) solved (too) complex GIS-problems. Rob Bijlsma made valuable and detailed comments on an earlier version of this report. We are very grateful to all of them.

Karité, *Vitellaria paradoxa*, do not attract woodland bird species, even when there are many flowers (top), but the (few) Palearctic birds recorded in Mango, *Mangifera indica*, were nearly all feeding in flowering trees (bottom).

2 Method

2.1 Sampling sites

In 2011, it took three persons 26 field days to perform the counts of birds and trees in 487 transects. Averaged over the entire field period, we did 4.3 transects per site and 18.7 transects per day. Most transects were 250 m by 50 m; the average surface area was 1.35 ha. The total area counted was 656 ha, thus we counted 25.2 ha per day, on average.

In 2012, we counted birds and trees again in transects being 50 m wide and (not 250 m but) 300 m long, usually three transects per site. We selected 256 sites beforehand, using the same criteria as in 2011: (1) Google images with a high resolution, (2) Avoidance of no-go areas, (3) Sites accessible by car (four-wheel drive), preferably situated along roads and tracks with a predominantly N-S direction.

Fig. 2 shows the spatial distribution of the 177 sites (507 transects) visited in 2012, together with 14 and 4 sites from the Inner Niger Delta in 2007-2010 and 2012, respectively, and the 113 sites from Senegal+Mauritania in 2011, in total 308 sites and 1033 transects. Fig. 3-6 gives the same information but with a different background: rainfall (Fig. 3), land use (Fig. 4), density of human population (Fig. 5) and density of goats (Fig. 6). Table 1 gives an overview of the collected data. There are two types of sampling sites: 295 random sites and 23 non-random sites.

Random sites were selected where the road intersected the latitude rounded at exactly one decimal (*e.g.* 15.1˚N, 15.2˚N, 15.3˚N). Hence, the sites were situated at a mutual latitudinal distance of 0.1˚, corresponding with 5.5 km if the road was running exactly N-S. The distance could increase to 20 km or more if the road was directed more W-E. The sites along the road were numbered: sites with even numbers were situated to the west of the road, uneven numbers to the east. As discussed by Zwarts *et al*. (2011) these random sites are not necessarily representative for the latitude concerned, but this can be corrected.

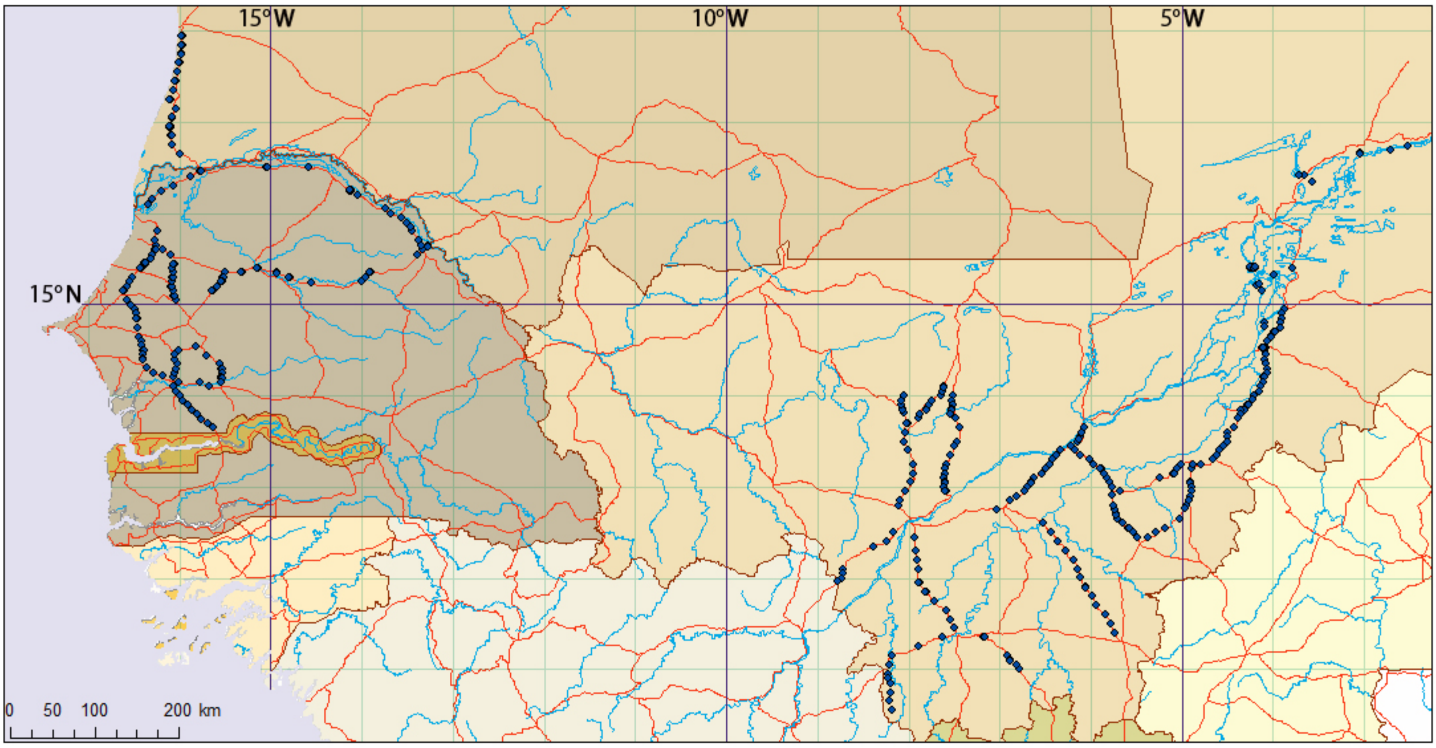


Fig. 2. The 1033 transects on 308 sites in Senegal, Mauritania and Mali where birds and trees have been counted are situated between 10.5 and 15°N and 4 and 17°W.

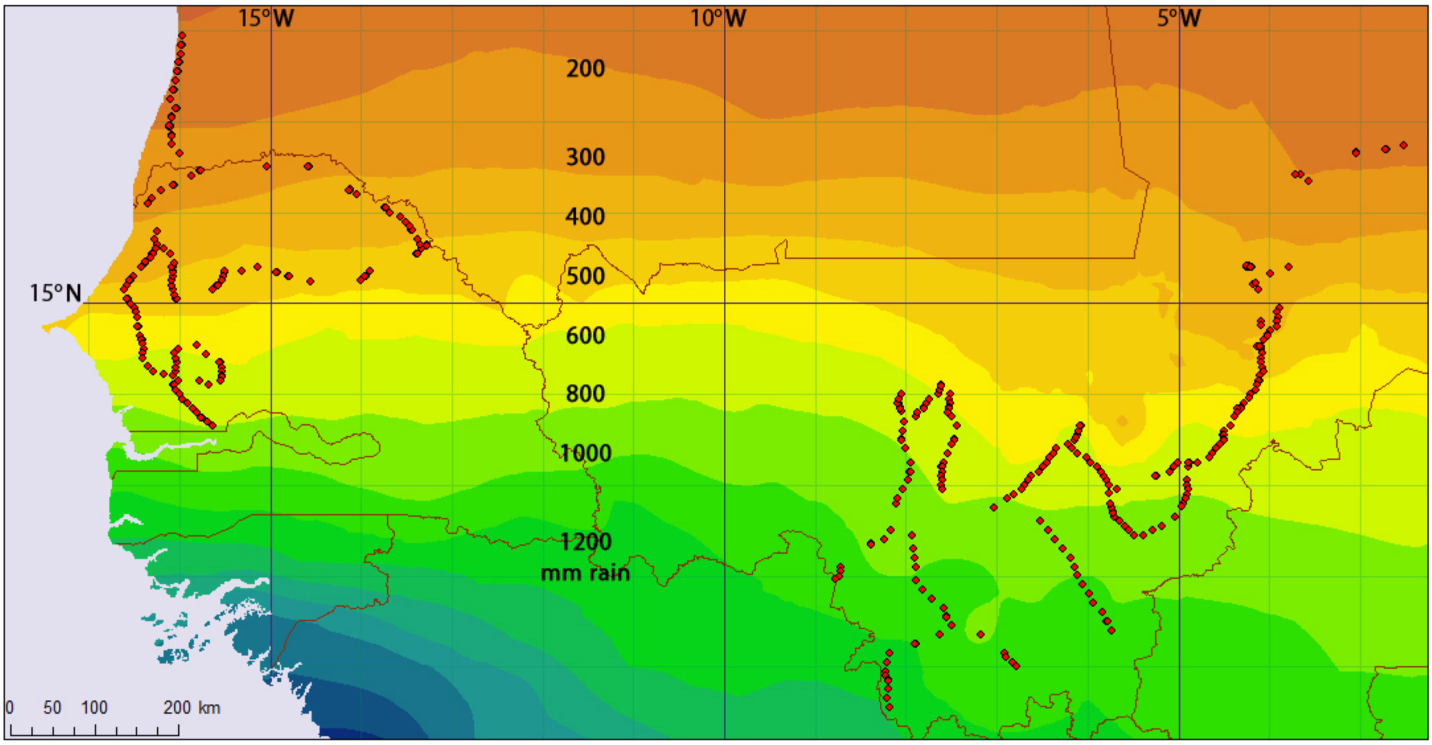


Fig. 3. The 1033 transects were situated in the zone where the average annual rainfall varies between 102 and 1301 mm. The annual rainfall at 484 meteorological stations, averaged for the period 1950 – 1990, were used to interpolate the rainfall for the entire area shown on the map (kriging method); meteorological data from Zwarts *et al*. (2009).

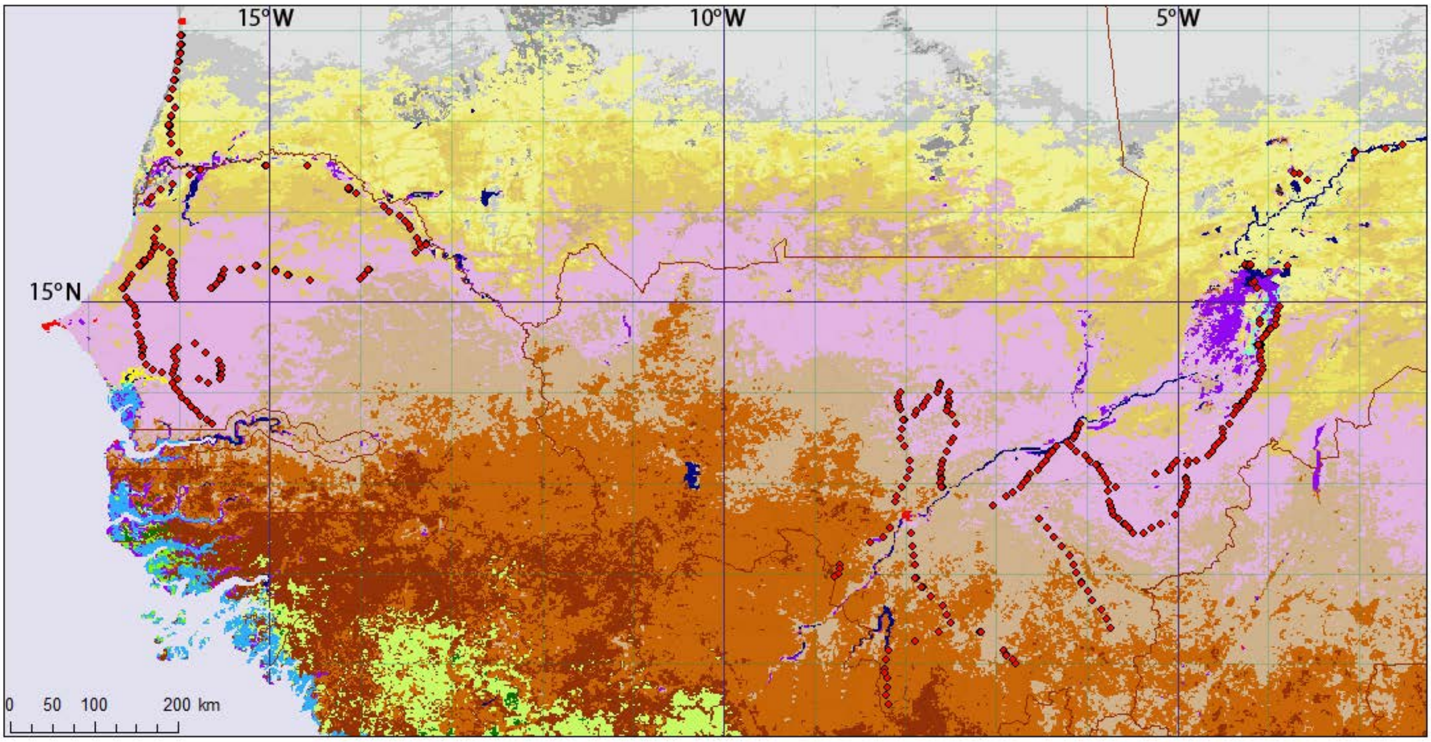


Fig. 4. Most transects were situated in cropland (purple on the map) and to a lesser degree in open grassland with sparse scrub (yellow brown). Transects were also made in other habitats: open and sparse grassland (light and dark yellow), croplands with open woody vegetation ("parkland"; brown) and deciduous woodland (red brown). The land cover map was taken from www.gem.jrc.it/glc20000.

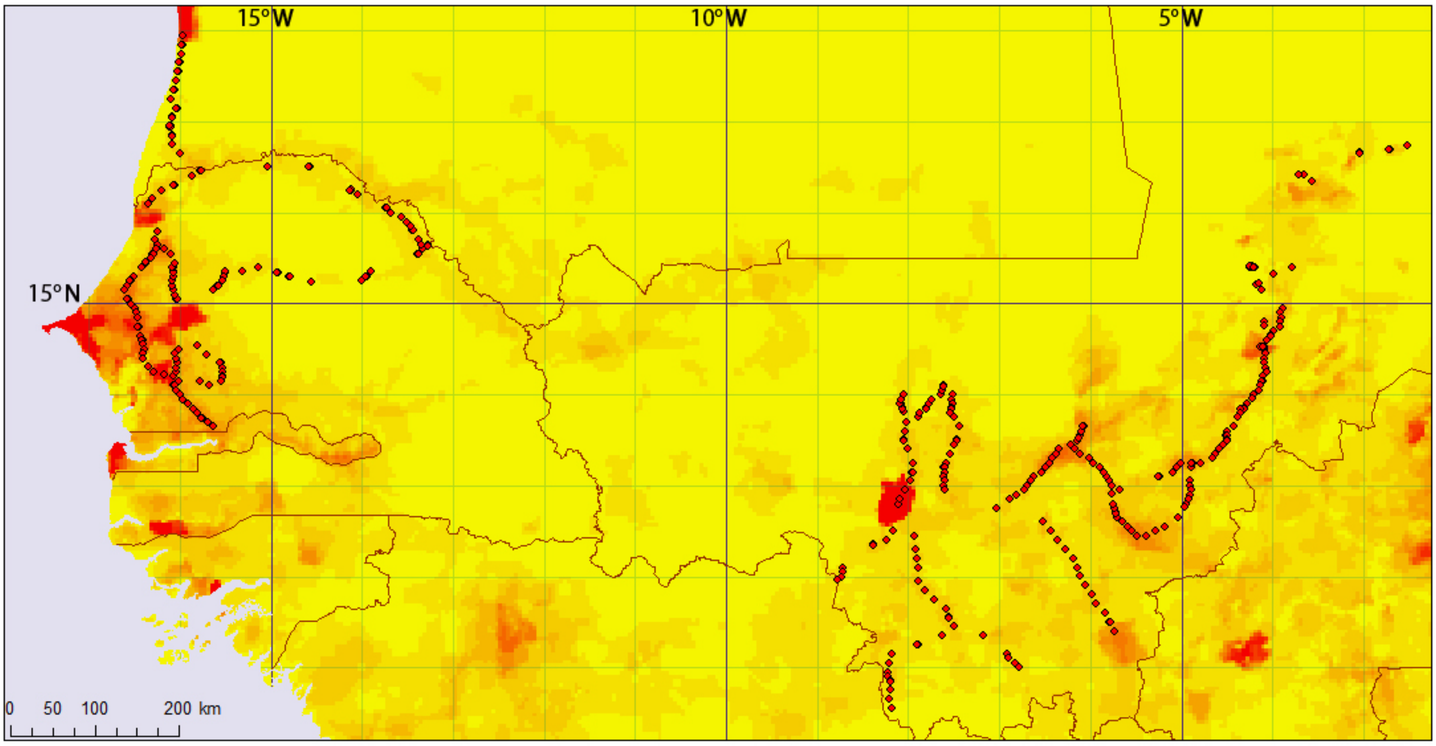


Fig. 5. The density of the human population (according to Nelson 2004) is low in the dry north and increases to the south, but declines again on the most southern sites. The large cities (Nouakchott, Dakar, Bamako) are visible on the map as dark red spots. Note the higher population density along the Senegal River (at the border of Mauritania and Senegal) and in west central Senegal ("Peanut Basin"). In contrast, few people live in east Senegal and west Mali and also in the National Parks (see also Figure 6). Altogether, the more densely-populated areas are over-represented in our sample.

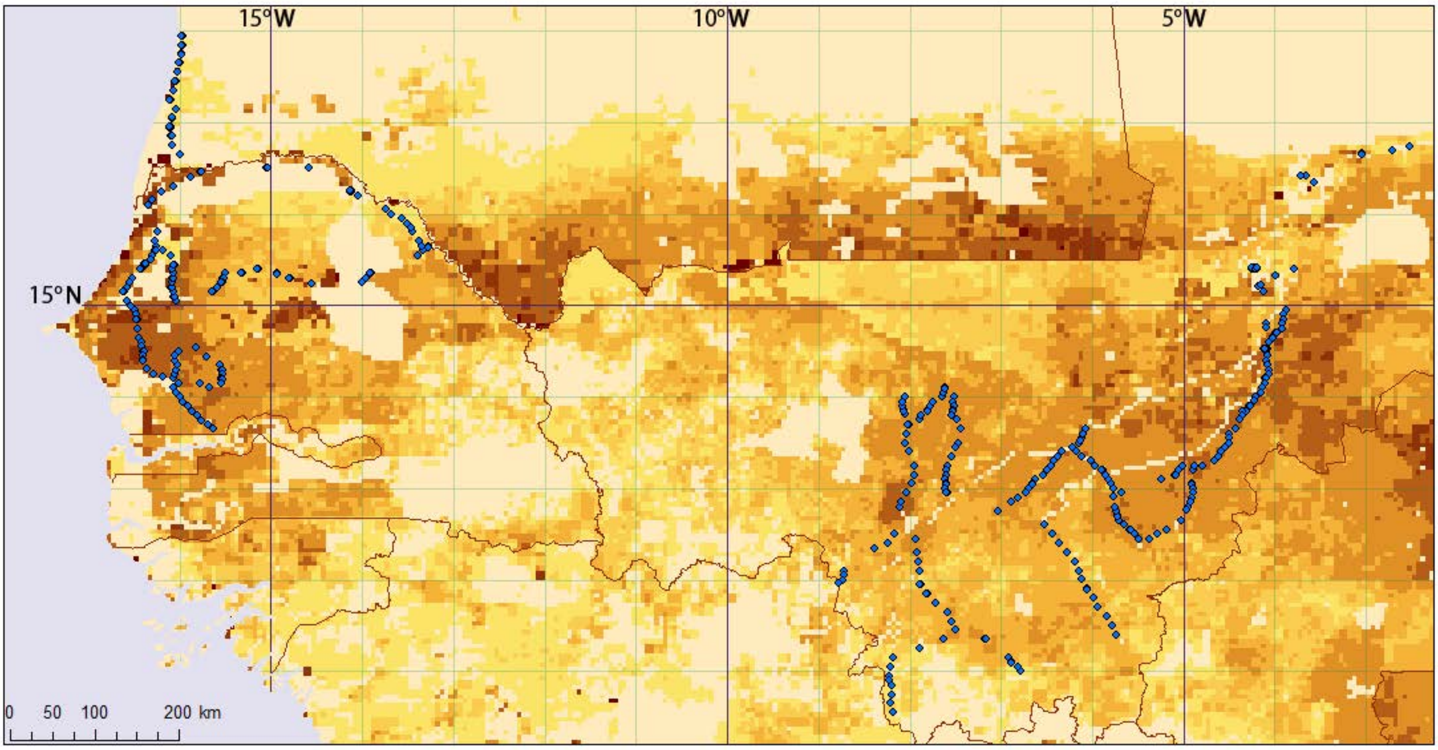


Fig. 6. The density of goats varies between 800/km^2 (dark brown) and close to 0/km^2 (light yellow). There are no (or hardly any) goats in the Sahara and the National Parks (e.g. Ferlo in N Senegal, Niokolo Koba in SE Senegal, Boucle du Baoulé in W Mali, Gourma in E Mali, the Sahel reserve in N Burkina Faso); data from FAO-AGA (www.fao.org/ag/aga/glipha).

Table 1. Overview of the data collected in Senegal+Mauritania (Sen.+Maur) in 2011, Mali in 2012 and in the Inner Niger Delta (IND) in 2012 and in 2007-2010. The digit given in the last column refers to the 18 notes.

site	Sen.+Maur.	Mali	IND	IND	Sum	line
year	2011	2012	2012	2007-2010		
trees, sum	58012	108097	872	3886	170867	1
birds, sum	1002	750	376	483	2611	2
period	21/1-21/2	5/1-10/2	13-20/2	1/2-7/3		3
transects, sum	487	507	12	27	1033	4
sites, sum	113	177	14	4	308	5
hour, sum	167.8	220.6	34.3	46.2	468.9	6
tracks,km,sum	173	224	23	?	420	7
km/h, avg	1.38	1.34	0.74	?		8
bird-ha, sum	691	798	27	35	1551	9
tree-ha, sum	691	763	27	35	1516	10
min./ha, avg	16.7	21.4	142.4	98.2		11
N°, avg	15.6	13.0	15.3	15.6		12
N°, range	13.2-18.0	10.5-15.0	15.2-15.4	14.5-16.7		13
rain/yr, avg	491	801	362	335		14
rain/yr, range	102-490	430-1301	346-374	189-493		15
canopy,%, avg	4.3	10.4	26.2	13.6		16
pop. dens, avg	15.36	13.32	0.39	11.96		17
birds/ha, avg	1.5	0.9	33.7	9.4		18

Notes (per line number):
1. trees, sum = total number of counted trees+shrubs (at least 0.5 m high).
2. birds, sum = total number of birds counted (selection made of species mentioned in the text).
3. period = time during which data were collected; the IND data in 2007-2010 were collected on 16-26 Feb 2007, 14-28 Feb 2008, 1-7 Feb 2009, 3-7 Mar 2009 and 18-27 Feb 2010.
4. transects, sum = number of transects.
5. sites, sum = number of sites.
6. hour, sum = total time spent on the transects counting trees and birds.
7. track, km, sum = distance covered while counting birds and trees within the transects (GPS data).
8. km/h, avg = walking speed during the field work (GPS data).
9. bird-ha, sum = total surface (ha) where birds have been counted; surface area was known for 18 of the 28 sites in the Inner Niger Delta (2007-2010).
10. tree-ha, sum = total surface (ha) where trees have been counted (usually the same as “bird-ha”, but in a few transects the tree density or diversity was so high that the trees were counted within 10 m (and the birds in a transect being 50 m wide); surface area was unknown for 10 of the 28 sites in the Inner Niger Delta (2007-2010).
11. min./ha, avg = average time (minutes) spent to count the birds on 1 ha.
12. N°, avg = average latitude of the visited sites (see Fig. 2).
13. N°, range = minimal and maximal latitude of the visited sites (see Fig. 2).
14. rain/yr, avg = average annual rainfall for the period 1950-1990 (see Fig. 3).
15. rain/yr, range = minimal and maximal average annual rainfall of the visited sites for the period 1950-1990 (see Fig. 4).
16. canopy, %, avg = average coverage by the canopy as % relative to the total surface area of the transect (explanation in text).
17. pop. dens, avg = density of human population per km^2 (see Fig. 5).
18. birds/ha, avg = average number of birds per ha.

We also recorded data in non-random sites. These sites were selected as additional information was not otherwise available. We visited a riverine forest of *Acacia nilotica* along the Senegal river and a plantation of *Khaya senegalensis* in Mali. Also the forests visited in the Inner Niger Delta refer to non-random sites. In non-random sites, the same data were collected as in random sites. The 23 non-random sites will be included in each analysis regarding the bird density per tree species, but will be discarded in analyses meant to describe latitudinal trends and relationship with rainfall, etc.

2.2 Tree species

We tried to identify all trees and shrubs within the plots, using Arbonnier (2002) as field guide. This sometimes proved to be problematic, especially when trees were without leaves, flowers or fruit. We made thousands of photographs to check identifications back home. In total, we identified 164 tree species.

In 2011, only 46 of the 57,899 trees and shrubs remained unidentified (0.8%), but this amounted to 11.4% in 2012 (12,416 of 108,969). The explanation of this difference is that species diversity increased further south. It would have been too time-consuming in some southern plots to identify all trees and shrubs. Hence, we regularly lumped shrubs and small trees per height class.

Most trees and shrubs were identified from a distance. Mistakes may have occurred in the identification of tree species resembling each other. The common tree species where almost all Palearctic bird species were detected, were easy to identify, however. Table 2 gives the full list.

Zanthoxylum zanthoxyloides, a spiny shrub with thorns on the leaves (left), is one of the few species in the southern Sahel and Sudan attracting Palearctic bird species, at least if there are ripe berries (right). The berries measured 4.1 – 5.2 mm.

We measured and estimated height and widest crown diameter of the trees (methods given in Zwarts *et al*. 2011). Assuming that each tree and shrub has a circular form in the horizontal plane, we may calculate for each tree and shrub its crown cover (also in a horizontal plane). The summated canopy surface area is the total cover of all trees and shrubs at a site. The relative canopy cover is the summated canopy as % of the surface of the site. The relative canopy cover could attain a value above 100% when in a closed woodland low trees and shrubs are found beneath larger trees. This was indeed the case at a few sites.

Table 2. Number of trees and shrubs counted in Senegal+Mauritania (S+M) in 2011, in Mali in 2012 and in the Inner Niger Delta (IND) in 2007-2012.

species	S+M	Mali	IND	sum
Acacia amythethophylla		1		1
Acacia ataxacantha	19	4313		4332
Acacia dudgeoni	13	452		465
Acacia hockii	9	7		16
Acacia kirkii			615	615
Acacia macrostachya	28	13		41
Acacia nilotica	262	408	27	697
Acacia polyacantha	1			1
Acacia senegal	292	2	7	301
Acacia seyal	454	208	1159	1821
Acacia sieberiana			2	2
Acacia tortilis	6536	86	267	6889
Adansonia digitata	118	84		202
Adenium obesum	82	10		92
Aeschynomene niltotica			1	1
Afzelia aficana		14		14
Agave sisalana		59		59
Albizia chevalieri		1		1
Albizia lebbeck		1		1
Albizia malacopphylla		1		1
Anacardium occidentale		654		654
Annona senegalensis	2	263		265
Anogeissus leiocarpa	61	564		625
Anthocleista procera		3		3
Aphania senegalensis	229			229
Azadirachta indica	111	678	296	1085
Balanites aegyptiaca	5300	676	214	6190
banana		80		80
Bauhinia rufescens	68	16	1	85
Blighia sapida		1		1
Bombax costatum	11	234		245
Borassus flabellifer		161		161
Boscia angustifolia	2348			2348
Boscia salicifolia		42		42
Boscia senegalensis		94		94
Breonadia salicina		3		3
Burkea africana		132		132
cactus	20			20
Cadaba farinosa	109	1		110
Cadaba glandulosa	316			316
Cajanus cajan		1		1
Calotropis procera	1277	79		1356
Capparis decidua	14	16		30
Capparis tomentosa	1			1
Carica papaya		2		2
Cassia sieberiana		3658		3658
Ceiba pentandra		4		4
Celtis integrifolia	1		15	16
Citrus sinensis		101		101
Combretum aculeatum	140	22		162
Combretum collinum		95		95
Combretum fragrans		1		1
Combretum glutinosum	1753	10470		12223
Combretum lecardii		160		160
Combretum micranthum	210	13843		14053
Combretum nigricans		821		821
Combretum spec.		304		304
Commiphora africana	37	2		39
Cordyla pinnata	59	108		167
Cotom tomentosum		1		1
Crateva adansonii		16		16
Crescentia cujete	2			2
Crossopteryx febrifuga	1	72		73
Croton macrastychyus		1		1
Dalbergia melanoxylon		13		13
Daniellia oliveri		1		1
Detarium microcarpum		2428		2428
Dichrostachys cinerea		110		110
Diospyros mespiliformis	88	7	66	161
Elaeis guineensis		15		15
Entada abyssinica		3		3
Entada africana		124		124
Erythrina senegalensis		4		4
Eucalyptus camaldulensis	251	2371	1560	4182
Euphorbia balsamifera	6297	238		6535
Faidherbia albida	740	1041	154	1935
Feretia apodanthera	64			64
Ficus abutifolia		1		1
Ficus cordata		2		2
Ficus platyphylla		1		1
Ficus spec.	11	88		99
Ficus sur	1			1
Ficus sycomorus		1	8	9
Ficus thonningii		1	1	2
Ficus trichopoda		2		2
Ficus umbellata		6		6

Table 2 (continued)

species	S+M	Mali	IND	sum
Ficus vogelii		1		1
Flacourtia indica		2		2
Gardenia aqualla		55		55
Gardenia erubescens		1138		1138
Gardenia sokotensis		895		895
Gmelina arborea		5		5
Grewia flavescens		11		11
Grewia lasiodiscus		2		2
Grewia spec.		66		66
Grewia venusta		17		17
Guiera senegalensis	25522	28206		53728
Gyrocarpus americanus ssp		1		1
Hannoa undulata		103		103
Hexolobus monopetalus		24		24
Holarrhena floribunda		12		12
Hymenocardia acida		3		3
Hyphaene thebaica		16	13	29
Isoberlina roka		3030		3030
Isoberlina tormentosa		347		347
Jatropha curcas		948		948
Jatropha gossypiifolia		38		38
Khaya senegalensis	10	81		91
Lannea acida		101		101
Lannea barteri		3		3
Lannea humilis		4		4
Lannea microcarpa		35		35
Lannea spec.		180		180
Lawsonia inermis		55		55
Leptadenia hastata	4			4
Leptadenia pyrotechnica	448	7	127	582
Lonchcarpus laxiflorus	1	5		6
Lophira lanceolata		62		62
Maerua angolensis		5		5
Maerua crassifolia	145	52	3	200
Mangifera indica	68	297		365
Manikara multinervis		1		1
Mimosa pigra	136		30	166
Mitragyna inermis	26	4		30
Monotes kerstingii		1		1
Moringa oleifera	1	7		8
Opilia celtidifolia		1		1
Oxytenanthera abyssinica		273		273

species	S+M	Mali	IND	sum
Ozoroa insignis		11		11
Parkia biglobosa	1	408		409
Parkinsonia aculeata	1	2		3
Phoenix dactylifera	30	1		31
Phyllanthus muellerianus		1		1
Piliostigma reticulatum	1221	4221	6	5448
Piliostigma thonningii	7	264		271
Prosopis africana	7	390		397
Prosopis juliflora	648	104	136	888
Pterocarpus erinaceus	180			180
Pterocarpus lucens		621		621
Ptleopsis suberosa		579		579
Raphia sudanica		15		15
Saba senegalensis		5		5
Salvadora persica	99		9	108
Sarcocephalus latifolius		1		1
Sclerocarya birrea	35	345		380
Securidaca longipendunculata	16	34		50
Senna siamea		3		3
Senna singueana		1		1
Sterculia setigera	2	275		277
Stereospermum kunthianum		1		1
Strychnos innocua		28		28
Strychnos spinosa	12	133		145
Tamarindus indica	29	94	3	126
Tamarix senegalensis	851			851
Tectona grandis		296		296
Terminalia avicennioides	15			15
Terminalia laxiflora		18		18
Terminalia macroptera		2672		2672
Terminalia mantaly		18		18
undetermined	32	12417	2	12451
Uvaria chamea	2			2
Vitellaria paradoxa		2707		2707
Vitex madiensis		2		2
Ximenia americana		203		203
Zanthoxylum zanthoxyloides		14		14
Ziziphus abyssinca		1		1
Ziziphus mauritiana	84	648	1	733
Ziziphus mucronata	510	80		590
Ziziphus spina-christii	419	2	21	442
SUM	57898	108131	4744	170773

2.3 Bird species

Table 3 gives the species list and the numbers encountered. Ten Palearctic bird species may be considered as common and associated with trees (purple in Table 3), eight other species much less so.

We noted 16 Palearctic species foraging within the boundaries of the transects but were not associated with trees, for example White and Yellow Wagtails feeding on the ground and House and Sand Martins feeding in the air. The numbers given in the table refer to birds being present during the count. Birds only present during a part of the time, or passing, were noted but not included in the count, e.g. Eurasian Marsh Harrier and Montagu's Harrier.

In 2011, we made notes about the occurrence of African species but refrained from counting in the systematic way as done for the Palearctic species. In 2012, we again ignored the seed-eating African birds (e.g. weavers), but we recorded systematically some species considered to be potential competitors of Palearctic woodland bird species; see Table 3.

It should be noted that we had three problems regarding the identification of species.

(1) In 2011, we did not check every Hoopoe (European or African).

(2) The table gives a total of 341 Iberian Chiffchaffs, but we cannot exclude the possibility that part of the birds were Common Chiffchaff. Both species can only be distinguished in the field when singing, but nearly all birds were still silent in January and February. The birds we heard were definitely Iberian Chiffchaffs, so for the time being we assume that we only saw this species.

(3) Olivaceous Warbler has recently been split into Western and Eastern Olivaceous, although they are hard to separate in the field (Svensson 2001). In 2011, we did not attempt to separate both species. In 2012, we were able to identify eleven Western and one Eastern Olivaceous Warbler, but the rest (n=106) were not identified as separate species.

Redstart in *Faidherbia albida*

Table 3. List of bird species encountered in Senegal+Mauritania in 2011 (S+M), along the transects in Mali in 2012 and observed in the Inner Niger Delta (2007-2012). The bird species have been split up in four categories: African species (Afr), species not bound to trees (0), birds bound to trees being common (+) or rare (-); nc= not counted.

	region				Afr	tree		
species	S+M	Mali	IND	sum		0	+	-
Little Bittern *Ixobrychus minutus*			1	1				
Cattle Egret *Bubulcus ibis*		1		1				
Lesser Kestrel *Falco naumanni*	1			1				
Common Quail *Coturnix coturnix*	1			1				
Little Ringed Plover *Charadrius dubius*	5			5				
Great Spotted Cuckoo *Clamator glandarius*		2	3	5				
European Bee-eater *Merops apiaster*		1		1				
Eurasian Wryneck *Jynx torquilla*	2	2		4				
Hoopoe *Upupa epops*	19		2	21				
African Hoopoe *Upupa africana*		2		2				
Greater Hoopoe-Lark *Alaemon alaudipes*	7			7				
Greater Short-toed Lark *Calandrella brachydactyla*	1			1				
Crested Lark *Galerida cristata*	40			40				
Common Sand Martin *Riparia riparia*			3	3				
Common House Martin *Delichon urbicum*	3			3				
Yellow Wagtail *Motacilla flava*	28	41	48	117				
White Wagtail *Motacilla alba*	3	2		5				
Tawny Pipit *Anthus campestris*	1	3		4				
Tree Pipit *Anthus trivialis*	8	10	3	21				
Meadow Pipit *Anthus pratensis*	2			2				
Bluethroat *Luscinia svecica*			5	5				
Rufous-tailed Scrub Robin *Cercotrichas galactotes*	12	24		36				
Common Redstart *Phoenicurus phoenicurus*	24	55	7	86				
Northern Wheatear *Oenanthe oenanthe*	67	21	7	95				
Black-eared Wheatear *Oenanthe hispanica*	8			8				
Isabelline Wheatear *Oenanthe isabellina*	1		1	2				
Grasshopper Warbler *Locustella naevia*	1		1	2				
Sedge Warbler *Acrocephalus schoenobaenus*			3	3				
Western Olivaceous Warbler *Hippolais opaca*	48	74	113	235				
Melodious Warbler *Hippolais polyglotta*	4	1	2	7				
Senegal Eremomela *Eremomela pusilla*	nc	53		53				
Northern Crombec *Sylvietta brachyura*	nc	7		7				
Iberian Chiffchaff *Phylloscopus ibericus*	37	16	288	341				
Western Bonelli's Warbler *Phylloscopus bonelli*	243	141	132	516				
Orphean Warbler *Sylvia hortensis*	53	5	6	64				
Blackcap *Sylvia atricapilla*	1			1				
Common Whitethroat *Sylvia communis*	70	45	22	137				
Sardinian Warbler *Sylvia melanocephala*			1	1				
Subalpine Warbler *Sylvia cantillans*	200	95	196	491				
Spectacled Warbler *Sylvia conspicillata*	2			2				
Grey-backed Camaroptera *Camaroptera brachyura*	nc	87		87				
European Pied Flycatcher *Ficedula hypoleuca*		24		24				
African Yellow White-eye *Zosterops senegalensis*	nc	10		10				
Southern Grey Shrike *Lanius meridionalis*	18	1	1	20				
Woodchat Shrike *Lanius senator*	92	26	14	132				
TOTAL	1002	750	859	2611				

2.4. Effort to discover all birds

We walked 1033 transects at 308 sites where we spent 468 hours to count the trees on 1511 ha and the birds on 1551 ha (Table 1). The surface area where we counted trees was smaller than where we counted birds, since we noted the trees in a more narrow strip if tree density or diversity were high.

During the counts we walked slowly (1.4 km/h), covering a total distance of 412 km. Most important for us was to know whether the search intensity was similar for 2011 and 2012, such as may be derived from the time spent per ha. This time varies a lot depending on the number and the size of the trees. On average, it took 16.7 min to cover 1 ha in 2011. This was a bit more in 2012, i.e. 21.4 min/ha.

It was to be expected that we had to spend more time per ha in 2012 since average relative tree canopy was more than twice higher in 2012 than in 2011 (10.4% vs. 4.3%; Table 1: line 16). In 2011, we counted 58,000 trees and shrubs during 27 working days and 168 hours, or 2150 trees and shrubs per day and 350 per hour. In 2012, we searched for birds in 108,000 trees and shrubs during 36 working days (3000 per day) and 218 hours (500 per hour). This suggests that, compared to 2011, we worked much faster in 2012 since we did 40% more trees per day and 43% more per hour.

Another way to analyse the speed at which we worked, is to plot, separately per year, the time spent per ha against the total relative canopy cover (Table 2). For an average site with a tree coverage of 10%, we spent 27min./ha in 2011 and 18 min./ha in 2012, thus we were 50% faster in 2012 than in 2011.

Table 4. The time (minutes) spent per ha as a function of the total canopy (% relative to total surface of the site) in 2011 and 2012.

Year	Regression equation	R^2	Coverage = 10%
2011	min./ha= 1.83*canopy +8.70	0.581	27.0 min./ha
2012	min./ha= 1.25*canopy +6.02	0.577	18.1 min./ha
2011/12	min./ha=1.35*canopy+7.93	0.525	21.4 min./ha

That we progressed faster in 2012 might be due to four factors:

(1) during a quarter of the time we worked with 4 persons, not 3 (an 8% higher time investment).

(2) in 2012, we encountered, despite the much higher canopy, fewer birds (0.9 bird/ha) than in 2011 (1.5 birds/ha) (Table 1: line 18).

(3) tree species composition differed between years (Table 2). In 2012, we had relatively many small shrubs, e.g. *Combretum* shrubs (see Table 2), which hardly took time to check for birds. The relative coverage of shrubs and trees of 2 m was 0.29% in 2011, but 2.10% in 2012.

(4) Finding birds in larger trees was not difficult if the crown was open. Most Acacia trees and Faidherbia albida are rather “transparent”, but dense-leaved *Balanites aegyptiaca* and *Tamarindus indica* took more time to search adequately. In 2011, we had more time-consuming trees than in 2012 (e.g. many Balanites in 2011, only a few in 2012; see Table 2).

Taking this into account, we have no reason to assume that the searching intensity differed much between years. The data were collected by the same persons and in both years our intention was the same: detect all birds present in order to avoid dubious corrections for undetected birds. Hence, the data for both years may be lumped.

3 Results

3.1 Latitudinal trend in canopy cover and tree size

The gradual shift from bare desert and steppe in the north to the more or less closed forests in the south can be illustrated with the total relative canopy. As shown in Figure 7, the coverage is less than 5%, on average, at sites north of 15°N. For sites further south, there is a large variation in tree coverage, being low on cropland and higher where there is no agriculture (sites which stony and rocky grounds; low-lying areas). Nevertheless, there is a gradual average increase in the tree coverage to more than 10-15% south of 12°N.

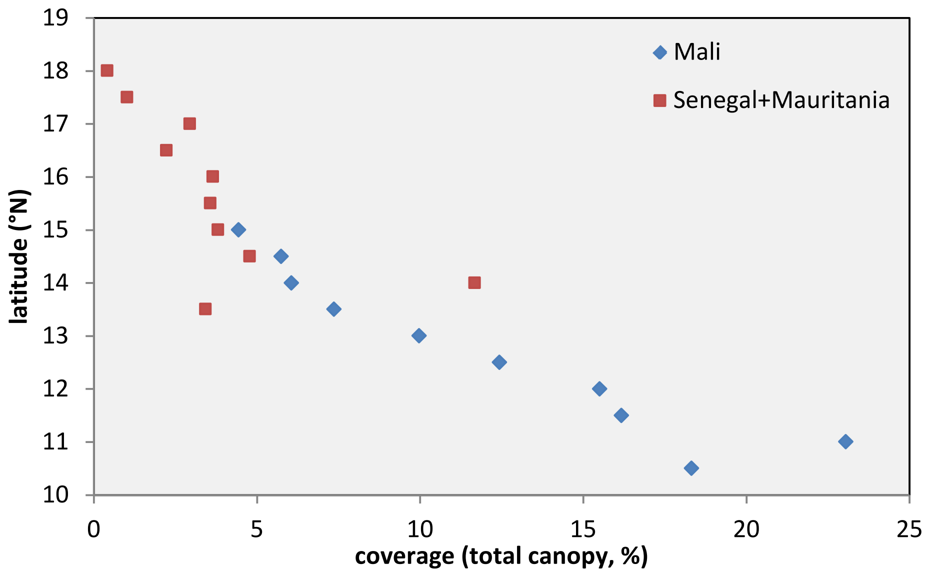


Fig. 7. The latitudinal increase of the tree coverage (summated canopy of all trees and shrubs found in a site, relative to the surface area of the site).

We would expect small shrubs and small trees in the desert and northern steppe and woodland giants only in the south. This trend was indeed visible in our data, but as Fig. 8 revealed large trees were also noted at 15-16°N.

3.2 Latitudinal distribution of tree species

Every book and paper about the landscape of the Sahel describes the large differences in vegetation depending on latitude or rainfall. Arbonnier (2002) splits up West Africa in different zones (Fig. 1) and describes for 360 tree and shrub species in which zone they can be found. The 20 *Acacia* species, for instance, may be arranged regarding their distribution from north to south and from dry to wet, with *A. ehrenbergiana* and *A. laeta* in the Sahara to *A. mellifera* in the Sudan zone. Some species have a wide range and occur in different zones, while others are limited to a single zone. The latitudinal shift depends on rainfall, but rainfall does not only differ per latitude, but also per longitude. For instance, the 500 mm isoline is found at 15°N in Senegal but 50 km further south, at 16°N, in eastern Mali (Fig. 3). Hence, we may expect that also the latitudinal distribution of trees, and thus woodland species, would differ for the western and central Sahel. This difference should disappear when distribution is plotted against average rainfall.

The literature gives few quantitative data on the distribution of tree species in West Africa. Our small data set may be used to describe the zoning. Fig. 8 shows the relative canopy cover for all trees and shrubs combined and, as an example, for two species, *Acacia tortilis* and *Faidherbia albida*. *A. tortilis* is found where the rainfall in Senegal and Mauritania varies between 200 and 400 mm. For Mali, we have hardly any plots with a similar rainfall, but we

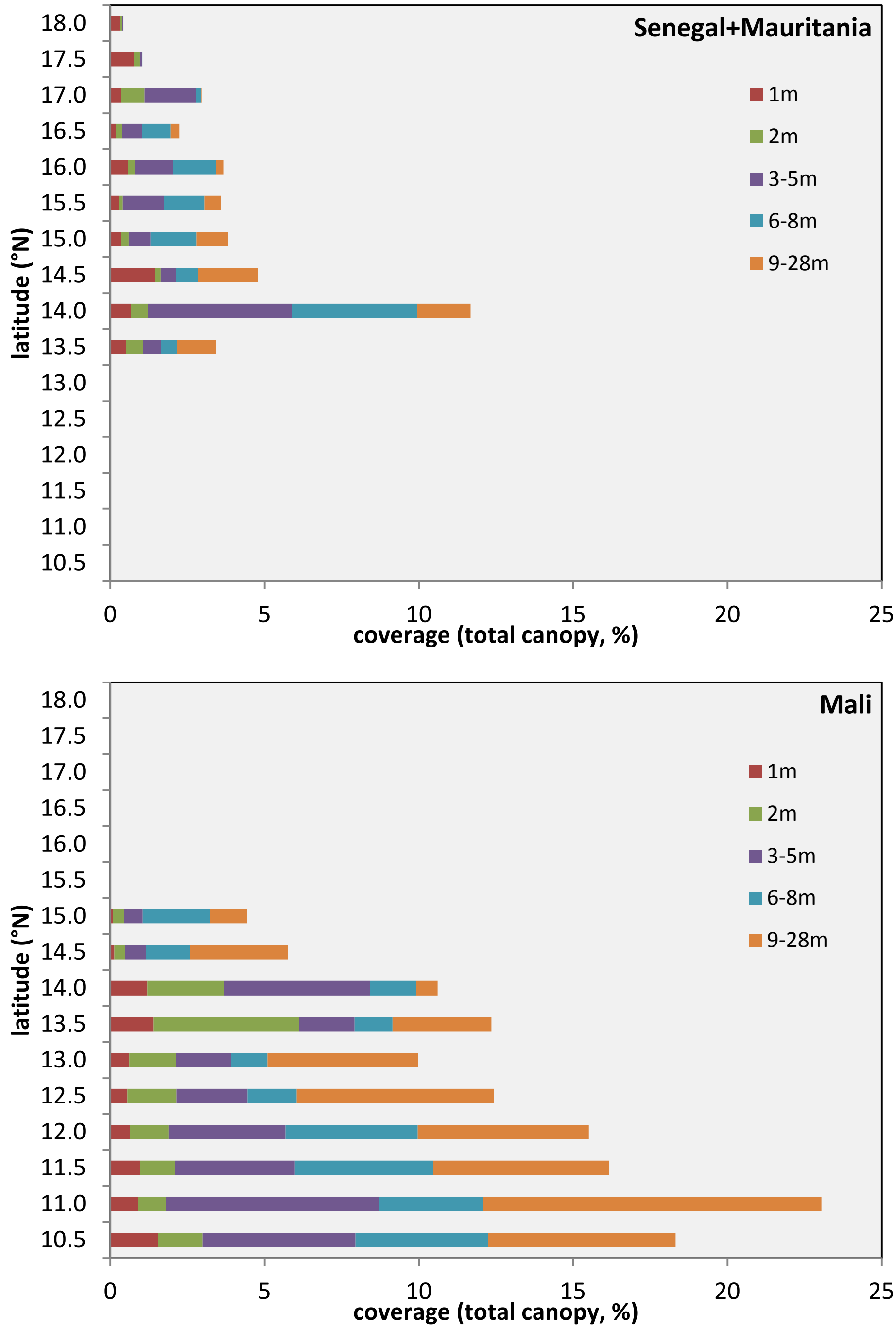
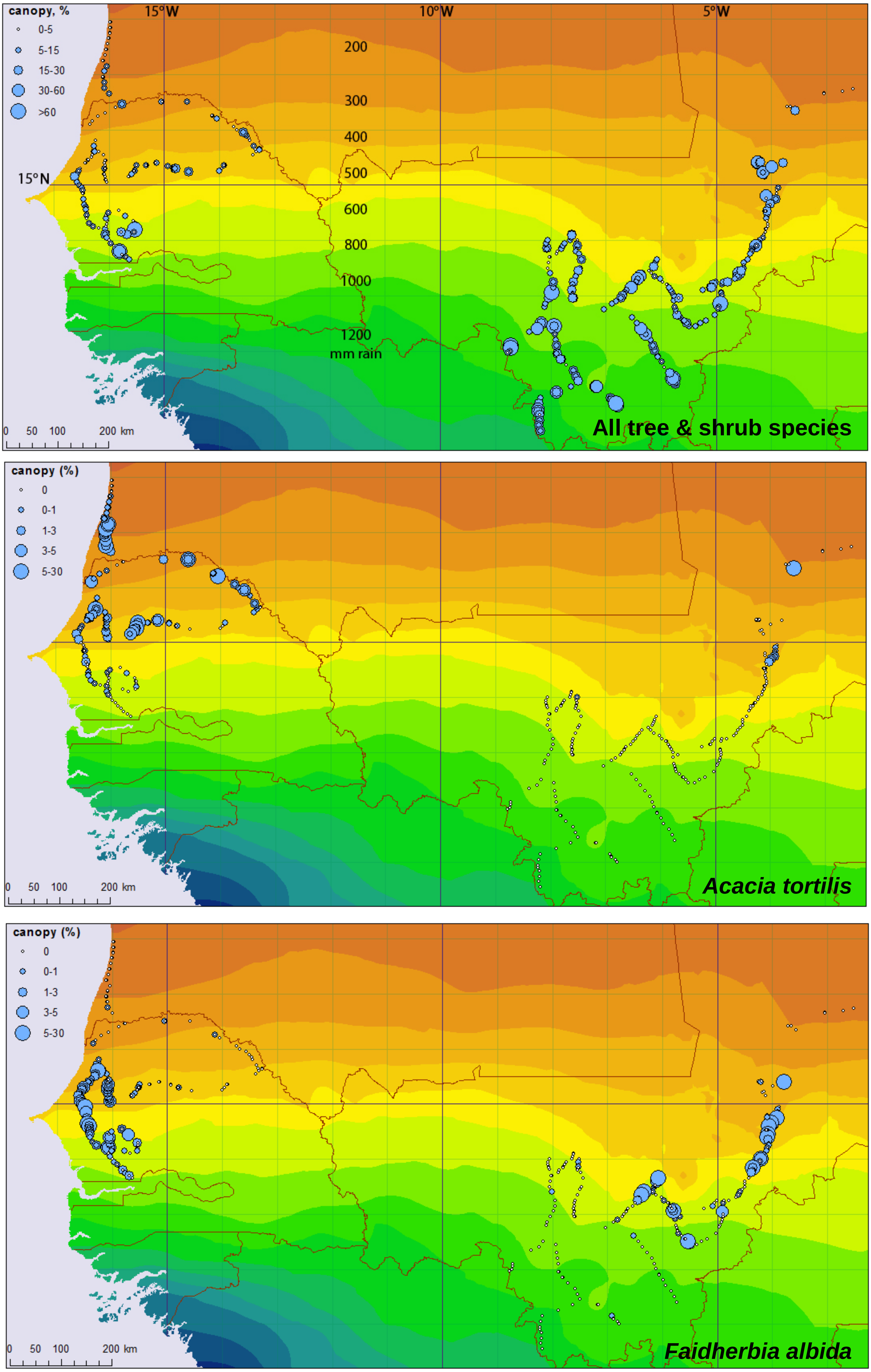


Fig. 8. The latitudinal increase of the relative coverage, as Fig. 6, but here split up per five height classes and given separately for Senegal + Mauritania (top) and Mali (bottom). A selection has been made for the random sites.

know from our earlier field work around the Inner Niger Delta that this tree species is found in exactly the same rainfall zone.

Faidherbia albida is limited to the zone where annual rainfall amounts to 300-800 mm, but it is most common in the 400-600 mm zone, in Senegal as well as in Mali. *F. albida* belongs to the northern agroforestry zone, being replaced further south by karité (*Vitellaria paradoxa*) and néré (*Parkia biglobosa*) (Fig. 10). Fig. 10 shows the latitudinal trends for the 14 species ranking highest regarding the average relative woody cover. The contribution of all other tree species combined increases from 14°N further southward.

Fig. 9 (page 15) The relative canopy cover (%) of all trees and shrubs combined (top), *Acacia tortilis* (middle) and *Faidherbia albida* (bottom) on the 1030 sites.


canopy, %
0-5
5-15
15-30
30-60
>60
15°W
10°W
5°W
15°N
200
300
400
500
600
800
1000
1200
mm rain
0 50 100 200 km
All tree & shrub species
canopy (%)
0
0-1
1-3
3-5
5-30
0 50 100 200 km
Acacia tortilis
canopy (%)
0
0-1
1-3
3-5
5-30
0 50 100 200 km
Faidherbia albida

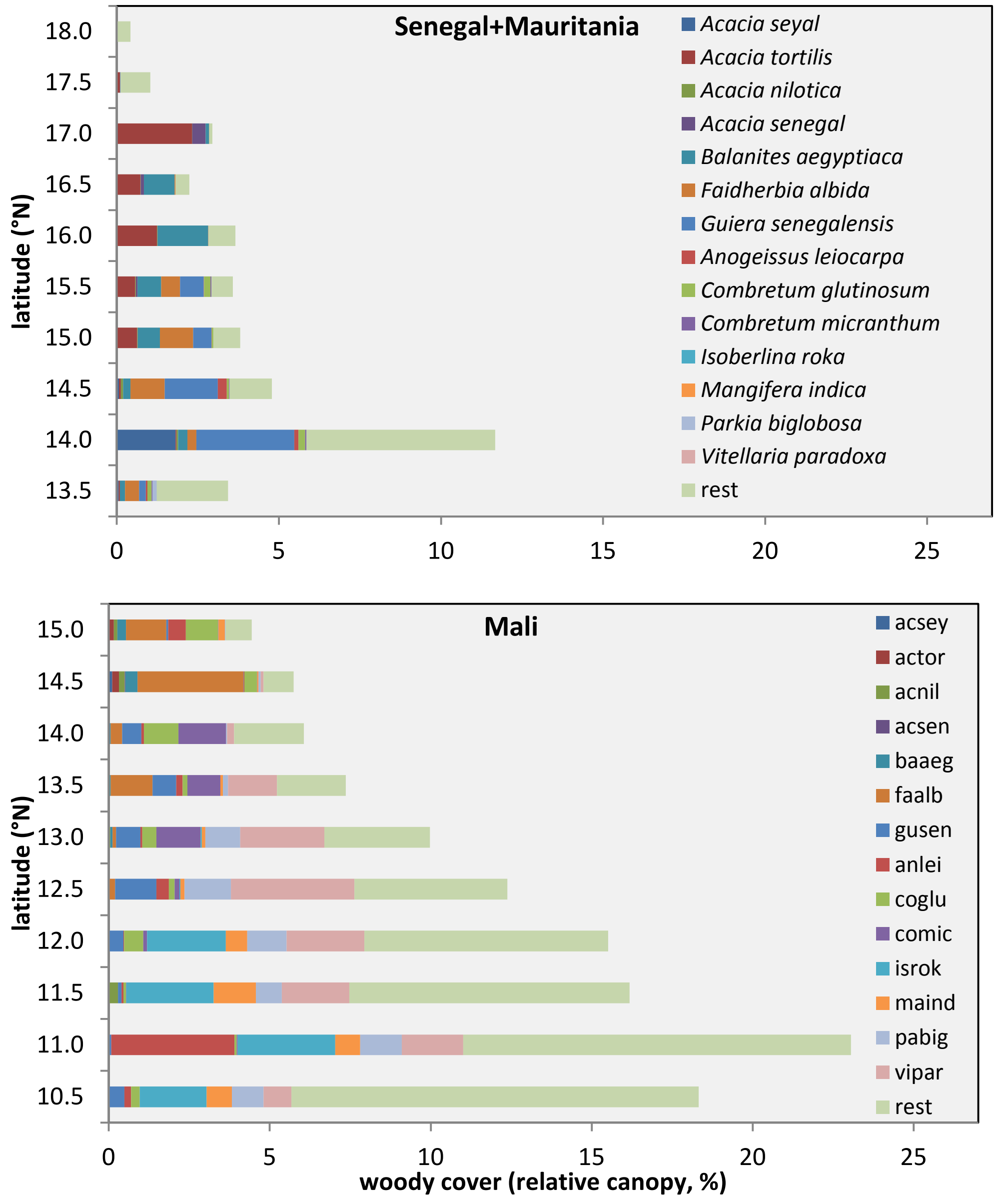


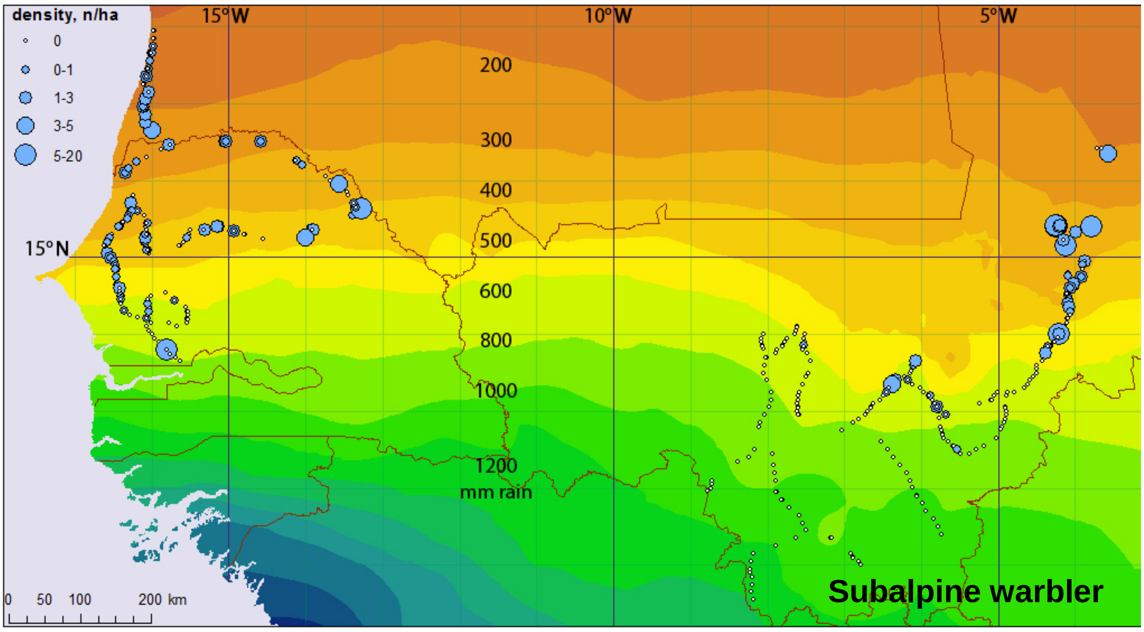
Fig. 10. The latitudinal distribution of 14 tree species; the 150 other species have been lumped as "rest". Full names are given in the upper panel, the five letter-code (used by us) in the Mali panel. The selection of the 14 tree species is based upon their contribution to the average relative canopy cover, such as calculated for the 1033 transects. The 14 species ranking highest are shown.

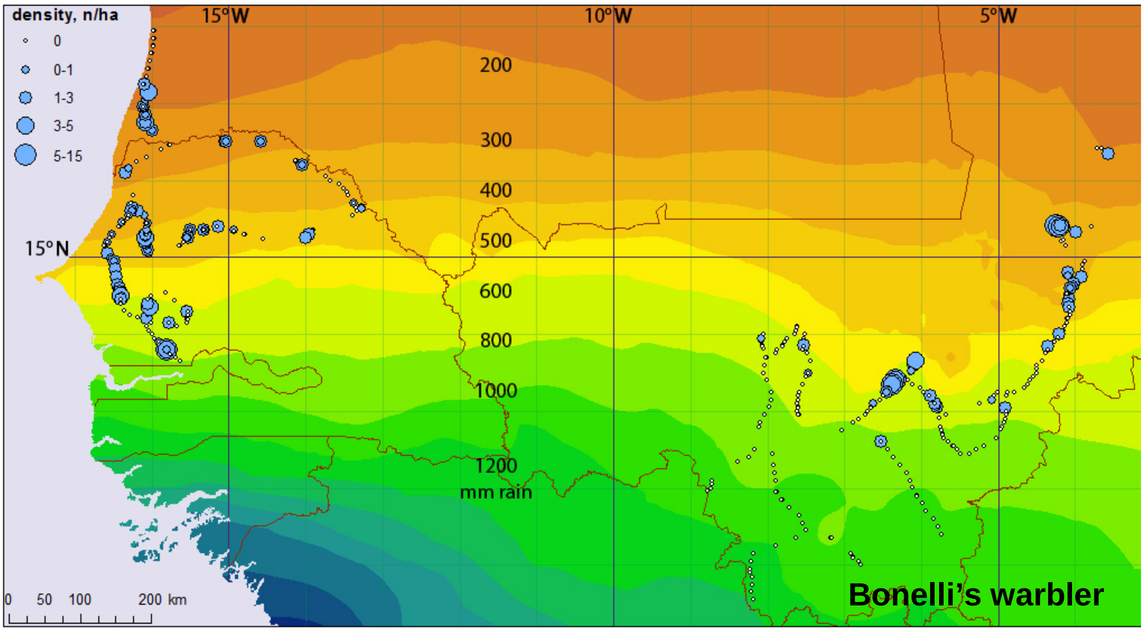
3.3 Latitudinal distribution of bird species

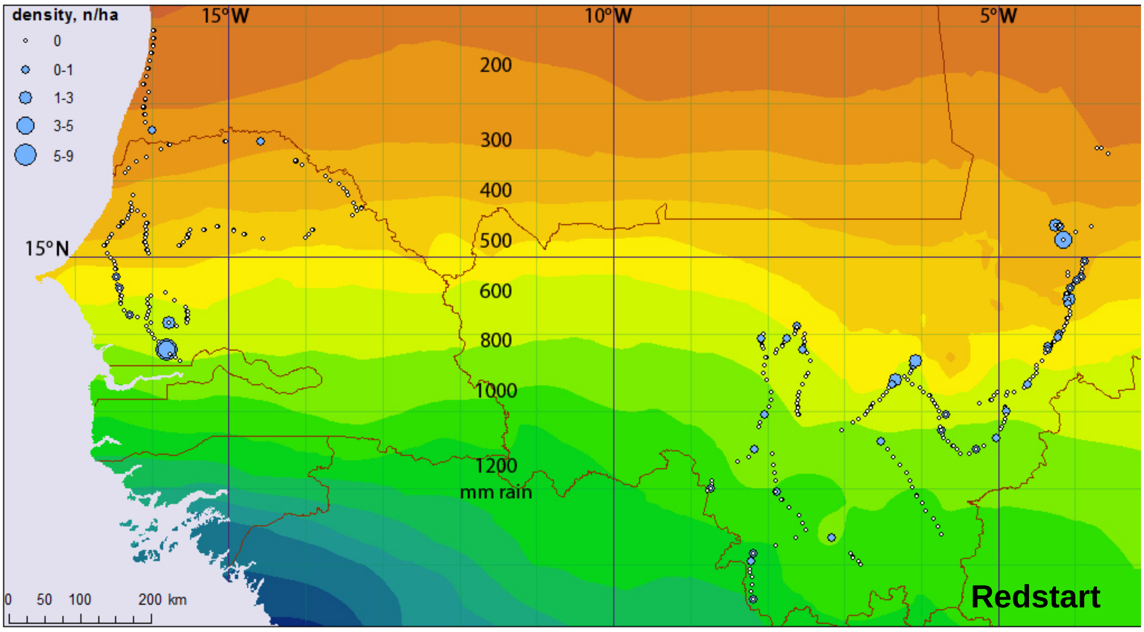
The density of three bird species was plotted in the same way as the relative tree canopy cover (Fig. 9). Subalpine Warblers are found further north than Bonelli's Warblers, while Redstarts are found at a much lower density over a wide range between 10 and 17°N (Fig. 11). Fig. 12 shows, separately for Senegal+Mauritania and Mali, the average bird density per latitude. The same data are combined in Fig. 13. Fig. 14 gives the average density as a function of the average annual rainfall.

Figs. 12-14 clearly show that most bird species are segregated and occupy various ranges. The Orphean Warbler was rather common at 17°N and at 200 mm rainfall, but was rare elsewhere. In contrast, the Redstart was found over a much wider range (see also Fig. 11), while the Pied Flycatcher has only been observed in the most southern plots (10-11°N and more than 1000 mm rainfall).

Fig. 11. (page 17) The density of three bird species in the 1030 transects.


density, n/ha
0
0-1
1-3
3-5
5-20
15°W
10°W
5°W
15°N
200
300
400
500
600
800
1000
1200
mm rain
0 50 100 200 km
Subalpine warbler


density, n/ha
0
0-1
1-3
3-5
5-15
15°W
10°W
5°W
15°N
200
300
400
500
600
800
1000
1200
mm rain
0 50 100 200 km
Bonelli's warbler


density, n/ha
0
0-1
1-3
3-5
5-9
15°W
10°W
5°W
15°N
200
300
400
500
600
800
1000
1200
mm rain
0 50 100 200 km
Redstart

It is not surprising that the bird density was rather low in the southern Sahara (18°N), but it was, in any case for us, a big surprise that bird density was also low in the southern Sahel (12-13°N; 700-1300 mm). Nearly all woodland species reached their highest density in the northern Sahel (14-17°; rainfall: 200-600 mm). A clear exception is the Pied Flycatcher, being only recorded in the southern Soudan plots.

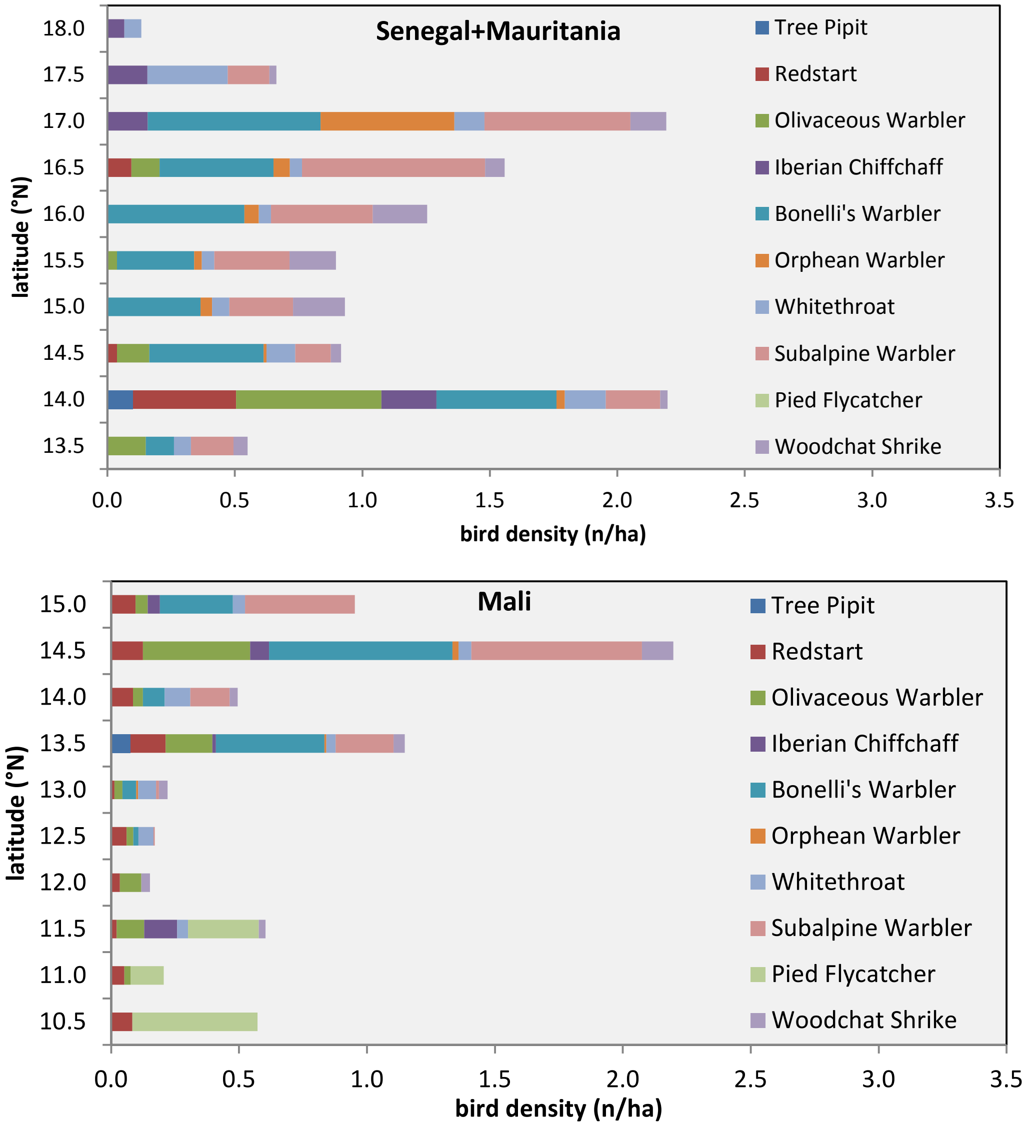


Fig. 12. The average density per latitude in Senegal + Mauritania (top) and Mali (bottom). A selection is made for the ten most common woodland bird species.

Wooded savanna north of Bamako in mid January.

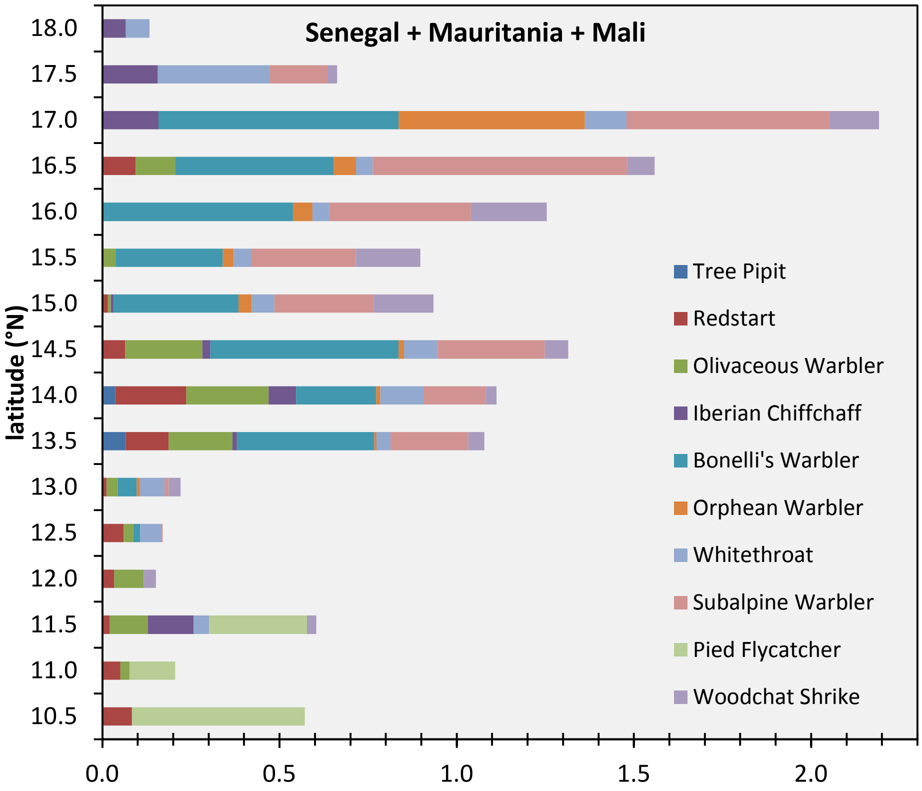


Fig. 13. The average density per latitude combined for the three countries; same data as Fig. 12.

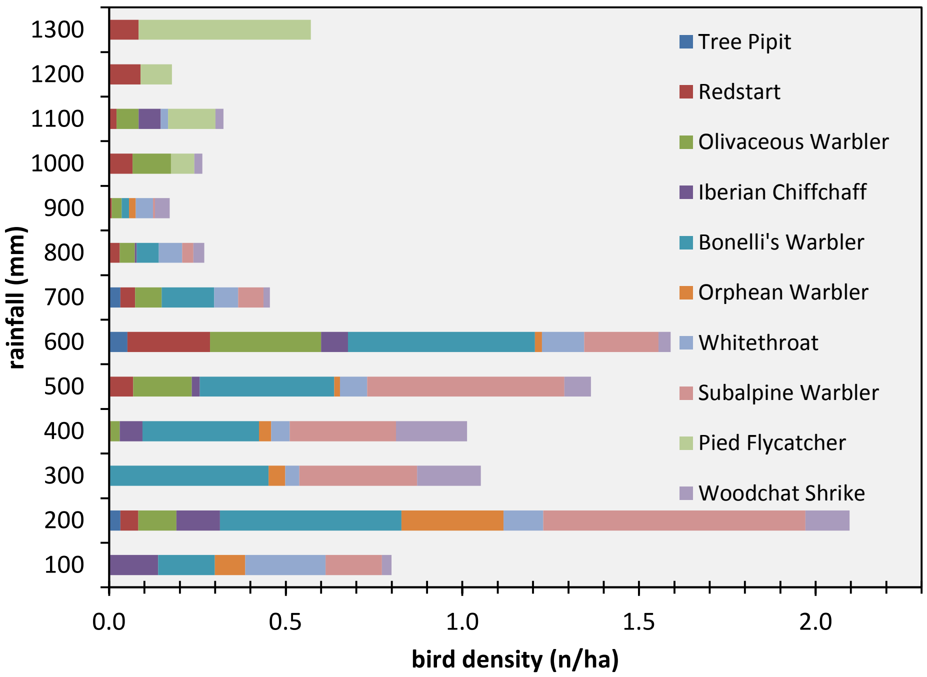


Fig. 14. The average density per rainfall zone; same data as Fig. 13.

3.4 Bird density in trees of different size

The larger the tree, the larger the probability to encounter a woodland bird. Fig. 15 shows, for seven common tree species, the relationship between bird number per 100 trees as a function of tree height. The graphs look similar when the numbers are plotted against tree width. A further analysis showed that, on average, more birds were seen in trees with a same height but a larger crown diameter or the other way around (more birds in wide trees with similar height). This suggests that bird numbers are related to canopy volume.

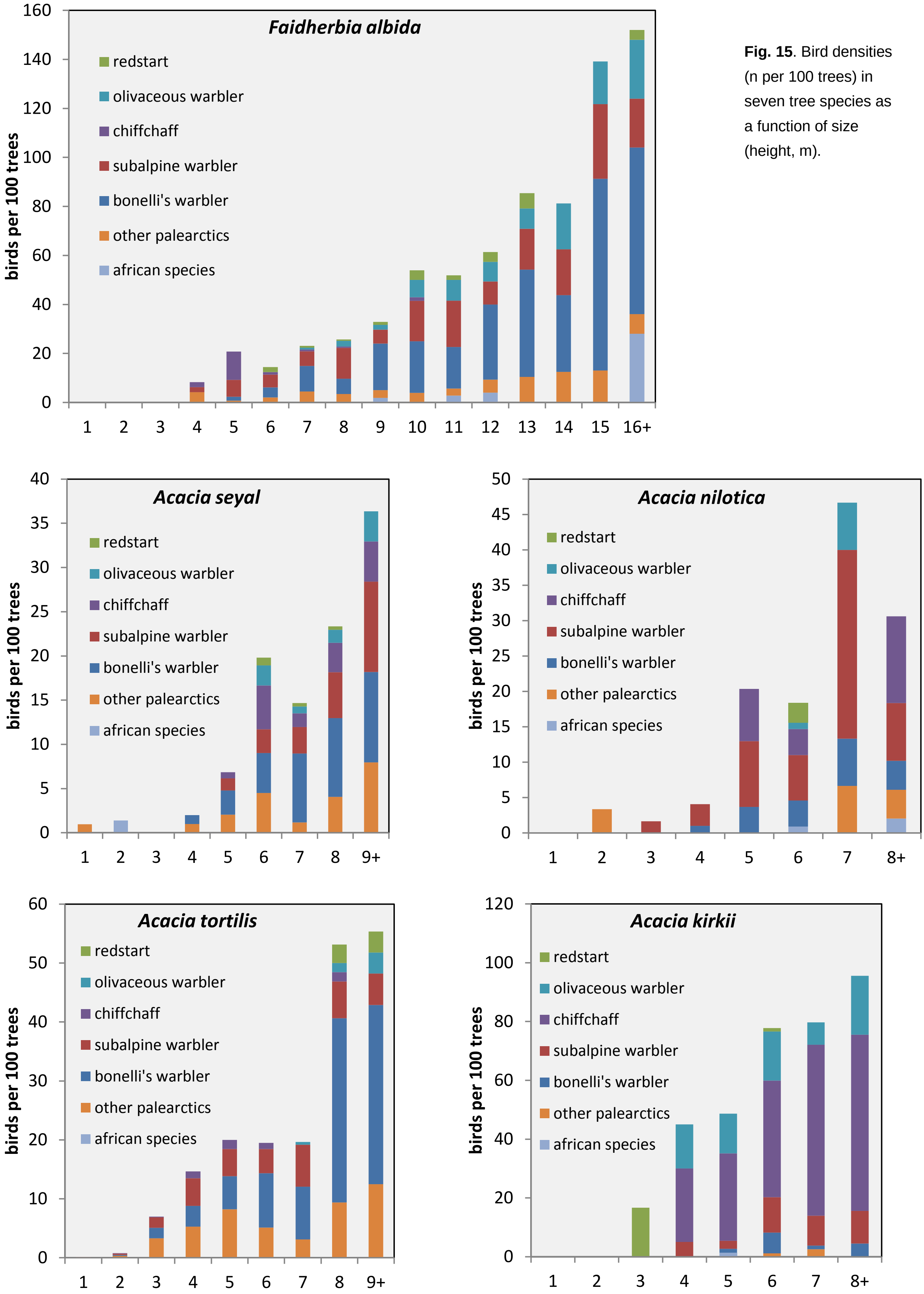
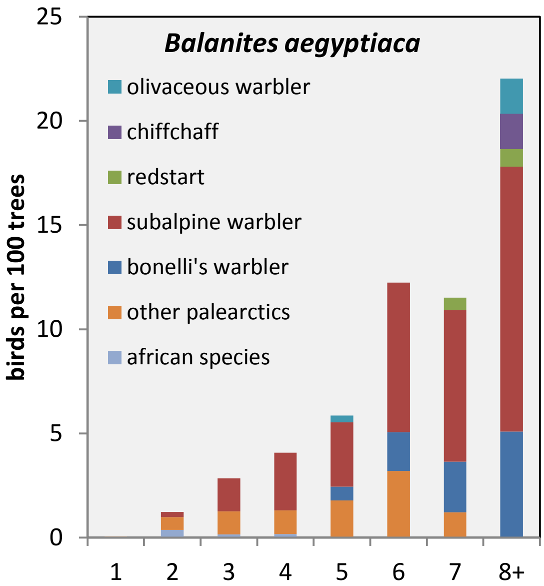
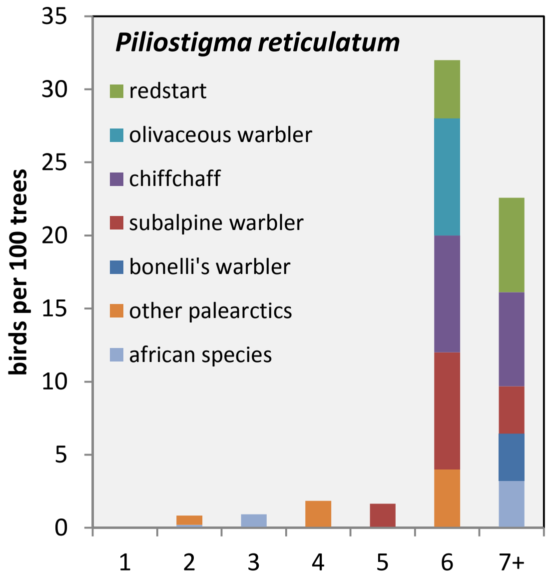


Fig. 15. Bird densities (n per 100 trees) in seven tree species as a function of size (height, m).





Trees have rarely the shape of a cylinder, but more often look like a cone, although usually not from ground level onwards. That makes it rather complex to calculate the canopy volume. Moreover, the shape of the cone differs per tree species. Hence we did so far no attempt to relate bird numbers to canopy volume.

Fig. 15 clearly shows that the preference for large trees differs per species. For instance, most Bonelli's Warblers were seen in large trees, but Chiffchaffs and Redstarts were also observed in smaller trees. The preference where to feed within a tree was measured by noting the height at which the bird was observed (averaged, if observed for a longer time). This position may be expressed in two ways: (1) absolute height (m) relative to ground level and (2) relative height as a function of tree height (%). Fig. 16 plots both measurements against each other. Both appear to be highly correlated. Bonelli's Warblers feed in the higher parts and prefer large trees, while Redstarts are found in the lower tree section (which was to be expected since they often feed on the ground). The only exception is the Woodchat Shrike which prefers to select a high position in a tree, independent of tree size.

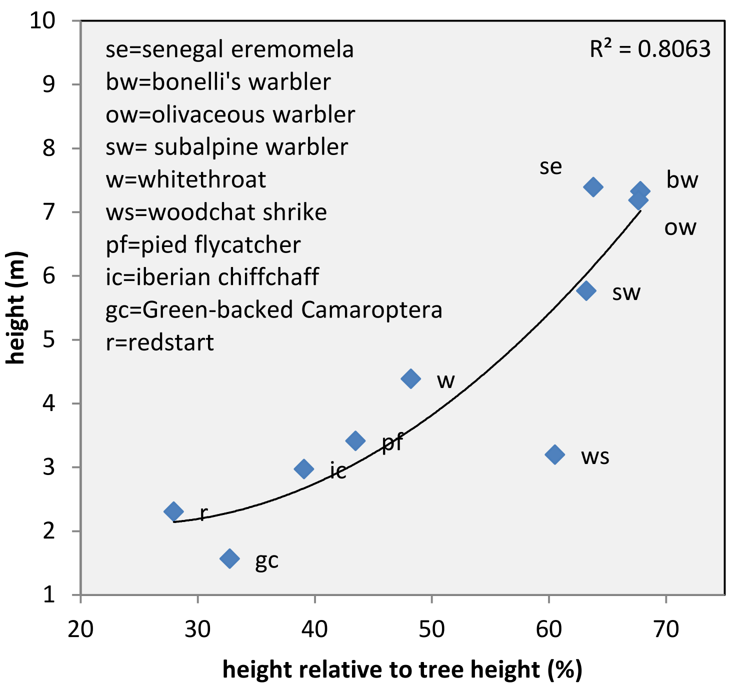


Fig. 16. Position within the canopy of a tree where ten bird species tend to feed. The average height (m above the ground) is plotted against the average position of the bird relative to the height of the tree (%). All data were collected in Mali in 2012, in random and non-random sites.

The absolute and relative height was measured 561 times, in total. Most data are available for Bonelli's Warbler (n=128) and fewest for Pied Flycatcher (n=11). Species with fewer measurements were omitted.

3.5 Bird density per tree species

Nearly all birds were seen in 10 to 15 tree species (Fig. 17). When we use the former name of *Faidherbia albida (Acacia albida)*, the seven tree species with the highest bird densities were all Acacias. Most birds were seen in *Acacia kirkii*, where Iberian Chiffchaff reached an extremely high density. Relatively high densities were reached in tree species usually found on floodplains and low-lying grounds *(Piliostigma, Ziziphus, Mitragyna)*.

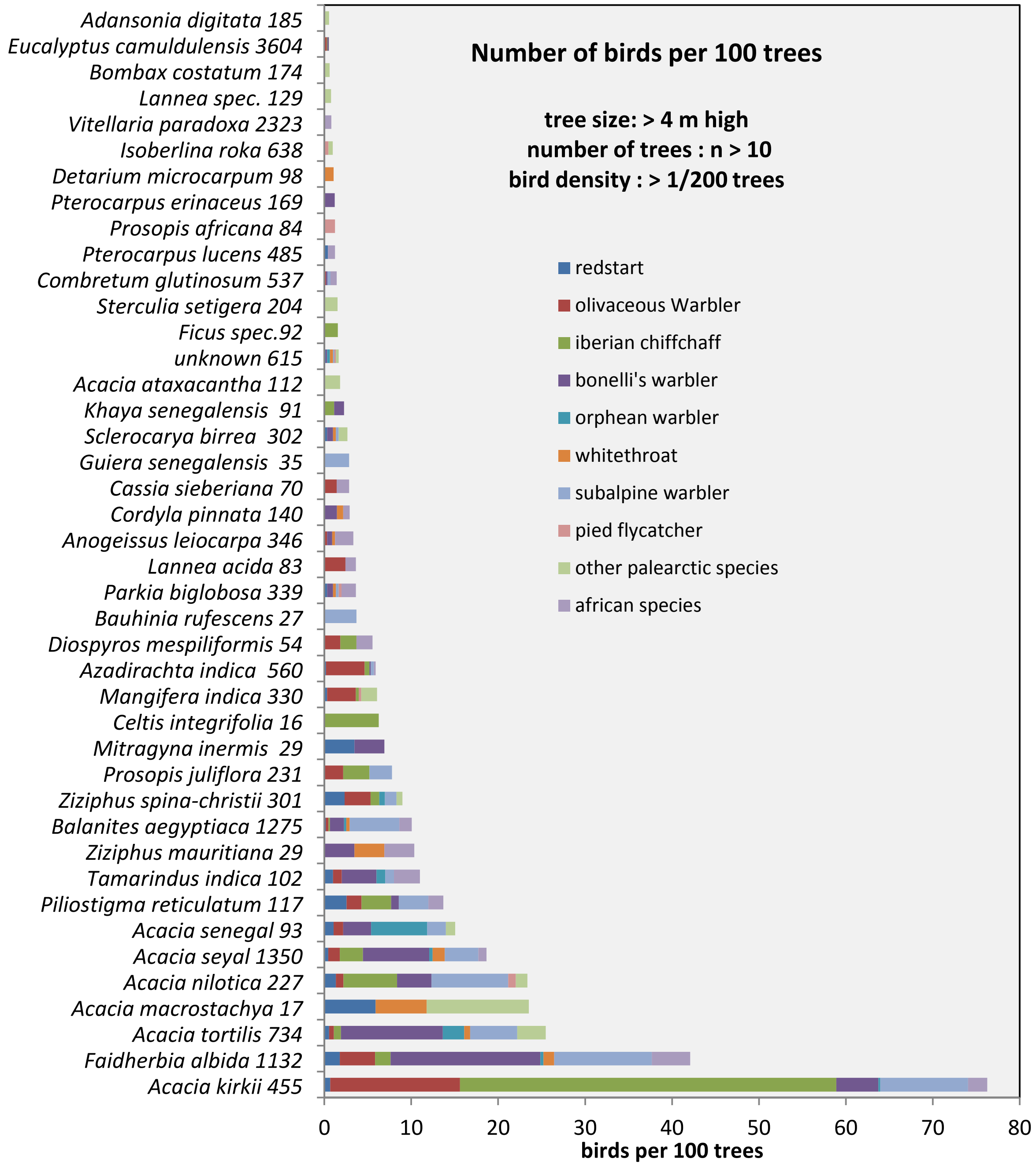


Fig. 17. The bird density (n per 100 trees) in 41 tree species being ranked according to the bird density. *Lannea* and *Ficus* have been lumped, as well as all unidentified tree species ("unknown"). Three selection criteria were applied: (1) only trees of 5 m and larger, (2) only species of which we observed more than 10 trees larger than 4 m, and (3) only tree species with at least one bird per 200 trees. The number after the name indicates the number of investigated trees, after these selections were made. The density of African bird species is too low since the species concerned (see Table 3) were counted only in 2012. Assuming that the density of the African bird species per tree species in 2011 was similar to that in 2012, its density must be 40% higher than indicated in the graph.

3.6. Variation in bird density per tree species

To understand why the bird density varies so much among tree species (Fig. 17), it would be necessary to study food selection of the different bird species and quantify the food supply available in the different trees (as done by Stoate & Moreby 1995, Stoate 1997, Vickery *et al.* 1999, Stoate *et al*. 2001). We did not collect these data, but we recorded other variables related to food supply. We counted, for instance, the number of flowers in Acacia trees or – if too many – made a classification. We did the same for fruit and foliage. In tree species found in or near water, we noted the distance to the water line and whether the ground beneath the tree was dry, wet or covered by water. This chapter gives some examples showing the significance of these variables.

Berries are no part of the food supply for woodland birds in the Sahel in the period January-February. One of the few exceptions is *Salvadora persica*, a very northern shrub species we encountered only between 16.5 and 17.5°N (and also a bit further south in Mali). It is not common (anymore), but its fruit attracts many birds (Fig. 18; see also Stoate & Moreby 1995).

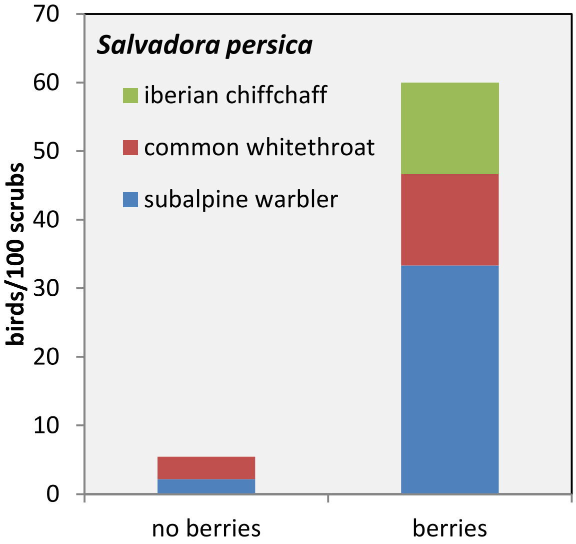


Fig. 18. Bird density (n/100 shrubs) in *Salvadora persica* without berries (n=5) or with at least 1 berry (n=60). We saw that Common Whitethroats and Subalpine Warblers were feeding on the berries, but it has not been noted in Chiffchaff. Nearly all observations were from southern Mauritania and northern Senegal (24-28 January 2011).

Iberian Chiffchaff reached a high density in *Acacia kirkii* (Fig. 17), a tree species typical for seasonally flooded areas. Within the flooded forest, Chiffchaffs prefer trees still standing in water, where they reach an extremely high density of 2 birds/tree, on average (Fig. 19). The same was found in a flooded *Acacia nilotica* forest in Senegal near Matam. This preference was not apparent in other woodland species. Within flooded forests, Bonelli's Warblers eached their highest densities in the dry part of the forest. Iberian Chiffchaffs often feed on the ground or floating water plants. In Bamako, we saw several Iberian Chiffchaffs making feeding trips from high trees to Water Hyacinth in a nearby creek.

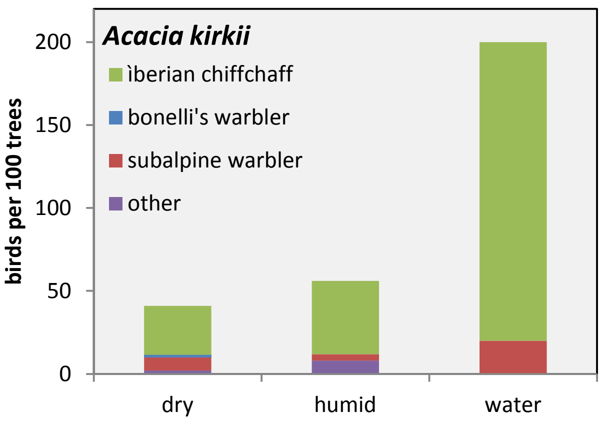


Fig. 19. Bird density (n/100 trees) in *Acacia kirkii* (mostly trees of 5-10 m high) standing on dry ground (n=78), humid ground (n=14) and in shallow water (n=10). All data were collected in the flooded forest of Akkagoun (Inner Niger Delta) on19-2-2012**.**

Flowering trees may attract many insects and also birds, as shown here for *Acacia seyal* (Fig. 20) and *Faidherbia albida* (Fig. 21). The data were collected in February, at the start of the flowering season of *A. seyal*, but after the flowering time of *F. albida* (hence the low numbers of flowers in the latter species).

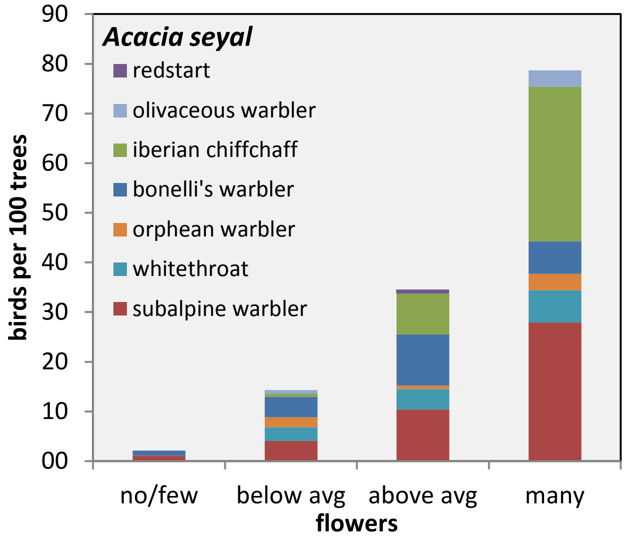


Fig. 20. Bird density (n/100 trees) in *Acacia seyal* (trees of 5-9 m; 6.3 m, on average) with no/ few flowers (n=93), number of flowers below average (n=147), above average (n=145) and with many flowers (n=61). All data from *A. seyal* forests on uncovered floodplains NE and NW of Akka (Inner Niger Delta) on 18 and 20 February 2012.

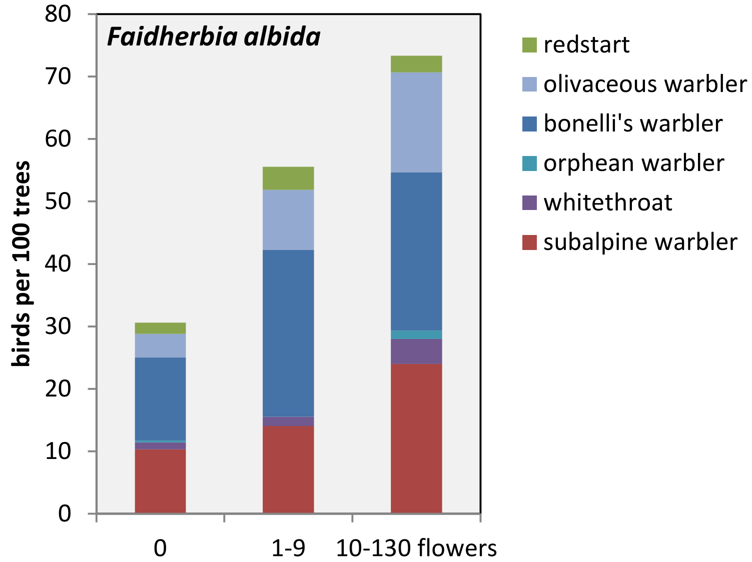


Fig. 21. Bird density (n/100 trees) in *Faidherbia albida* (trees of 5 to 21 m; 10.6 m, on average) with no flowers (n=96), 1-9 flowers (n=72) or 10 flowers or more (n=43). All data were collected in eastern Mali between 25-1-2012 and 10-2-2012.

Beside flowers, also the foliage is a factor determining the density of woodland birds. In the *Acacia seyal* flood forest where we collected our data, some trees were leafless or had few leaves (apparently dying); some 40% of the trees was in a poor condition. In *Faidherbia albida*, not many leaves are left after pruning by the local populace. In both tree species bird numbers increased when more leaves were available (Fig. 22 and 23).

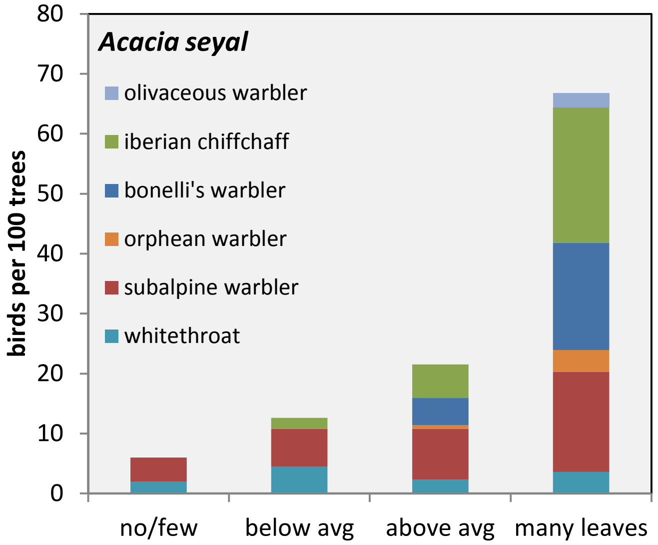


Fig. 22. Bird density (n/100 trees) in *Acacia seyal* (trees of 5-9 m; 6.3 m on average) with no/few leaves (n=62), foliage below average (n=113), above average (n=178) and a dense foliage (n=59). All data were collected in the dry floodplains NE and NW of Akka (Inner Niger Delta) on18 and 20 February 2012.

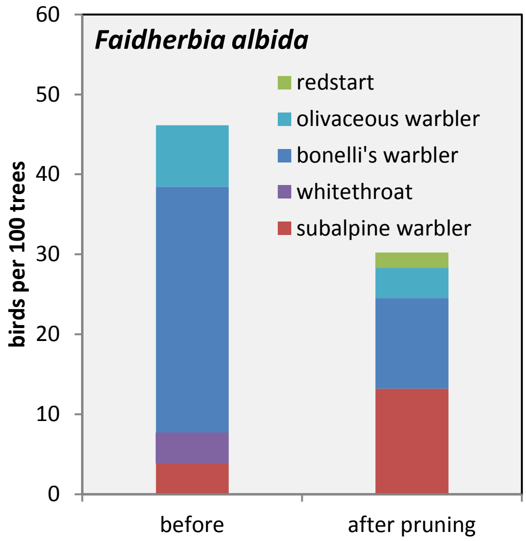


Fig. 23. Bird density (n/100 trees) in *Faidherbia albida* (trees of 5 to 21 m; 10.6 m, on average) before (n=26) and after pruning (n=53). All data were collected in eastern Mali between 2 and 10 February 2012.

4 Discussion

4.1 Population size

The data were not collected with the intention to provide an estimate of the numbers of birds wintering in the Sahel, but since bird density was measured in plots selected in a stratified, random way, a total estimate can easily be made using the average density per 0.5 degree of latitude (Fig. 13). The extrapolation refers to the area indicated in Fig. 24, measuring 885 x 2100 km and 1.89 million km^2 (of which 1.77 million km^2 land) The Sahel as a whole is nearly three times as large, stretching 5500 km from the Atlantic Ocean to the Red Sea. The estimated total number for the western Sahel is compared to the estimated population size in Europe (Table 5).

The total bird numbers present in the western Sahel may also be estimated using the average density per rainfall zone. This estimate is better than those based on the latitude, since the distribution of trees is primarily related to rainfall and not latitude. However, the plots refer to the rainfall zones <100 mm to 1200-1300 mm/year, but within the large area indicated in Fig. 24, the rainfall may reach 3000 mm/year. Hence we had to assume that the bird density measured at 1300-3000 mm was similar to the density measured at 1200-1300 mm.

An alternative is to estimate the total numbers present in the Sahel from the calculated average bird density per habitat type. As shown in Fig. 4, there is relatively much cropland in western Senegal and eastern Mali (where we had nearly all sampling sites), but not in the area between. Thus we had “too many” plots of cropland. Hence the extrapolation based on habitat types corrects for this bias. The extrapolation is too low, however, for the species found in the southern Sahara. Since we had hardly any plots in the sandy desert we assumed that the bird density was zero, which is close to the truth, but given its huge surface area (143,000 km^2) bird species found in the northern *Acacia tortilis* are seriously underestimated.

The three estimates of the total numbers present in the western Sahel deviate from each other, on average 12%. The estimates may be improved in different ways. For instance, the tree density may be calculated per rainfall zone or habitat type, after which the numbers of trees of the different species and size classes may be multiplied with the average bird density per tree species and size class.

For Palearctic species wintering in the entire Sahel, we would expect that 25-40% of the European populations would be found in the western Sahel - the area for which an extrapolation was made – and the rest further east. That is true in Redstart and Wheatear, but our estimates are (much) smaller in Pied Flycatcher and Tree Pipit (of which many birds winter further south), and also in Yellow Wagtail (of which millions are concentrated in the large floodplains in West Africa). For some species, we arrive at remarkably high wintering numbers in the western Sahel, far exceeding the estimate for entire Europe. There are several explanations for that:

(1) Our estimate includes birds breeding in NW Africa; this may explain the high number of Iberian Chiffchaff and Woodchat Shrike.

(2) Wheatears from northern America and Greenland winter in West Africa (Thorup *et al*. 2006, F. Bairlein pers. comm.). Presumably, in several species many birds from Asian breeding grounds spend the winter in West Africa.

(3) Chiffchaffs were still silent during our field work, but the few singing birds we heard were exclusively Iberian Chiffchaffs. We therefore assume that all Chiffchaffs were Iberian, but in fact, an unknown number may have been Common Chiffchaffs.

Table 5. Estimated total (in millions) of common Palearctic bird species spending the northern winter in the western Sahel, compared to their estimated population sizes in Europe (minimal and maximal, such as given by BirdLife International 2004); the number of breeding pairs has been multiplied by 3 to arrive at a total winter population. The estimates for the western Sahel refer to the area between 10.25 and 18.25°N and between 2°E and the Atlantic ocean, a total land surface of 1.77 km^2. The three estimates for the western Sahel are based on the average bird density per 0.5 degree of latitude (Fig. 13), the average density per rainfall zone (Fig. 14) and the average density per habitat type (see Fig. 4 for the map).

Woodland bird species	W.Sahel latitude	W. Sahel rain	W. Sahel habitat	W. Sahel average	Europe minimum	Europe maximum
Tree Pipit	1.1	1.9	0.8	1.3	81.0	126.0
Common Redstart	8.3	9.7	8.9	9.0	20.4	48.0
Western Olivaceous Warbler	11.8	13.6	10.5	12.0	9.9	20.1
Iberian Chiffchaff	6.9	6.5	6.1	6.5	1.1	1.6
Western Bonelli's Warbler	39.6	45.3	32.1	39.0	4.2	10.5
Orphean Warbler	8.4	10.2	7.8	8.8	0.5	1.4
Common Whitethroat	12.5	9.7	10.9	11.0	42.0	75.0
Subalpine Warbler	34.8	45.7	31.0	37.2	4.2	9.6
European Pied Flycatcher	9.2	12.4	9.2	10.3	36.0	60.0
Woodchat Shrike	11.7	14.1	9.1	11.6	1.4	3.6
Other bird species						
Northern Wheatear	11.7	10.1	10.5	10.8	13.8	39.0
Yellow Wagtail	6.7	9.6	4.5	6.9	23.7	42.0

(4) Not all Olivaceous Warblers seen belong to the Western species. Most were not identified as to species, but of the 11 birds closely observed in Mali, 10 were identified as Western and 1 as Eastern. Jan van der Kamp & Jan Visser (unpublished) also captured both species in the Inner Niger Delta, as did Salewski (2008) in N Senegal and Salewski & Herremans (2006) in central Mauritania during migration. Hence, a still unknown part of the estimated 10.5 – 13.6 million Western Olivaceous Warblers, must have been Eastern Olivaceous Warblers.

(5) We found no reason to assume that the estimate for common, widely distributed species, as Bonelli's Warbler and Subalpine Warbler, would be wrong. The estimates of wintering numbers in West Africa have, however, a variable reliability. For instance, density estimates for most northern latitudes are based on few plots in SW Mauritania. Consequently, the estimate for Orphean Warbler (only found in the north) is less reliable than for species wintering further south.

(6) Our estimate for the bird numbers in the western Sahel is not more than preliminary, but it should be noted that the estimates for the European breeding populations are also not much more than an educated guess, certainly for eastern Europe. Hence estimated population sizes of species breeding in S and SE Europe may be (much) too low.

We have no reason to assume that our estimates are, on average, too high. On the contrary, for two reasons the extrapolated numbers for the western Sahel are assumed to be too low.

(1) Our density estimates are based on *observed* birds. We did no attempt to correct for missed birds. Hence, the bird numbers tend to be underestimated, although we strived to minimise this potential error as much as possible.

(2) The extrapolation for the western Sahel refers to a large square of 1.77 million km^2. The Inner Niger Delta and surrounding forests, covering about 6% of this huge area, are situated within this large square. The implicit assumption in our extrapolation is that bird densities within the Inner Niger Delta did not differ from those elsewhere within the same latitudinal or

rainfall zones. This assumption is certainly wrong. For example, we counted woodland birds in 39 transects within the Inner Niger Delta (data not used in the calculation since the plots were not chosen at random). These non-random plots clearly show that the flooded forests (*Acacia kirkii* and *Acacia seyal* on the lower and higher floodplains, respectively) are extremely rich in birds (Fig. 17), with 33.7 birds/ha, on average, against 0.9 birds/ha averaged for the random sites in Mali (Table 1). We do not yet know the total surface of the flooded forests, but it is for sure that millions of woodland birds, mainly Subalpine and Bonelli's Warblers, are concentrated in the Inner Niger Delta. These numbers have to be added to the totals given in Table 5 for the western Sahel.

4.2 Why are woodland species in decline?

The most important finding of this study is that nearly all birds in the western Sahel are concentrated in Acacia trees and that many other, also very common, tree species are poor or even very poor in birds, at least in January-February. Is the decline of the bird species wintering in Sahelian woodlands due to a decline of Acacia trees? We have started an extensive survey of the literature to investigate this possibility.

The decline of the flooded forests along the Senegal River, notably *Acacia nilotica*, has been quantified in detail (Tappan *et al.* 2004). Most of the flooded *Acacia kirkii* forests in the Inner Niger Delta have been removed by the local people in the 1970s and 1980s. At the same time, the extensive *Acacia seyal* forests surrounding the floodplains of the Inner Niger Delta have died off on many places during the Great Drought (1972-1992). The loss of these hotspots must have had a large impact on the bird species present in the Sahel, but the impact of the loss of flooded forests cannot fully explain the decline of bird populations by so many millions. Most likely, the changes in the Sahelian drylands have had a larger impact on the woodland bird species.

The Sahelian landscape has been shaped by local people. At present, parkland covers a large part of the Sahel between 14 and 16°N, a zone more than 200 km wide where annual rainfall varies between 400 and 800 mm. Within this wide zone, nearly all trees have been removed by the people, except the few of economic interest: *Faidherbia albida* in the north, *Parkia biglobosa* in the south and an in-between zone dominated by a monoculture of *Vitellaria paradoxa*. We recorded very few birds in *V. paradoxa* and *P. biglobosa*, but *F. albida* was very rich in birds. Given the wide distribution of *F. albida*, we may conclude that a large part of woodland bird species wintering in the Sahel are concentrated in this type of agroforestry. This means that most woodland bird species are concentrated on farmer's land. Our survey of the literature must reveal whether *F. albida* has declined the last decades.

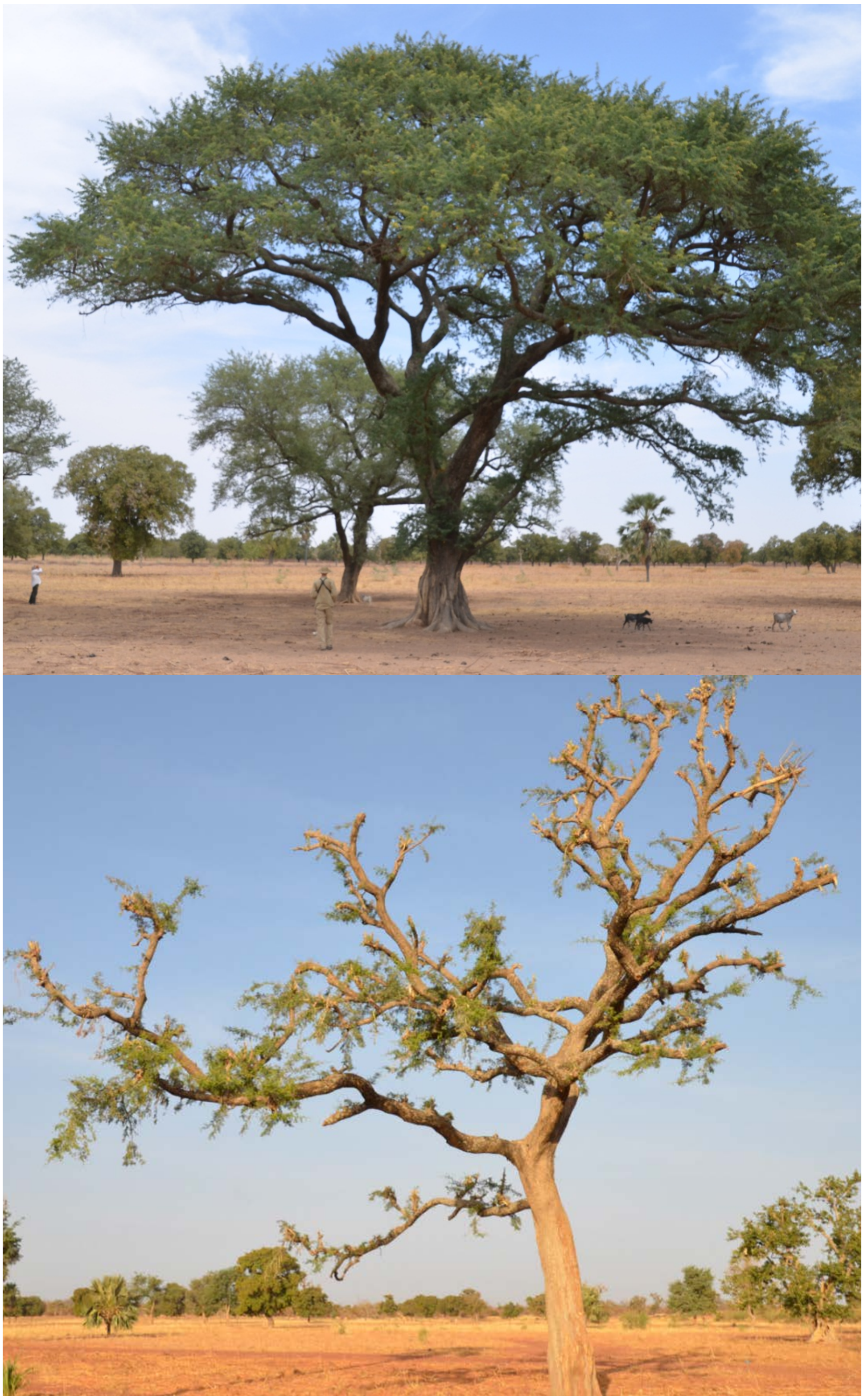
It would be too simple to describe habitat choice of woodland bird species merely in terms of density of trees and tree diversity. First, trees must reach a certain size before woodland bird species start to use them (Fig.15). Secondly, flowering trees or trees bearing fruit attract many more birds (Fig. 15, 18-23).

To understand why woodland bird species have declined, we need to know whether large, old trees have become less common in recent decades. A comparison of aerial photographs (available since the 1950s) and recent high resolution satellite images might give the answer. It would be more difficult to ascertain whether Sahelian trees have fewer flowers and berries than in the time long past. But there are indications this may be true. Goats and sheep have, indirectly, a negative impact on woodland bird species. This impact becomes larger and larger since the number of goats and sheep in the western Sahel have increased from 30 million in the early 1960s to 90 million forty years later. Three examples are given to show the impact of goats and sheep on woodland birds:

(1) Wilson & Cresswell (2006) mention browsing of *Salvadora* and other berry-carrying shrubs by dominant livestock, as a consequence of which fewer berries are available for birds.

(2) Herders in the Inner Niger Delta beat the branches of flowering *Acacia seyal* to feed the flowers to goats and sheep, by which the food supply for birds declines (Fig. 20).

(3) People cut the twigs and branches of trees to feed their livestock. In contrast to other tree species in the Sahel, *F. albida* is bare in the wet season (August). Its leaf biomass is maximal in January. Across the entire region, people cut the branches of *F. albida* in the dry season,



Faidherbia albida trees in early February, before and after pruning.

usually after the fruit is ripe from February onwards. Pruning may occur so drastically that only bare branches remain (see photographs on page 28). Birds were absent in trees treated like that. The overall effect of pruning on birds must be much larger than shown in Fig. 23.

Since the number of goats and sheep increases by more than 3% per year (thus doubling per 25 years), the just mentioned exploitation of trees must have increased at the same pace during the last decades. It is reasonable to assume that woodland birds therefore face an on-going deterioration of their winter habitat.

4.3 Possible application of the results

The whereabouts of migratory birds in the Sahel and beyond since long has been an intriguing quest. Since Moreau (1972) and Morel (1973) wrote their classic reviews, our state of knowledge on this topic has increased only fragmentarily (Zwarts *et al*. 2009). However, with new tracking techniques becoming available, the ´black box´ status of African wintering quarters may change in the near future (e.g. http://www.bto.org/science/migration/tracking-studies). Tracking techniques tell us detailed stories of individual birds during migration and wintering, revealing - amongst others - staging sites, stop-over times and intermediate flight distances. Although these studies yield a wealth of information and new insights, they still do not explain why migratory birds make their choices as they do. To get hold on this, basic field work is still needed in the habitats used by the birds during migration and wintering. The current study is an attempt to gather such information in a systematic way. Still more data are needed, however, to better understand distribution patterns and habitat use (see Section 4.4).

Authorities in the Sahel countries have tried to stop deforestation in the past by establishing large protected forest reserves where wood cutting is limited or even prohibited. The large majority of these classified forests only exist on paper, however. Fortunately, many trees have been planted in the Sahel (FAO 2006), but – unfortunately – often in single-species plantations with exotic trees: Eucalyptus spec. (from Australia), *Prosopis juliflora* (South America) and *Azadirachta indica* (SE Asia). These tree species have been chosen for their high growth rate or insect-resistant wood, but their ecological function is limited, and only very few birds are found in these kind of plantations.

Our study shows that some indigenous trees, often planted by local people, are crucial for the survival of several woodland bird species. Indigenous trees have also an important social and cultural function for the rural population. When asked, people in the Sahel rank tree species in order of their significance to them (Lykke *et al*. 2004, Paré 2008). Depending on the specific question the local people produce different lists: some species yield good firewood, others are more suitable for charcoal production or the wood is more suitable for constructing tools and equipment. Twigs and leaves from some tree species may be attractive as fodder while from others these products may be uneatable. Depending on the species, these trees provide shadow, fruits, medicine etc. Also, the flowering and cropping season differs per species in the Sahel (Hiernaux *et al*. 1994; Arbonnier 2000), and partly are complementary. In that respect local communities benefit from a large diversity of tree species within their home range. Since some tree species are in favor there has been preferential exploitation, by which some tree species have been in decline more than others (Cresswell *et al*. 2001).

Our study clearly shows that, from an ecological point of view, it is worthwhile to plant indigenous instead of exotic trees. In a later phase of the study, we intend to produce an ecological guideline for planting trees in the Sahel, meant for the many organisations being active in this field.

4.4 What data do we need now?

4.4.1 Seasonal shift in habitat use

We now know that foraging birds prefer flowering trees (Figs. 22 & 23). Since the flowering period varies between trees species, birds shift from one tree species to another during the course of their wintering period (Morel 1973). For instance, most birds likely shift from *F. albida* (flowering peak in November-December) to *A. seyal* (flowering peak in February). Many tree species in the Sahel flower in the late dry season (March-May). Thus it might be that later in the season woodland birds move from *Acacia* to other tree species, such as *Lannea*, which carry flowers from mid-February onwards.

Palearctic woodland bird species wintering in the Sahel do not store fat to overcome short periods of food shortage. When they arrive in August, they must daily find enough food until March (for species leaving early) or even until May (for birds leaving late). Their food supply varies seasonally, although detailed information is scarce. To understand how woodland species survive their overwintering period in the Sahel, we need to investigate the seasonal preference of foraging birds for the different tree species. The best way to do that is to make a selection from the present plots and count the numbers in the different trees in the same way as done so far, and repeat these measurements regularly between September and May.

We saw hardly any bird in *Parkia biglobosa*, but if there are flowers (appearing at the end of the dry season) the tree species attracts many birds, at least in northern Ghana (pers. comm. Rob Bijlsma).

4.4.2 Monitoring the same plots to reveal long-term trends

Revisiting the same plots during more than one year offers an opportunity to monitor the population size of birds as well as on-going changes in the Sahel (as done already for one site in North Nigeria by Cresswell *et al*. (2007) and by Jan van der Kamp (unpublished) in flooded forests in the Inner Niger Delta during four years.

4.4.3 More plots elsewhere in the Sahel

May our conclusions based on field work in W Senegal, SW Mauritania and central Mali be extrapolated to the rest of the Sahel? It may seem superfluous to repeat our censuses for another 100,000 Sahelian trees in January/February. However, our data – although seemingly a large sample - were collected at 308 sites, which can be considered a rather small sample when taking into account the size of the area covered (about an area as large as western Europe). This is precisely why a continuation of the study is necessary, using the same methodology, and covering regions elsewhere in the Sahel, for instance in E Senegal, W Mali and Burkina Faso (the red dots in Fig. 24).

This work should be done in January-February to allow comparisons with data collected in 2011 and 2012. This extension would also improve the reliability of our estimates of the total number of Palearctic birds wintering in the Sahel

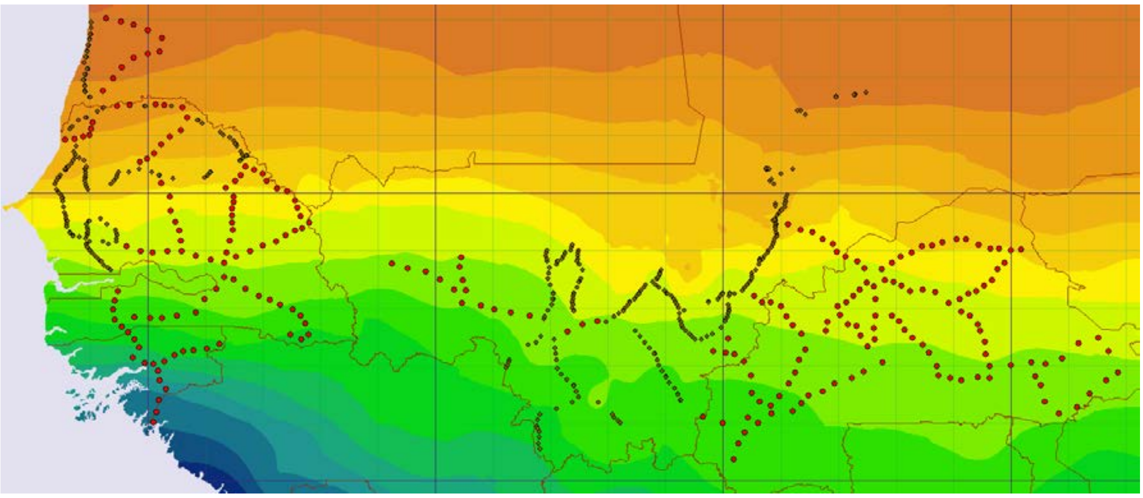


Fig. 24. The western Sahel between 10.25 and 18.25°N and from the Atlantic coast to 2.25°E, shown on the map, measures 1.77 million km^2. To arrive at a good collection of samples for this huge area, the intention is to visit the sites marked as red dots, in addition to the sites being visited in 2011 and 2012 (black dots). A selection has been made for areas being considered as safe: SW Mauritania, N, E and S Senegal, Guinea-Bissau, SW and SE Mali and Burkina Faso.

4.5 Main conclusions

Most Palearctic woodland bird species spending the northern winter in West Africa are concentrated in the Northern Sahel (13-17 °N; annual rainfall: 200–600 mm) where the large majority were recorded in *Faidherbia albida* and Acacia trees.

The birds reached their highest densities in the last remaining flooded forests.

The woodland birds prefer large trees and trees with flowers and/or a dense foliage.

These conclusions are based upon data collected in January-February and may not be extrapolated to the rest of the year due to the seasonal variation in the flowering period of the different tree species. That is why we expect that the birds show a shift in the tree preference during the course of the season, but actual data are still lacking.

The large decline of the woodland bird species during the last decades may partly be attributed to the loss of flooded Acacia forests along the Senegal River, in the Inner Niger Delta and elsewhere. More important is the changing exploitation of the dry agroforestry parkland, where the grazing pressure by livestock increases by 3% per year. This must have a large impact on the bird populations since nearly all woodland birds in the Sahel spend the winter on farmer´s land.

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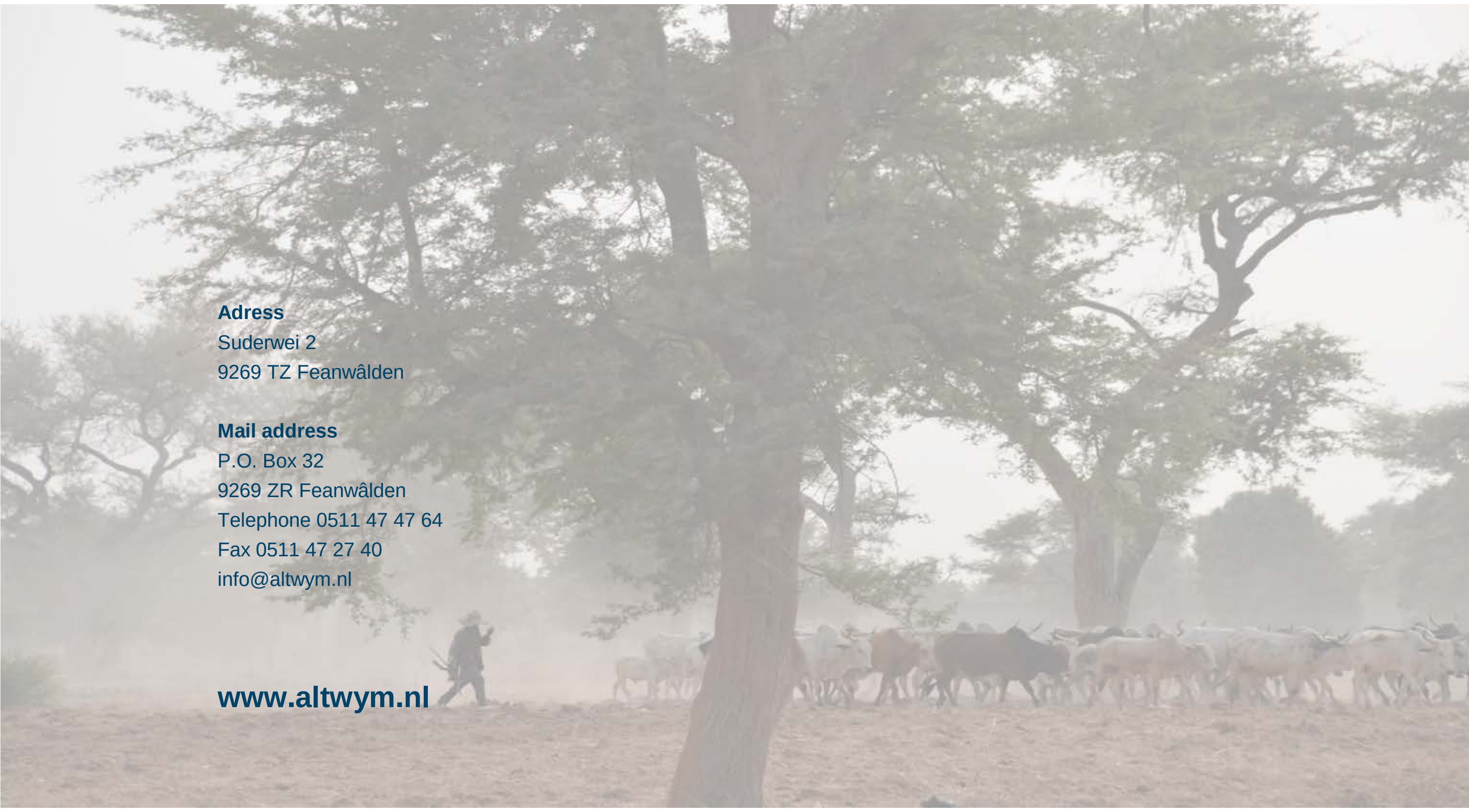

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