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Ciconiiformes Nesting on Trees in Cereal-dominated Farmlands: Importance of Scattered Trees for Heronries in Lowland Nepal

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Abstract.—Cereal farming is on the increase globally, and trees on these agricultural landscapes are selectively removed by farmers. Waterbird populations, supported on many cereal farmlands, need trees to place heronries and can be impacted by farmers' habits. In a cereal-dominated landscape in lowland Nepal, a landscape-scale field design was used to quantify characteristics of existing trees (density, species, girth, height), and contrasted against heronry trees to understand how choice of nest trees by select Ciconiiformes species was affected by farmers' habits. Tree density was patchy and tree species richness low, dominated by two tree species that had direct utility to farmers (*Dalbergia sissoo* – timber; *Mangifera indica* – fruits). Heronries were preferentially located on two wild tree species that were 8% of available trees and were either revered in local religion (*Ficus religiosa*; 36% of all heronries) or favored for agroforestry (*Bombax ceiba*; 42%). Heronries were preferentially located on larger trees. Availability of suitable trees for heronries was reduced by farmers' habits, but religious beliefs and agroforestry continued to support multi-functionality of cereal-dominated cropfields in lowland Nepal. *Received 22 June 2019, accepted 21 September 2019.*

Key words.—Asian Openbill, Cattle Egret, farmland trees, heronry tree preference, Kapilbastu, Lesser Adjutant Stork, lowland Nepal, Rupandehi.

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Mature scattered trees on agricultural landscapes support high levels of biodiversity on farmland and provide immense ecosystem services, but they have unpredictable or short lifespans since they are frequently cut down for revenue (Gibbons *et al.* 2008; Fischer *et al.* 2010a). Tree planting by farmers, especially in countries with low incomes, is utilitarian focused on enhancing food, fuel, medical security, and income diversification to lower production-related risks (Arnold and Dewees 1995). As natural forests decline in extent and vegetation quality, the contribution of scattered trees on agricultural landscapes to overall tree canopy cover in the landscape increases significantly over time (Place and Otsuka 2000). Scattered trees support biodiversity in a variety of production landscapes including fruit orchards (Mellink *et al.* 2017), pastures (Harvey and Haber 1999), tea and coffee estates where shade trees are essential (Yashmita-Ulman *et al.* 2018), and on roadsides and streamsides (Hall *et al.* 2019). However, cereal farms are rapidly becoming dominant, and farmers clear-cut areas and minimize trees to reduce shade, leading to greatly lowered tree cover and tree diversity (Augusseau *et al.* 2006). There is increasing understanding of the contribution of trees to support biodiversity on cereal farmlands, but the majority of assessments document presence of species with exceedingly few studies focussing on the importance of these landscapes for waterbird breeding (Sundar 2009; Pierlussi 2010; Sundar *et al.* 2019).

Several waterbird species breed in aggregations located on trees, called heronries, that constitute the majority of the breeding population of several species in an area. Heronries are therefore an immensely important facet of waterbird populations, and factors that serve to limit heronry formation can potentially lead to population declines of multiple waterbird species. Agricultural landscapes, particularly cereal-dominated farmlands, offer unique challenges to such waterbird species. Heronry locations in such unnatural settings require balancing between proximity to foraging habitat such as wetlands or flooded rice fields, and safety from human disturbance and human-induced mortality (Fasola and Alieri 1992; Tourenq *et al.* 2004; Fasola *et al.* 2010). A particularly acute challenge in many such agricultural areas is the limited availability of nest trees.

Various studies have investigated the role of foraging habitats on heronry locations (Gibbs 1991; Fasola and Alieri 1992; Tourenq *et al.* 2004; Kelly *et al.* 2008) and have characterized nest trees (Löhmus and Sellis 2003; Kim and Koo 2009). Exceedingly few, however, have studied if farmer' choices to retain and plant certain tree species biases choice of nest trees for heronries by waterbirds. In Japan and Uganda, waterbirds chose nest trees in large patches of trees near agriculture, reflecting affiliation with contiguous nesting habitat and possibly decreasing human-related disturbance (Nachuha and Quinn 2012; Carrasco *et al.* 2014). In Italy, heronries were located closer to remnant wetland patches reflecting the need to maintain proximity to higher quality foraging habitats, and likely also reflected that trees were not limited (Fasola and Alieri 1992). These findings suggest that disparate factors drive heronry location on different agricultural landscapes and underscore the paucity of studies on nest tree preference at landscape scales.

The majority of existing studies on heronry nest trees have explored selection of nest trees within the tree patch where nests occurred (e.g., Kim and Koo 2009). It is not clear, however, if waterbirds preferentially chose nest trees at landscape scales. Also, very few agricultural landscapes have been explored, and such studies are particularly important in south Asia where many landscapes have been converted to multi-season farming characterized by sparse remnant natural habitats, different agro-forestry practices, and high human densities (Sundar and Kittur 2012). Recent explorations in south Asia have shown that despite heavy landscape modification over long time periods to farming, and high human presence, several agricultural landscapes support considerable waterbird populations and heronries (Sundar and Kittur 2012; Sundar *et al.* 2016, 2019; Koli *et al.* 2019). Studies to understand if waterbirds preferentially choose nest trees are however missing from south Asia (Pierlussi 2010; Sundar and Subramanya 2010). This lack of understanding is significant given south Asian farmlands have very high farmer densities, relatively small landholdings, and farmers favoring tree species that have direct utility – all of which are factors that exacerbate declines in scattered trees (Arnold and Dewees 1995; Endale *et al.* 2017). A sound understanding of how waterbird species interact with persisting trees on agricultural landscapes is essential to aid with developing effective conservation plans.

In Nepal, agroforestry has a long history with sound policy leading to tree planting on private farmlands, especially on hillsides. This has helped reduce soil erosion while also conserving tree diversity on production landscapes (Bartlett 1992; Acharya 2008). However, farmers in lowland areas have increased their dependence on multi-season cereal and vegetable crops, and these areas are characterized by low tree diversity dominated by very few species, with high farmer densities and relatively small landholding sizes further exacerbating the situation (Kharal and Oli 2009). There is sparse information from most areas across lowland Nepal to understand what trees remain on the landscape, whether heronry-forming waterbirds continue to nest in such conditions, and if they do, how they adapt to these altered landscapes.

In this study, we enumerated trees at the landscape-scale and estimated nest tree preference by colonially-nesting Ciconiiformes species (two stork species and one heron species) on an agricultural landscape dominated by cereal cropping in lowland Nepal. We used a spatially explicit field design and a use-availability framework to answer the question of whether heronry trees were preferentially used relative to available tree density, and if characteristics of these trees such as species, diameter, and height, varied from trees available on the landscape. We also investigated if existing tree species diversity was skewed to certain species, and whether this influenced choice of tree species used by Ciconiiformes species for heronries.

Methods

Study Area

The study was carried out in the adjoining districts of Rupandehi and Kapilbastu of lowland, southern Nepal (Fig. 1A, B). The districts experience strong seasonality with agriculture being the dominant land use, and cropping patterns are matched with seasons. The principal crops were flooded paddy in the monsoon or rainy season (July-October), followed by wheat, lentils and mustard in winter (November-December), and reduced but mixed cropping in the summer (March-June). These districts are in the northern extent of the Indo-Gangetic floodplain. The surface gradually slopes southwards, with several rainwater basins and natural flooded depressions. At the time of the study, districts were sub-divided for governance into Village Development Committees (VDCs). More details are available elsewhere (Koju 2015; Sundar *et al.* 2016, 2019).

Natural trees and bamboo clumps were scattered all over the landscape, with some patches of fruit and forestry orchards (R. Koju and B. Maharjan, pers. obs.). Orchards were largely planted with mango (*Mangifera indica*), bamboo (various species), and simal (*Bombax ceiba*), and natural tree species included trees like peepal (*Ficus religiosa*) that have local religious significance (Koju 2015).

Field Methods

We used existing road routes to survey the study area for waterbird colonies between September 2014 and January 2015 (Fig. 1B), covering 680.27 km^2 at least once every two weeks (Koju 2015; Sundar *et al.* 2016). Ciconiiformes nesting on trees (single nests and colonies) were located by sight and by questioning farmers. Nests were counted to determine heronry size and summary statistics calculated. Location of each heronry was recorded using a hand-held Global Position System (GPS) receiver. For each tree with a heronry, we recorded the tree species, diameter at breast height (DBH) in cm, and tree height to the nearest 5 m using a range finder measured from just beyond the fringes of the canopy width. All heronries observed succeeded in hatching and fledging chicks, and factors affecting breeding success are detailed elsewhere (Sundar *et al.* 2019).

To determine availability of trees, we generated random points across the study area stratified by VDCs using ArcGIS 10.2 software (Environmental Systems Research Institute 2014). The stratification ensured better spread of random points across the entire study area. We generated five random points per VDC for a total of 235 points. Points were plotted on 1:50,000 topographic sheets, and were located on the ground with the help of maps and a GPS. If the point did not fall in a tree patch, we walked to the nearest tree with the potential to support nests and repeated all the measurements made at nest trees, and measured the distance walked using a range finder. We excluded points in large wetlands and rivers, and we sampled available trees in 222 accessible, random field points, providing a sampling density of one point every 2.9 km^2.

Data Analysis

We estimated preference at the level of the heronry, and for individual waterbird species that had > 10 heronries each. To assess if heronries were located preferentially in areas with more trees at the landscape scale, we first undertook ordinary kriging of distances walked from random field points to the nearest tree. Kriging is a method of interpolation using a Gaussian process governed by measurements taken at a few random locations, and incorporates autocorrelation to produce an interpolated, continuous spatial surface (Stein 2012). ArcGIS 10.2 was used to undertake kriging as a spatial measure of relative tree density on the entire landscape, with smaller distances representing greater tree density (Fig. 1C). To assess available tree density in an unbiased manner, we generated five new random points per VDC and extracted distance to tree measures for these spatial random points using the surface generated by kriging. This second set of spatial random points was necessary since availability of tree density was being assessed for the tree density surface created by kriging. From the density surface, we also extracted imputed measures of distance to trees for all heronry locations.

For single-species heronry analyses, we focused on three Ciconiiformes species: Asian Openbills (*Anastomus oscitans*), Lesser Adjutant Storks (*Leptoptilos javanicus*), and Cattle Egrets (*Bubulcus ibis*). We included all heronries where a particular species nested (without excluding the single Lesser Adjutant Stork heronry that was multi-species; see Results), and did not use Little Egret (*Egretta garzetta*) and Lesser Cormorant (*Phalacrocorax niger*) heronries as a separate category, instead representing these collectively as "Others" since they were always in multi-species heronries (see Results).

We compared measurements at heronry locations against availability (measured at random points) to test the null hypothesis of no difference in the means of the two sets of measurements. Distributions of variables measured at random locations and at heronries were nearly always significantly different from normal (Shapiro-Wilk test, $P < 0.05$). We therefore assessed differences between availability and heronry locations using the non-parametric independent samples Wilcoxon rank sum test using the package 'dplyr' in statistical program R (Wickham *et al.* 2019). Wilcoxon rank sum tests were conducted for distance to trees, and for each measured tree dimension (DBH and height). Ridgeline density plots were generated using packages 'ggplot2' (Wickham *et al.* 2018), 'ggridges' (Wilke 2018) and 'gg-

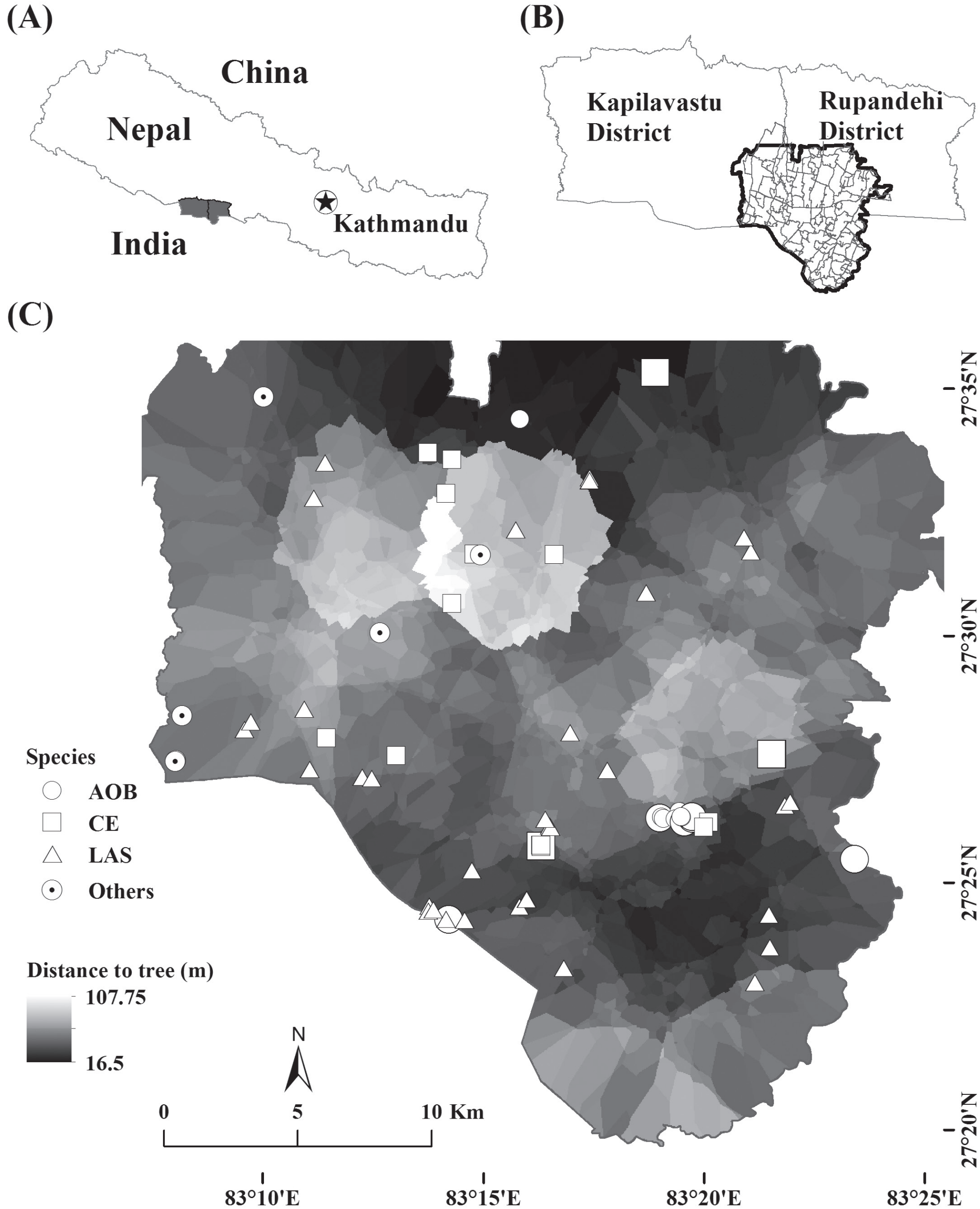

Figure 1. Study area map showing: (A) the location of the focal districts in Nepal; (B) the surveyed area in the two districts (bold line), with the road routes (gray lines) taken to find Ciconiiformes heronries; and (C) heronry locations plotted on a spatially interpolated map created using kriging of distances (m) to trees from 222 random locations. Higher tree density (lower distances from points to trees) indicated by darker colors and lower tree density (greater distances between points and trees) indicated by lighter colors. Single-species Ciconiiformes heronries are mapped for the Asian Openbill (AOB), Lesser Adjutant Stork (LAS), and Cattle Egret (CE). Two heronry size classes are indicated: < 25 nests (smaller symbols) and > 25 nests (larger symbols).

pubr' (Kassambara 2018) in the statistical package R to determine where differences, if any, occurred.

Chi-square tests (with Yate's correction factor when sample sizes were small) were used with count data to assess the hypothesis that heronries were not located differently between tree species with differing human uses ("domestic" versus "wild"), relative to available tree species. We segregated trees as "domestic" to mean those that were planted in nurseries, were commonly used as plantation or roadside trees, or in fruit orchards. "Domestic" did not therefore mean that these species were absent from local forests naturally. Instead, these were tree species that farmers expended regular effort to maintain when they retained them or planted them in their fields. We classified tree species as "wild" when they were native, were uncommon as nursery species, and did not experience regular maintenance from farmers. Tree use was provided by farmers, botanists, and ecologists locally and is not an exhaustive list. Also, this differentiation is not without some subjectivity and may vary with location depending on different uses of trees by farmers. Zero values prevented a formal statistical testing of the hypothesis that counts of tree species did not vary in random locations from heronry trees, and we used bar graphs to visually evaluate hypotheses. To confirm visual evaluations, we conducted post-hoc Fisher-Freeman-Halton exact tests with count data and 2000 simulations to develop P-values including only tree species that had non-zero values each time for four tables (all heronries combined, and each of three waterbird species that had > 10 heronries each).

Results

Heronries

Nests of seven Ciconiiformes species were found, but Woolly-necked Storks (*Ciconia episcopus*) always nested singly and were not included in the analyses. Seventy-eight heronries were found, with four being multi-species and the rest being single-species. Single-species heronries were formed by Asian Openbills (n = 14 heronries), Lesser Adjutant Stork (n = 35 heronries, with only one as a multi-species heronry shared with Little Egret), Red-naped Ibis (*Pseudibis papillosa*, n = 2 heronries), and Pond Heron (*Ardeola grayii*, n = 4 heronries). Multi-species heronries were formed by Cattle Egret (n = 19 heronries, with three multi-species heronries, one shared with Little Egrets and two with Lesser Cormorants), and Little Egrets (n = 2, both as multi-species heronries). Heronry sizes of Asian Openbills were magnitudes higher than those of the other species (Table 1).

Tree Species

A total of 300 trees were enumerated from random points and heronry locations, of which 295 could be identified to 26 species. An almost-equal number of tree species were categorized as wild (14) or domestic (12; Table 2). Fifty-one percent of all trees at random locations were of two domestic species (*Dalbergia sissoo*, *Mangifera indica*; Table 2). Wild tree species were relatively sparse on the landscape (29% of all trees), and the most numerous among them were *Vachellia nilotica* (12.6% of all trees), *Ficus religiosa* (4.5%), and *Bombax ceiba* (3.6%). *B. ceiba* trees were cultivated for agro-forestry purposes, and *Ficus* tree species were retained by farmers due to religious beliefs (Table 2).

Heronries were found only on nine tree species, and 78% of these were found on two wild tree species (*B. ceiba* and *F. religiosa*) that were 8% of available trees (Fig. 2, Table 2). Heronries were located significantly more often on wild tree species relative to their availability (χ^2 = 86.32, P < 0.0001). Considerable choice of nest trees was evident when analyses considered all heronries combined across species, and also when the three focal Ciconiiformes species were considered individually (Fisher-Freeman-Halton exact test, P < 0.0005, Fig. 2). Cattle Egrets showed the highest plasticity in being able to use both domestic and wild tree species, but 79% of their heronries were located on three *Ficus* species that constituted < 6% of all available trees (Fig. 2B). Asian Openbill and Lesser Adjutant Storks were nearly entirely reliant on *B. ceiba* and *F. religiosa* for nesting (Fig. 2A, B).

Table 1. Summary statistics of heronry sizes of selected Ciconiiformes species observed in lowland Nepal.

Species	Mean	SD	Min-Max
Asian Openbill (n = 14)	51.43	50.8	5-130
Cattle Egret (n = 19)	17.16	16.5	2-25
Lesser Adjutant Stork (n = 35)	2.86	2.67	1-13
Pond Heron (n = 4)	6.00	3.46	1-9
Red-naped Ibis (n = 2)	2.50	0.71	2-3

Table 2. Categorization of tree species found at random points and on which heronries were located, along with information on their common uses, in lowland Nepal. We also indicate when species were exotic to the area. Ciconiiformes species are Asian Openbill (AOB), Cattle Egret (CE), and Lesser Adjutant Stork (LAS).

	Number of heronries				
Tree species	AOB	CE	LAS	Others	Common uses and other comments
Domestic trees					
Albizia lebbeck		2			Agroforestry.
Azadirachta indica					Brushing teeth, medicine, timber.
Bixa orellana					Cosmetics, spice. Exotic species, largely a shrub rarely growing to a small tree.
Dalbergia sissoo	1	2		1	Agroforestry, roadside shade tree.
Leucaena diversifolia					Timber, paper, charcoal. Exotic species.
Mangifera indica				1	Fruits, rarely timber.
Myristica fragrans					Medicine.
Phyllanthus sp.					Fruits.
Syzygium cumini					Fruits and medicine.
Tectona grandis					Agroforestry and medicine.
Toona ciliata					Agroforestry and medicine.
Zizyphus mauritiana					Fruits.
Wild trees					
Adina cordifolia			1		Local medicine.
Aegle marmelos					Fruits, also revered in local religion.
Artocarpus lakoocha					Fruits.
Bombax ceiba	11		20	2	Agroforestry, timber and medicine.
Ficus benghalensis			2		Revered in local religion.
Ficus racemosa		1			Revered in local religion, rarely agroforestry.
Ficus religiosa	2	10	12	4	Revered in local religion, bark for paper, fruits, timber, medicine.
Ficus virens		4		2	Revered in local religion, fruits, timber, medicine.
Melia azaderach					Timber and medicine.
Neolamarckia kadamba					Fruits and timber.
Shorea robusta					Timber, medicine, leaves to make cups and plates.
Trewia nudiflora					Timber for picture frames and musical instruments.
Vachellia nilotica					Cattle fodder, timber.
Xeromphis spinulosa					Dye, fruits and medicine.

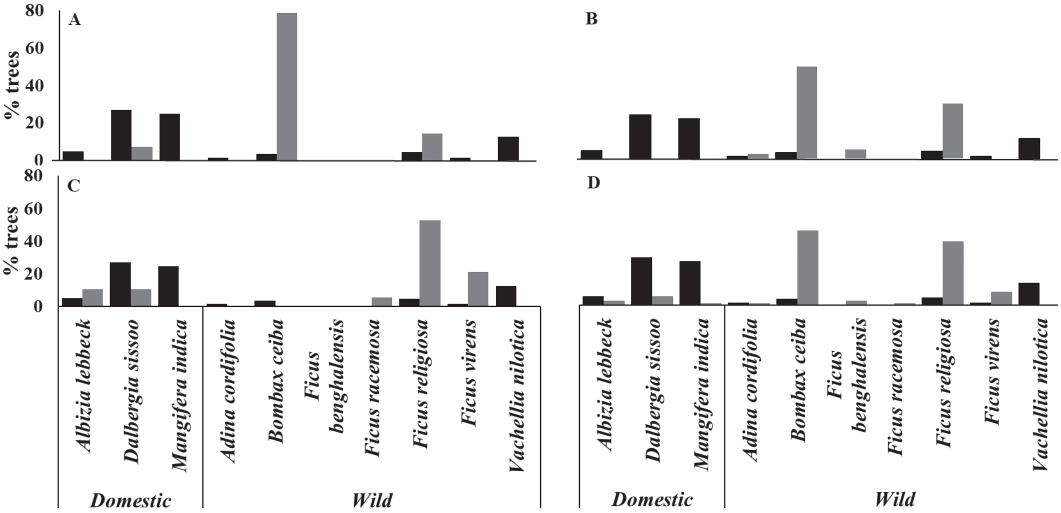

Figure 2. Proportions of individuals of tree species available (black bars, *n* = 222) contrasted with trees used by Ciconiiformes for heronries (gray bars) in Kapilbastu and Rupandehi districts of lowland Nepal. Tree species are segregated by human use, and only tree species that were dominant (> 12%) or were used for heronries are included. Graphs show tree availability versus heronry trees for Asian Openbills (A; *n* = 14), Lesser Adjutant Storks (B; *n* = 35), Cattle Egret (C; *n* = 19) and all heronries combined (D; *n* = 78).

Tree Density

Tree occurrence across the study area was patchy (Fig. 1C). Only Asian Openbills had most heronries clustered in one location, and heronries of all other species were widely distributed (Fig. 1C). Tree density differed significantly at heronry locations relative to random locations (Wilcoxon rank sum test, $P = 0.026$). This difference was biased by Asian Openbill heronries (Wilcoxon rank sum test, $P = 0.001$), that preferred areas with lower tree densities (Fig. 3A, Table 3) compared to random locations. Tree density in locations with Lesser Adjutant (Wilcoxon rank sum test, $P = 0.106$) and Cattle Egret heronries (Wilcoxon rank sum test, $P = 0.824$) were not different from tree density available at random locations (Fig. 3).

Tree Dimensions

Girth. Eighty-nine percent of trees measured at random locations had DBH < 200 cm (Fig. 3B). In contrast, heronry trees frequently exceeded DBH of 400 cm. Heronry trees were spread across all available DBH classes, but significantly, included very large trees whose size class was too rare to be captured in random samples. On average, heronry trees had three times the DBH relative to available trees (Wilcoxon rank sum test, $P < 0.0001$, Fig. 3B, Table 3). All individual species used nest trees that had significantly larger DBH than that of available trees (Wilcoxon rank sum tests, $P < 0.001$). The majority of heronry trees of Asian Openbills and Lesser Adjutant Storks had > 200 cm DBH. Trees in the 0-100 cm range and in the > 600 cm range were entirely avoided by Asian Openbills (Fig. 3B). In contrast, most of the Lesser Adjutant Stork colonies were located on trees with DBH of 200-700 cm, with this species using the largest measured heronry trees. On average, Lesser Adjutant Stork heronry trees had over three times the average DBH relative to available trees (Table 3). Cattle Egrets used many more size classes of nest trees compared to Asian Openbills and Lesser Adjutant Storks (Fig. 3B).

Height. Most of the available trees were < 10 m tall, but the majority of heronries were on trees > 10 m height, with several located on trees > 30 m tall (Fig. 3C). Heronry trees were, on average, 1.8 times the height of available trees (Wilcoxon rank sum test, $P < 0.0001$, Fig. 3C, Table 3). All three Ciconiiformes species that had > 10 heronries each had heronries on much taller trees than the mean of those available at random locations

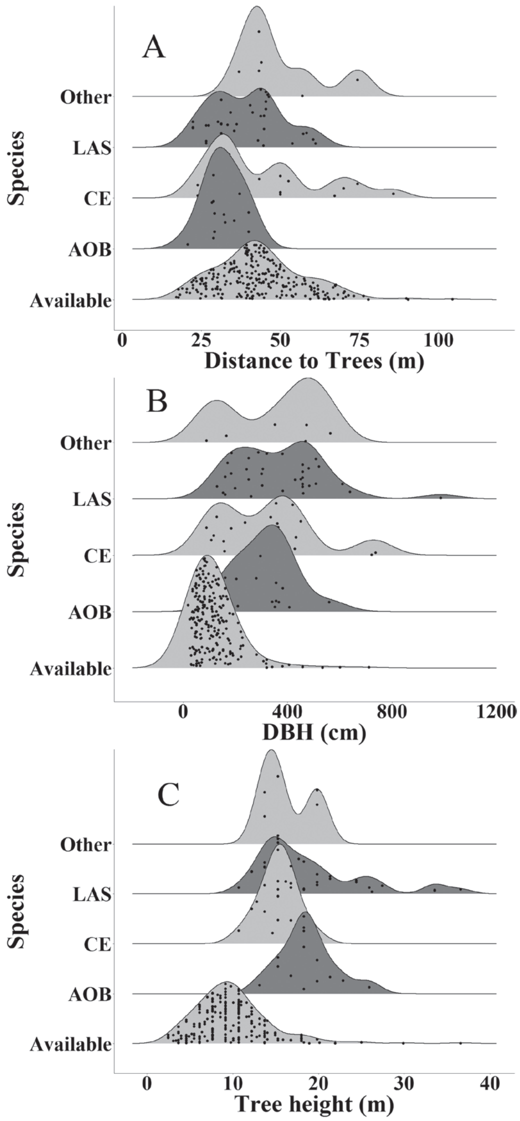

Figure 3. Ridgeline plots showing smoothed probability density functions of measures of: (A) distance of trees from heronry locations or random points (lower distances = higher tree density); (B) tree height (m); and (C) tree diameter at breast height (DBH, cm) at single-species heronry locations of nesting Asian Openbills (AOB), Cattle Egrets (CE), Lesser Adjutant Storks (LAS), multi-species heronries (Other), and random points (Available) in an agricultural landscape in lowland Nepal. For easy viewing raw data are included as jittered points and alternate colors are used on density plots.

(Wilcoxon rank sum test, $P < 0.0001$, Fig. 3C, Table 3). Lesser Adjutant Storks preferred nesting on the tallest trees that were twice the mean height of available trees (Table 3). Of the three species, Cattle Egrets used the shortest trees to form heronries, mostly using trees of 10-20 m height, entirely avoiding trees taller than 20 m.

DISCUSSION

Positive impacts of scattered trees in increasing species richness of birds and bats has been observed in a variety of agricultural production landscapes (Fischer *et al.* 2010a,b; Mellink *et al.* 2017). In this paper, we present the first evidence of such scattered trees on agricultural areas supporting the breeding of significant numbers of Ciconiiformes species. Our study has also discovered the largest breeding population of Lesser Adjutant Storks in south Asia, a species which has previously been assumed to avoid agricultural areas for breeding (see also Sundar *et al.* 2016, 2019).

Farmers' choice of reducing tree cover has greatly biased tree species richness and diversity in lowland Nepal's agricultural landscape towards dominance of a very small number of species that are commercially useful. These domestic tree species were almost entirely avoided by Ciconiiformes for nesting, likely due to constant human disturbance for timber harvesting (e.g. *D. sissoo*), or actively scared away to prevent damage to fruits (e.g. *M. indica*). Domestic trees were also much smaller than some of the wild tree species that were not exploited. The most important trees for heronries, *F. religiosa* and *B. ceiba*, were both relatively rare wild species in the study area. Local farmers revered trees of *Ficus* species as part of regional religious beliefs resulting in single and very large *Ficus* trees scattered across the landscape. These trees were not cut down despite being very large and offering considerable shade to cereal crops (R. Koju and B. Maharjan, pers. obs.). However, we did not learn of any planning to add more *Ficus* trees on the landscape. *B. ceiba* is valued as an agroforestry tree with legally mandated pricing for its flowers, bark, and fruits. Nepal's forestry laws prohibit cutting down this species, except with explicit permission from the Government (www.lawcommission.gov.np).

Table 3. Summary statistics of measurements of trees at random locations (Available) and of heronry trees used by Ciconiiformes in lowland Nepal.

	Count	Mean	SD	Min-Max	Shapiro-Wilk test
Distance to trees					
Available	240	43.6	14.4	17.1-104.0	$W = 0.99$; $P = 1.93e\text{-}05$
All heronries	74	40.0	13.6	20.7-85.7	$W = 0.92$; $P = 7.57e\text{-}05$
Asian Openbill	14	32.2	5.58	20.7-40	$W = 0.91$; $P = 0.156$
Cattle Egret	19	44.6	18.3	23.8-85.7	$W = 0.89$; $P = 0.026$
Lesser Adjutant Stork	35	39	11.1	22.3-61.1	$W = 0.94$; $P = 0.066$
Diameter at breast height					
Available	222	116	91.2	17.8-711	$W = 0.7148$, $P = 2.2e\text{-}16$
All heronries	74	346	169	88.9-987	$W = 0.9411$, $P = 0.0018$
Asian Openbill	14	317	107	160-559	$W = 0.931$, $P = 0.3147$
Cattle Egret	19	322	190	88.9-737	$W = 0.8948$, $P = 0.039$
Lesser Adjutant Stork	35	371	177	130-987	$W = 0.8997$, $P = 0.0039$
Tree height					
Available	222	10	4.65	2-37	$W = 0.8868$, $P = 7.48e\text{-}12$
All heronries	74	17.8	5	11-37	$W = 0.8457$, $P = 2.73e\text{-}07$
Asian Openbill	14	18.7	3.26	13-26	$W = 0.9526$, $P = 0.602$
Cattle Egret	19	15.3	2.13	11-20	$W = 0.9652$, $P = 0.679$
Lesser Adjutant Stork	35	19	6.41	11-37	$W = 0.872$, $P = 0.0008$

However, illegal felling of trees valuable for timber was also common in lowland Nepal (Khadka 2010), and we observed several *B. ceiba* trees cut down subsequent to our study.

The situation of the scattered trees important for heronries of several Ciconiiformes species is therefore tenuous, and comparable with the situation in other production landscapes where farming has accelerated the decline of multi-functionality of agricultural landscapes (Augusseau *et al.* 2006; Gibbons *et al.* 2008; Fisher *et al.* 2010a,b). Religious beliefs and a combination of agroforestry and policy appear entirely responsible for ensuring that large trees are still available for Ciconiiformes nesting in lowland Nepal. Ensuring that trees identified to be important for heronries in this study, and other potential species that grow to be large with wide canopies, is critical to ensure that this multi-functionality remains in lowland Nepal. Immediate efforts to encourage farmers to plant *Ficus* species, enhance the planting and protection of *B. ceiba* trees for the long-term, and enabling access to other wild trees via creating nurseries of these species are essential. These efforts will need to relate explicitly to Ciconiiformes rather than potential ecosystem services such as soil conservation. Connecting farmers with Ciconiiformes species is relatively easy in lowland Nepal since the Asian Openbill is the most numerous heronry forming species and is a specialist feeder on large, exotic snails that are a major threat to cereal crops (Ali and Ripley 2007). Additionally, none of the observed breeding waterbird species depredated crops, and nearly all of them fed on agricultural pests such as locusts, beetles, and other invertebrates (Ali and Ripley 2007). Finally, recognizing and praising farmers who retain large, old trees such as *F. religiosa* and *B. ceiba* on their farms will help strengthen farmers' connections with non-commercial tree species and Ciconiiformes, while also instilling pride in farmers that their local beliefs provide globally relevant value-addition to securing important breeding populations of several waterbird species. It is very likely that farmers in other cereal-dominated landscapes have locally relevant attitudes, such as the religious beliefs in lowland Nepal, that can help secure and increase scattered trees on agricultural landscapes. Urgent explorations in more diverse farmland areas, where heronry-forming waterbirds associate with cereal croplands, can help with uncovering, revitalizing, and strengthening such attitudes to benefit both farmers and biodiversity conservation.

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