Global Ecology and Conservation 44 (2023) e02487

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Low-intensive agricultural landscapes could help to sustain Green Peafowl *Pavo muticus* inhabiting surrounding forest patches in Northern Thailand

Ghan Saridnirun[a,1,*], Niti Sukumal[a], Matthew J. Grainger[b], Tommaso Savini[a]

[a] *Conservation Ecology Program, King Mongkut's University of Technology Thonburi, 49 Soi Thian Thale 25, Bang Khun Thian Chai Thale Road, Bangkok 10150, Thailand*
[b] *Norwegian Institute for Nature Research, Postbox 5685 Torgarden, 7485 Trondheim, Norway*

ARTICLE INFO

Keywords:
Low-intensity agriculture
Compositional analysis
Endangered species
Fragmented landscape
Habitat use
Habitat selection

ABSTRACT

Wildlife in Southeast Asia is greatly affected by agricultural expansion. While intensive farming causes biodiversity decline, low-intensive farming can support some adapted wildlife. In Thailand, the rapid transformation of forests to agricultural landscapes over three decades has resulted in large forest and biodiversity loss, with several Endangered species suffering from cropland expansion. Among these, the Green Peafowl, an Endangered Galliformes widely distributed across Southeast Asia, has shown the capacity to adapt well to low-intensive agriculture landscapes by using crops as food sources. Here we investigated in detail the Green Peafowl's habitat use in an agricultural landscape surrounding a large forest patch composed of three protected areas in northern Thailand. Using line transect surveys and compositional analysis, we estimated the monthly Peafowl use of different crop types and different crop structures between January 2020 and January 2021. The Green Peafowl's habitat use was significantly non-random. The order of habitat preference was timber plantations > orchards > cropland > fallow land. The species also preferred cropland within a 500 m buffer zone around the forest patch. The species preferred crops with a canopy structure (timber and orchards) that resembles their natural habitat. Our results confirm that low-intensive and diversified agricultural landscapes could help to sustain the Green Peafowl population. Importantly, we also show that closed canopy crops, such as large tree plantations like teak, rubber and orchards, can provide good alternatives for reforestation to reconnect forest fragments and isolated patches in highly degraded habitats as they allow the species to move further away from forest edges within the degraded landscape.

1. Introduction

Southeast Asian biodiversity is primarily threatened by habitat degradation, fragmentation and loss (Laurance et al., 2014), mainly as a direct consequence of the expansion of agriculture and infrastructure (Sodhi et al., 2009), which have displaced resident wildlife, increasing the threats of hunting (Doherty et al., 2017; Home et al., 2018; Yen et al., 2019) and conflict with humans (Scanes, 2018). The use of agricultural landscapes by wildlife is affected by farming practices, intensity and crop diversity (Olivier et al., 2020). On the

* Corresponding author.
E-mail address: g.saridnirun@gmail.com (G. Saridnirun).
[1] ORCID: 0000–0001-9667–5632

https://doi.org/10.1016/j.gecco.2023.e02487
Received 12 February 2023; Received in revised form 23 April 2023; Accepted 23 April 2023
Available online 24 April 2023
2351-9894/

one hand, intensive monoculture landscapes impact wildlife negatively due to the poor structural diversity and high use of chemicals, both fertilizers and pesticides, to increase crop productivity (Kehoe et al., 2017; Zabel et al., 2019). On the other hand, low-intensity and diversified agriculture landscapes share some structural similarities to the natural habitat and, therefore, can support some wildlife in the long term as semi-natural habitats (Katayama et al., 2019a; Hendershot et al., 2020).

Forest birds are known to be highly affected by habitat degradation, with several species in the region predicted to go extinct by 2100 (Sodhi et al., 2010). Forest bird species respond differently to habitat degradation and agricultural expansion (Gaüzère et al., 2020). While forest specialists tend to go extinct due to adverse effects of agricultural practices, generalists can adapt to degraded habitats, particularly those represented by low-intensity cropland (Muñoz-Sáez et al., 2020). However, little is still known about the effects and responses of generalists to diversified agriculture systems (Borges et al., 2017). It is, therefore, fundamental to understand forest birds' flexibility in using and surviving in human-modified habitats (Sanz-Pérez et al., 2019).

Several forest bird species in the family Phasianidae are under threat due primarily to habitat loss and degradation (Savini et al., 2021). Among them, the Endangered Green Peafowl (*Pavo muticus*) is mainly impacted by habitat encroachment and degradation (BirdLife International, 2018). The species inhabits open forests, mainly dry dipterocarp and mixed deciduous forests (Brickle, 2002), as well as surrounding agricultural landscapes (Saridnirun et al., 2021), preferring low-intensive and diversified crops (Shwe et al., 2021). One of the remaining population strongholds for the species is in northern Thailand (Sukumal et al., 2020), particularly in natural open forests and surrounding agricultural landscapes (Saridnirun et al., 2021) with diverse crops, ground vegetation cover, understory structure and canopy cover (Saridnirun et al., 2021).

This research aims to investigate the effect of agriculture on Green Peafowl, which is considered a good indicator of habitat structural quality (Savini et al., 2021). In detail, the study investigates the micro-habitat used by the species when ranging between the natural dry forest, its preferred habitat (Sukumal et al., 2020), and the surrounding agricultural landscape to assess the birds' adaptation to human-modified habitats. To understand the role of crop diversification, we investigate the species' micro-habitat selection, focusing on crop type and stage of development, by comparing the selected habitat and the available one to highlight how the species responds to different forest and agricultural landscape structures.

2. Study area

The study was conducted in three protected areas in the northern Thailand stronghold where the species uses both the natural forest habitat and surrounding crop fields (Saridnirun et al., 2021). The three protected areas are Tub Phaya Lor Non-Hunting Area (19°26'56.40"N, 100°4′28.22"E), Wiang Lor Wildlife Sanctuary (19°16'45.17"N, 100°9′8.34"E) and Doi Phu Nang National Park (18°51'22.73"N, 100°10'55.70"E) (see Fig. 1 for details) covering approximately 1500 km^2 at an elevation ranging between 300 and 1200 m. The area is primarily covered by dry dipterocarp and mixed deciduous forests with an estimated density of Green Peafowl between 14.88 and 19.89 calling males/km^2 (Saridnirun et al., 2021). The site experiences a dry season from September to May, with an average monthly rainfall of 79 mm, and a rainy season from June to October, with an average monthly rainfall of 134 mm. The annual rainfall is 1095 mm (TMD, 2022), and temperature ranges from 14° to 31°C. The surrounding agricultural areas, with an estimated Peafowl density ranging between 11.47 and 17.79 calling males/km^2 (Saridnirun et al., 2021), consist of several crop types, mostly rice fields (*Orysa sativa*), mountain rice (local variety of *O. sativa*), corn (*Zea mays*), rubber (*Hevea brasiliensis*), teak (*Tectona grandis*) and orchards such as mango (*Mangifera indica*), orange (*Citrus sinensis*), tamarind (*Tamarindus indica*) and longan (*Dimocarpus longan*).

3. Method

3.1. Field survey and data collection

To investigate the use of agricultural landscapes by Green Peafowl, we established seven 2 km line transects (total transect length 14 km) in the agricultural landscape outside but surrounding the three protected areas (three outside Tub Pha Ya Lor Non-Hunting Area, three outside Wiang Lor Wildlife Sanctuary and one outside Doi Phu Nang National Park). We walked transects in both directions twice daily (07.00–09.00 and 16.00–18.00), on three consecutive days every month for 13 months (January 2020 – January 2021). Observers recorded the number of individuals spotted, their age (adults or chick), sex and the habitat/crop being used. The crop type and growth stage were also recorded when birds were detected in agricultural landscapes.

We created a 500 m buffer around each line transect based on an effective strip width for estimating the density of Green Peafowl in our study areas (Saridnirun et al., 2021). Within this 500 m buffer, we digitized each micro-habitat boundary using *Google Earth* (Google, Mountain View, USA) (see details on Figs. S1 to S3). We also conducted monthly ground checks by walking the transects while conducting the surveys to confirm micro-habitat types, for example crop types, and note any seasonal crop pattern changes. We calculated the coverage of each micro-habitat using *ArcGIS 10.3* (Esri, Redlands, USA). In total, 13 micro-habitats were defined (Table 1) and grouped based on five main habitat categories: 1) forests, mainly dry-dipterocarp and mixed-deciduous forests within the protected area; 2) fallow, uncultivated fields with no agricultural activities during the survey period; 3) orchards, consisting of durian, jackfruit, longan and mulberry; 4) cropland, consisting of cassava, chili, corn, grass, rice; and 5) timber plantations, including rubber and teak.

We compared the frequency of detections within each micro-habitat at different distances from the forest edge to determine the most used micro-habitats and crop types.

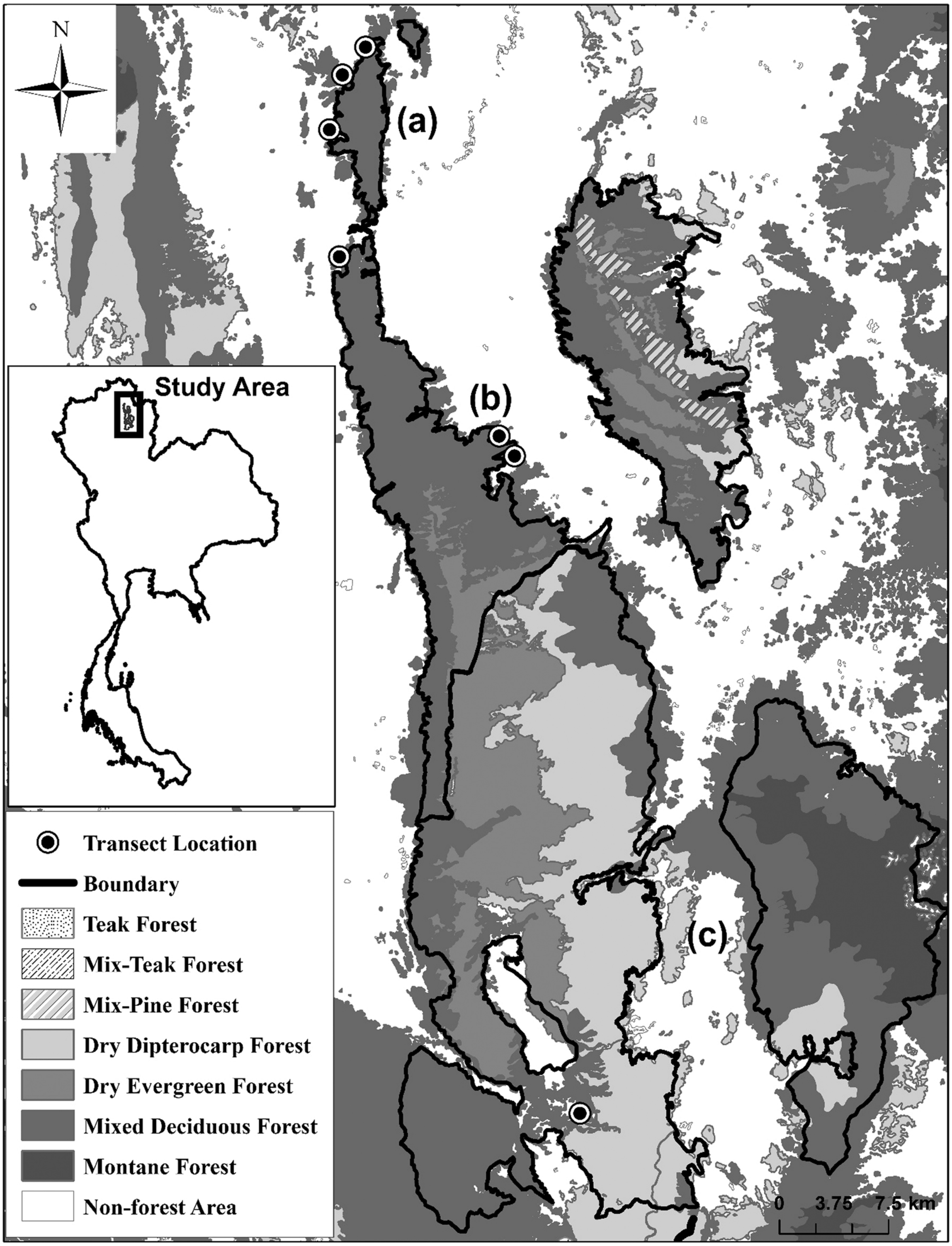

Fig. 1. Line transect locations in three protected areas: Tub Phaya Lor Wildlife non-hunting area (a), Wiang Lor Wildlife Sanctuary (b) and Doi Phu Nang National Park (c).

3.2. Data analysis

3.2.1. Habitat utilization

We analyzed micro-habitat selection by Green Peafowl using compositional analysis with the package adehabitatHS in program R (Calenge, 2006), which indicates any statistically significant habitat-type preferences or avoidance and ranks habitats in the order of preference (Aebischer et al., 1993; Shwe et al., 2021). We used a minimum of 1000 iterations in all tests (Smith, 2015).

3.3. Density estimation

The density of Green Peafowl was estimated by using sighting detections in DISTANCE (Buckland et al., 2015). To estimate the effect of crop types on the estimated densities, we started by categorizing crops into two types: open cropland (cropland and fallow) and closed cropland (orchards, timber plantations). We took into account as covariates the difference in line transect locations and habitat types (by stratified categories), which could affect peafowl detection. The key functions, including the half-normal and hazard-rate, were examined to select the best detectability function; the best model was chosen based on the lowest AIC value (Buckland, 2001). We then ran a t-test comparing the numbers of green peafowl detected in closed vs. open cropland over the 13 months' study period.

3.4. Investigation on variables influencing Green Peafowl selection

A generalized linear model (GLM) with a logit link function and negative-binomial distribution modeling was used to investigate the relationship between the bird number and given variables. We used the number of birds detected within different crop types in the transects as the response variable. The predictor variables were: 1) crop area, 2) distance to the forest edge, 3) crop stage and 4) presence of domestic dogs. There were five crop stages: 1) land preparation, 2) cultivation, 3) maturity, 4) harvest, and 5) postharvest stages (for details of crop types and stages see Table S1). We assessed the correlation between predictor variables before running the analysis. When two variables were highly correlated ($r > 0.7$), only the variable most relevant to the species was selected, based on Shwe et al. (2021). We ran both single and combined-variable models. We compared the model containing variables of interest with the base model containing just the constant term and measured the difference in Akaike's Information Criterion (AIC) and AIC weights between the two models. We were interested in the top model with the lowest AIC. A confidence interval of 95% was used to consider variables influencing the bird density. In the end, we compared the number of closed and open cropland detections using logistic regression.

4. Results

4.1. Habitat utilization

We detected Green Peafowl a total of 6983 times, including both direct sightings 6003 and calling 980 (only in the natural forest), during the 13 months of the survey. Of the sightings, 3145 (52%) were detected in orchards, 2220 (37%) in cropland, 419 in timber plantations (7%), 70 in fallow (1%) and 149 (2%) in forests (for detailed of habitat mosaic in each line transect with Green Peafowls detected see Figs. S1 to S3).

On average, there were 462 sightings per month, with the highest detected in December 2020 (798 detections) and the lowest in April 2020 (204 detections). Calling detection averaged 75 per month, with the highest found in February 2020 (219 detections) and the lowest (no detections), in August 2020 (Fig. S4).

Habitat selection in relation to availability was non-random (Wilk's $\lambda =$.

Table 1
Habitat types and coverage in the entire study area.

Categories		Habitat types	Area (km^2)	Area (%)
Forest	Forest	Forest	65.04	86.26
Open cropland	Cropland	Cassava	0.15	0.2
		Chili	0.01	0.01
		Corn	0.95	1.25
		Grass	0.01	0.01
		Rice	3.80	5.03
	Fallow	Fallow	0.24	0.31
Closed cropland	Orchard	Durian	0.01	0.02
		Jackfruit	0.00	0.01
		Longan	4.67	6.19
		Mulberry	0.02	0.03
	Timber	Rubble	0.51	0.67
		Teak	0.01	0.01
Total			75.41	100

0.00, $\chi^2 = 89.50$, df = 12, $P < 0.01$). The simplified ranking matrix of micro-habitat selection indicated durian plantation was the most utilized habitat ($P < 0.01$), followed by chili plantation and mulberry plantations (Table 2). Preference rankings for the main habitat categories were in the order of timber plantations > orchards > cropland > fallow, related to availability, with non-random habitat selection (Wilk's $\lambda = 0.02$, $\chi^2 = 51.90$, df = 4, $P < 0.01$) (Table 3).

The number of Green Peafowl detections in closed cropland was higher than in open cropland (3564 and 2290, respectively). Also, the detection distance further from forest edge was significantly higher in closed cropland (average 82.2 ± 1.47) than in open cropland (average 47.2 ± 1.19) (Logistic regression (Binomial): $n_{\text{closed cropland}} = 3564$, $n_{\text{open cropland}} = 2290$, $\beta = 0.01$, $P <$ 2E-16) (Fig. 2). While The comparison of the species' micro-habitat uses by Chi-square test showed mostly significant differences between pairs of habitat categories, except for 'timber with fallow" and "crop with fallow" (Table 4).

4.2. Density estimate

The Multiple Covariates Distance Sampling (MCDS) model without stratification using different line transects as covariates proved the fittest model based on its lowest AIC. The overall density estimate for the whole study area based on the total 6003 sightings was 11.83 birds/km^2. The density in closed cropland was estimated at 13.47 birds/km^2, while that in open cropland was 10.19 birds/km^2 (Table 5). A significantly higher number of green peafowl were detected in closed cropland (t-test; M= 274, SD=104) vs. open cropland (M= 176, SD=164), (t(12) = 2.5, $P = 0.03$).

4.3. Variables influencing Green Peafowl selection in agriculture landscapes

The best GLM model with lowest AIC included only two variables of crop stage and presence of domestic dogs, and showed three stages of crop and presence of domestic dogs significantly influencing the Green Peafowl number. Birds were detected in high numbers within crop fields at the post-harvest stage (stage 5, $\beta = 0.25$, CI: 0.04– 0.45) and in low numbers within crop fields during the land preparation (stage 1, $\beta = -0.81$, CI: −1.20 to −0.41) and maturity stages (stage 3, $\beta = -0.27$, CI: −0.51 to −0.02) and in crop areas where feral or domestic dogs were present ($\beta = -0.42$, CI: −0.53 to −0.31). While cultivation stage (stage 2, $\beta = -0.03$, CI: −0.37 to 0.32) and harvest stage (stage 4, $\beta = 0.14$, CI: −0.09 to 0.37) do not significantly influence bird number (Table 6).

5. Discussion

In agricultural landscapes, Green Peafowl selected, primarily, closed cropland (orchards and timber plantations) compared to open cropland (cropland, fallow and natural forest edges). The higher use of closed cropland, most likely due to its similarity to the species'

Table 2
Simplified ranking from compositional analysis for all available micro-habitat types across the entire study area, showing whether the habitat types in rows are selected (+), significantly selected (+++), avoided (-) or significantly avoided (—) relative to the habitat types in columns (*t* test P < 0.0001).

	Cas	Chil	Cor	Dur	Fal	For	Gra	Jac	Lon	Mul	Ric	Rub	Tea	Ranking
Dur	+ ++	+	+	0	+ ++	+ ++	+ ++	+ ++	+ ++	+	+ ++	+ ++	+ ++	12
Chil	+	0	+	-	+ ++	+ ++	+	+	+	+	+ ++	+	+	11
Mul	+	-	+	-	+ ++	+ ++	+	+	+	0	+ ++	+	+	10
Rub	+	-	+	—	+ ++	+ ++	+	+	+	-	+ ++	0	+	9
Cor	+	-	0	-	+ ++	+ ++	+	+	+	-	+ ++	-	+	8
Lon	+	-	-	—	+ ++	+ ++	+	+	0	-	+ ++	-	+	7
Cas	0	-	-	—	+ ++	+ ++	+	+	-	-	+ ++	-	+	6
Gra	-	-	-	—	+ ++	+ ++	0	+	-	-	+	-	+	5
Jac	-	-	-	—	+ ++	+ ++	-	0	-	-	+	-	+	4
Tea	-	-	-	—	+	+ ++	-	-	-	-	+	-	0	3
Ric	—	—	—	—	+	+ ++	-	-	—	—	0	—	-	2
Fal	—	—	—	—	0	+ ++	—	—	—	—	-	—	-	1
For	—	—	—	—	—	0	—	—	—	—	—	—	—	0

Note: Cas = Cassava, Chil= Chili, Cor = Corn, Dur = Durian, Fal = Fallow, For = Forest, Gra = Grass, Jac = Jackfriut, Lon = Longang, Mul = Mulberry, Ric = Rice, Rub = Rubber, and Tea = Teak

Table 3
Simplified ranking matrix of detections in all available habitat types showing whether the habitat types in rows are selected (+), significantly selected (+++), avoided (-) or significantly avoided (—) relative to habitat types in columns (*t* test P < 0.0001).

	Forest	Fallow	Orchard	Crop	Timber	Rank
Timber	+ ++	+ ++	+	+ ++	0	4
Orchard	+ ++	+ ++	0	+ ++	-	3
Crop	+ ++	+ ++	—	0	—	2
Fallow	+ ++	0	—	—	—	1
Forest	0	—	—	—	—	0

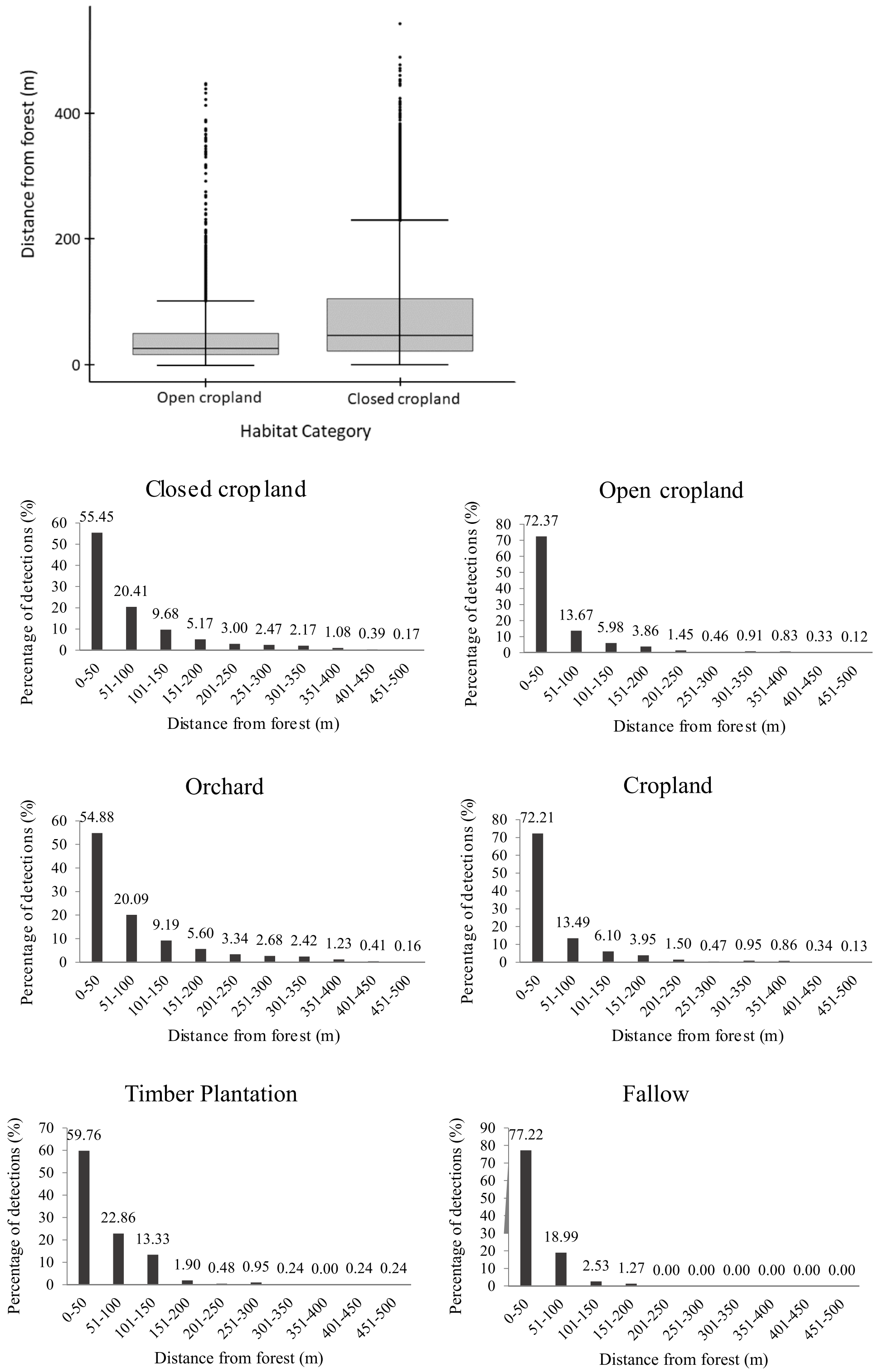

Fig. 2. The number of Green Peafowl detected within different distance ranges from the forest edge for each micro-habitat category.

Table 4
Comparison of the species' micro-habitat use performed by Chi-square test.

Comparison habitat types		X^2	df	*P- value*
Orchard	Crop	190.75	9	2.20E-16
Orchard	Fallow	21.495	9	0.01062
Orchard	Timber	47.695	9	2.91E-07
Timber	Fallow	12.2	8	0.1423
Crop	Timber	60.53	9	1.06E-09
Crop	Fallow	8.71	9	0.5

Table 5
Density estimates for Green Peafowl from 7 line transects in agriculture landscapes within two main habitat categories, closed habitat (canopy covered) and open habitat.

Categories	Number of transects	Number of observations	Total length (km)	Survey effort time of observations	Density estimates (bird/km^2)	95% confidence intervals
Pooled Estimated	7	6003	546	39	11.80	2.05–68.20
Closed	7	3713	546	39	13.50	13.20–13.80
Open	7	2290	546	39	10.20	9.90–10.50

Table 6
Variables that influence Green Peafowl selection in agriculture landscapes.

Parameters	β	SE	95%LCI	95%UCI
Crop stage 1[a]	-0.8135	0.2000	-1.2030	-0.4200
Crop stage 2	-0.0305	0.2000	-0.3730	0.3210
Crop stage 3[a]	-0.2717	0.1300	-0.5200	-0.0261
Crop stage 4	0.1411	0.1200	-0.0940	0.3730
Crop stage 5[a]	0.2501	0.1042	0.0430	0.4520
Dog presence[a]	-0.4222	0.0567	-0.5340	-0.3110

[a] Indicates significant influence of variables on Green Peafowl number.

natural habitat, also allowed the species to penetrate deeper into agricultural landscapes away from the forest edge. This could, in fragmented habitats, enable the species to travel between forest fragments or from a forest patch to open cropland during the harvest and post-harvest stages to forage.

The relatively high Green peafowl's density recorded in the agricultural area surrounding natural forest could be linked, as already suggested by Shwe et al. (2021), to the relatively high food availability found in it. However, detailed studies investigating the species diet in agricultural landscape are currently not available neither for this or for other areas. The higher density estimated in closed cropland (13.47 birds/km^2, CI 13.20–13.80) compared to open cropland (10.19 birds/km^2, CI 9.90–10.50) could be linked to the similarities of the former to the open understory structure Green Peafowl select within their natural forest habitat (Brickle, 2002). The pooled density estimate for closed and open cropland showed a wide range of the 95% confidence interval (2.05–68.20) despite the high detection number (6003) (Sinclair and Hobbs, 2009; Oono, 2017). That was most likely a consequence of variations in the habitat structure of closed and open cropland. When looking at the two categories separately, we saw that the 95% confidence interval shrank significantly (see Table 5).

Similar results were reported in southern Shan State (Myanmar) where Green Peafowl appear to prefer forest edges to the surrounding cropland (Shwe et al., 2021). The difference might be a result of the different landscape mosaics and structural complexities between the sites. Agricultural fields in Myanmar are composed uniquely of open cropland with forest edges as the only shelter available. On the other hand, the agricultural landscapes in our site combined a mixed matrix of open and closed cropland, providing a complex habitat mosaic and vegetation structure from ground to canopy levels, mimicking the mosaic structure found in the open dry forest habitats used by Green Peafowl (Sukumal et al., 2017; Saridnirun et al., 2021). The tall trees and dense canopy with clear understory found in plantations allow the species to extend their movement in anthropogenic landscapes (Ersoy et al., 2019; Ford et al., 2020) and further away from the natural habitat edges. Despite the lack of quantitative data on the species direct benefit from using closed cropland, our statistical analysis shows that those habitats were used significantly more than those representing open cropland. Mixed tree species of closed cropland attract mammals (Muhammad Aminuddin Baqi et al., 2020) and birds (Palomino and Carrascal, 2006), provide them shelter (Tu et al., 2020) and food resources (Jarrett et al., 2021), and allow them to disperse further from fragmented natural habitats (Theresa and Frank, 2015). Closed cropland also enables Green Peafowl to access open cropland located within and represents a primary feeding ground of the species in agricultural areas. From the maturity stage to the postharvest stage, crop products are available to the birds.

Following the limited availability of natural predators in the area (Saridnirun et al., 2021), the major threats to Green Peafowl foraging in cropland is represented by the disturbance and predation of feral and domestic dogs (Doherty et al., 2017; Yen et al., 2019) abundant around the protected forest patches at the study site (Marshall et al., in review). In agricultural landscapes surrounding fragmented forest patches, free-roaming dogs are driving wildlife species to extinction (Home et al., 2018). The result of our study showed a negative effect of domestic/feral dogs on Green Peafowl density with Green Peafowl generally avoid predators by running, and by concealing in denser vegetation (Hernowo et al., 2011), a vegetation structure more common to be found in closed vs. open cropland.

6. Conservation implications

From a conservation/management perspective, our results show that peafowl can use closed cropland to move away from forest edges, making such crop type a potentially suitable candidate to connect forest fragments. Crops have been shown to function as potential corridors for wildlife, including Green Peafowl (Win et al., 2023), allowing animals to move between forest fragments (Hilty et al., 2019), including mammals (Etana et al., 2021), birds (Withaningsih et al., 2020), reptiles and amphibians (Cabral et al., 2020). However, establishing suitable wildlife corridors must often take into account land ownership and associated benefits (Blackmore, 2020). As in the region most of agricultural land is owned by small farmers it will be extremely hard to convince them to renounce some of their land for complex multi-strata forest restoration as this will reduce their income below what is sufficient for their livelihood. Despite agreeing that "plantation corridors" are not ideal for all wildlife, we can consider it the best solution for the current available scenario. Moreover, forest regrowth to a level suitable for connectivity can be a long and complex process (Evans et al., 2017). Using suitable crops as wildlife corridors helps prevent conflict with private landowners and can save time as they usually grow faster than natural species (e.g., logan needs four years, mango around five years and rubber six years). Moreover, even small patches of diversified cropland have been shown to support Green Peafowl (Shwe et al., 2021), making them effective corridors. Therefore, closed cropland can facilitate wildlife conservation with appropriate management (Katayama et al., 2019b), for example, by providing financial benefits to local communities surrounding fragmented habitats to prevent conflicts with humans (Mekonen, 2020), as recorded for Indian Peafowl (*Pavo cristatus*) in paddy fields (Herath et al., 2021). The Green Peafowl in Shan State, Myanmar, are reported to be protected by monks in the local monastery nearby (Shwe et al., 2021). Conflict in our study area has largely been limited by the development of ecotourism using the species to attract tourists.

Our results have highlighted the importance of croplands, and in particular of closed cropland, for green Peafowl management and conservation. In this regard more questions are emerging on issues that might relate to the use of such habitats. First, the impact of agrochemicals and pesticides. These have proven to be deleteraous for wild birds as they could affect their health directly (Richard et al., 2021) and reduce their feeding sources, specifically in the case of insects (Møller et al., 2021). Second, as already mentioned the high density of birds found in croplands could be linked to the foraging resources those habitats represent. Detailed studies on this are recommended as similar aspects have been suggested for other sites (Shwe et al., 2021) and, more importantly from a conservation point of view, feeding directly on crops could results in human wildlife Conflicts (Saridnirun et al., 2021).

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ghan Saridnirun reports financial support was provided by King Mongkut's University of Technology Thonburi. Ghan Saridnirun reports a relationship with King Mongkut's University of Technology Thonburi that includes: funding grants. Ghan Saridnirun has patent King Mongkut's University of Technology Thonburi pending to Ghan Saridnirun.

Data availability

No data was used for the research described in the article.

Acknowledgments

This research was supported by King Mongkut's University of Technology Thonburi, Thailand, Petchra Phra Jom Klao Ph.D. Research Scholarship ID 6236080080562, the National Science and Technology Development Agency, Thailand ID P-19–50806, ASAHI Glass Foundation 2019 and the Department of National Parks, Wildlife and Plant Conservation, Thailand. Special thanks to the Chiefs and officers of the four protected areas for their assistance in the field.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2023.e02487.

References

Aebischer, N.J., Robertson, P.A., Kenward, R.E., 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74, 1313–1325.

BirdLife International, 2018, Pavo muticus. The IUCN Red List of Threatened Species (2018). e.T22679440A131749282. ⟨https://doi.org/10.2305/IUCN.UK.2018–2.RLTS.T22679440A131749282.en⟩. accessed 04 September 2022.

Blackmore, A., 2020. Climate change and the ownership of game: A concern for fenced wildlife areas. Koedoe 62, 1–5.
Borges, F., Glemnitz, M., Schultz, A., Stachow, U., 2017. Assessing the habitat suitability of agricultural landscapes for characteristic breeding bird guilds using landscape metrics. Environ. Monit. Assess. 189, 166.
Brickle, N.W., 2002. Habitat use, predicted distribution and conservation of green peafowl (Pavo muticus) in Dak Lak Province, Vietnam. Biol. Conserv. 105, 189–197.
Buckland, S.T., 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press,.
Buckland, S.T., Rexstad, E.A., Marques, T.A., Oedekoven, C.S., 2015. Distance Sampling: Methods and Applications. Springer International Publishing,, Switzerland.
Cabral, H., Coronel-Bejarano, D., Ruiz, R., Cañete, L., Britez, E., Rojas, V., 2020. Living in the shadows: Diversity of amphibians, reptiles and birds in shade-grown yerba mate (Ilex paraguariensis) plantations. Austral Ecol. 45, 1123–1134.
Calenge, C., 2006. The package adehabitat for the R software: tool for the analysis of space and habitat use by animals. Ecol. Model. 197, 1035.
Doherty, T.S., Dickman, C.R., Glen, A.S., Newsome, T.M., Nimmo, D.G., Ritchie, E.G., Vanak, A.T., Wirsing, A.J., 2017. The global impacts of domestic dogs on threatened vertebrates. Biol. Conserv. 210, 56–59.
Ersoy, E., Jorgensen, A., Warren, P.H., 2019. Identifying multispecies connectivity corridors and the spatial pattern of the landscape. Urban For. Urban Green. 40, 308–322.
Etana, B., Atickem, A., Tsegaye, D., Bekele, A., De Beenhouwer, M., Hundera, K., Lens, L., Fashing, P.J., Stenseth, N.C., 2021. Traditional shade coffee forest systems act as refuges for medium- and large-sized mammals as natural forest dwindles in Ethiopia. Biol. Conserv. 260, 109219.
Evans, L.J., Goossens, B., Asner, G.P., 2017. Underproductive agriculture aids connectivity in tropical forests. For. Ecol. Manag. 401, 159–165.
Ford, A.T., Sunter, E.J., Fauvelle, C., Bradshaw, J.L., Ford, B., Hutchen, J., Phillipow, N., Teichman, K.J., 2020. Effective corridor width: linking the spatial ecology of wildlife with land use policy. Eur. J. Wildl. Res. 66, 69.
Gaüzère, P., Barbaro, L., Calatayud, F., Princé, K., Devictor, V., Raison, L., Sirami, C., Balent, G., 2020. Long-term effects of combined land-use and climate changes on local bird communities in mosaic agricultural landscapes. Agric., Ecosyst. Environ. 289, 106722.
Hendershot, J.N., Smith, J.R., Anderson, C.B., Letten, A.D., Frishkoff, L.O., Zook, J.R., Fukami, T., Daily, G.C., 2020. Intensive farming drives long-term shifts in avian community composition. Nature 579, 393–396.
Herath, H., Gunathilake, K., Chandrasekara, C., 2021. A Site Specific Study on Peacock and Human Conflict—A Case Study from Jayanthipura Grama Niladhari Division. Polonnaruwa—Sri Lanka. In Multi-Hazard Early Warning and Disaster Risks. Springer,, pp. 211–221.
Hernowo, J.B., Mardiastuti, A.N.I., Alikodra, H.S., Kusmana, C., 2011. Behavior Ecology of the Javan Green Peafowl (Pavo muticus muticus Linnaeus 1758) in Baluran and Alas Purwo National Park, East Java. HAYATI J. Biosci. 18, 164–176.
Hilty, J.A., Keeley, A.T.H., Merenlender, A.M., Lidicker, W.Z., 2019. Corridor Ecology. Linking Landscapes for Biodiversity Conservation and Climate Adaptation, Second edition.,. Island Press,.
Home, C., Bhatnagar, Y.V., Vanak, A.T., 2018. Canine Conundrum: domestic dogs as an invasive species and their impacts on wildlife in India. Anim. Conserv. 21, 275–282.
Jarrett, C., Smith, T.B., Claire, T.T.R., Ferreira, D.F., Tchoumbou, M., Elikwo, M.N.F., Wolfe, J., Brzeski, K., Welch, A.J., Hanna, R., Powell, L.L., 2021. Bird communities in African cocoa agroforestry are diverse but lack specialized insectivores. J. Appl. Ecol. 58, 1237–1247.
Katayama, N., Osada, Y., Mashiko, M., Baba, Y.G., Tanaka, K., Kusumoto, Y., Okubo, S., Ikeda, H., Natuhara, Y., 2019a. Organic farming and associated management practices benefit multiple wildlife taxa: A large-scale field study in rice paddy landscapes. J. Appl. Ecol. 56, 1970–1981.
Katayama, N., Bouam, I., Koshida, C., Baba, Y.G., 2019b. Biodiversity and yield under different land-use types in orchard/vineyard landscapes: A meta-analysis. Biol. Conserv. 229, 125–133.
Kehoe, L., Romero-Muñoz, A., Polaina, E., Estes, L., Kreft, H., Kuemmerle, T., 2017. Biodiversity at risk under future cropland expansion and intensification. Nat. Ecol. Evol. 1, 1129–1135.
Laurance, W.F., Sayer, J., Cassman, K.G., 2014. Agricultural expansion and its impacts on tropical nature. Trends Ecol. Evol. 29, 107–116.
Marshall, H.E., Sukumal, N., Ngoprasert, D. ([__])#38; Savini, T. (in preparation) The Spatial and Temporal Displacement of Native Species by Domestic Dogs. Global Ecology and Conservation. Coming soon.
Mekonen, S., 2020. Coexistence between human and wildlife: the nature, causes and mitigations of human wildlife conflict around Bale Mountains National Park, Southeast Ethiopia. BMC Ecol. 20, 51.
Møller, A.P., Czeszczewik, D., Flensted-Jensen, E., Erritzøe, J., Krams, I., Laursen, K., Liang, W., Walankiewicz, W., 2021. Abundance of insects and aerial insectivorous birds in relation to pesticide and fertilizer use. Avian Res. 12, 43.
Muhammad Aminuddin Baqi, H.F., Mohamad Iqbal, N.H., Nur Nabilah, A.R., Nur Ain Aiman, A.R., Suganthi, A., Fong, P.H. & Jayaraj, V.K. (2020) The diversity of small mammals in a mixed fruit orchard at Bukit Bekong limestone massif, Merapoh, Pahang, Malaysia. IOP Conference Series: Earth and Environmental Science, 596, 012073.
Muñoz-Sáez, A., Heaton, E.E., Reynolds, M., Merenlender, A.M., 2020. Agricultural adapters from the vineyard landscape impact native oak woodland birds. Agric., Ecosyst. Environ. 300, 106960.
Olivier, T., Thébault, E., Elias, M., Fontaine, B., Fontaine, C., 2020. Urbanization and agricultural intensification destabilize animal communities differently than diversity loss. Nat. Commun. 11, 2686.
Oono, R., 2017. A confidence interval analysis of sampling effort, sequencing depth, and taxonomic resolution of fungal community ecology in the era of high-throughput sequencing. PLOS ONE 12, e0189796.
Palomino, D., Carrascal, L.M., 2006. Urban influence on birds at a regional scale: A case study with the avifauna of northern Madrid province. Landsc. Urban Plan. 77, 276–290.
Richard, F.-J., Southern, I., Gigauri, M., Bellini, G., Rojas, O., Runde, A., 2021. Warning on nine pollutants and their effects on avian communities. Glob. Ecol. Conserv. 32, e01898.
Sanz-Pérez, A., Giralt, D., Robleño, I., Bota, G., Milleret, C., Mañosa, S., Sardà-Palomera, F., 2019. Fallow management increases habitat suitability for endangered steppe bird species through changes in vegetation structure. J. Appl. Ecol. 56, 2166–2175.
Saridnirun, G., Sukumal, N., Grainger, M.J., Savini, T., 2021. Living with human encroachment: Status and distribution of Green Peafowl in northern stronghold of Thailand. Glob. Ecol. Conserv. 28, e01674.
Savini, T., Namkhan, M., Sukumal, N., 2021. Conservation status of Southeast Asian natural habitat estimated using Galliformes spatio-temporal range decline. Glob. Ecol. Conserv. 29, e01723.
Scanes, C.G., 2018. Chapter 19 - Human Activity and Habitat Loss: Destruction, Fragmentation, and Degradation. In: Scanes, C.G., Toukhsati, S.R. (Eds.), Animals and Human Society. Academic Press, pp. 451–482.
Shwe, N.M., Sukumal, N., Oo, K.M., Dowell, S., Browne, S., Savini, T., 2021. Importance of isolated forest fragments and low intensity agriculture for the long-term conservation of the green peafowl Pavo muticus. Oryx 1–7.
Sinclair, E.A., Hobbs, R.J., 2009. Sample Size Effects on Estimates of Population Genetic Structure: Implications for Ecological Restoration. Restor. Ecol. 17, 837–844.
Smith, P.G., 2015. Compos Analysis Version 6.3 User's Guide Issue 2. Smith Ecology Ltd.,, Abergavenny, UK.
Sodhi, N.S., Lee, T.M., Koh, L.P., Brook, B.W., 2009. A Meta-Analysis of the Impact of Anthropogenic Forest Disturbance on Southeast Asia's Biotas. Biotropica 41, 103–109.
Sodhi, N.S., Koh, L.P., Clements, R., Wanger, T.C., Hill, J.K., Hamer, K.C., Clough, Y., Tscharntke, T., Posa, M.R.C., Lee, T.M., 2010. Conserving Southeast Asian forest biodiversity in human-modified landscapes. Biol. Conserv. 143, 2375–2384.
Sukumal, N., Dowell, S.D., Savini, T., 2017. Micro-habitat selection and population recovery of the Endangered Green Peafowl Pavo muticus in western Thailand: implications for conservation guidance. Bird. Conserv. Int. 27, 414–430.
Sukumal, N., Dowell, S.D., Savini, T., 2020. Modelling occurrence probability of the Endangered green peafowl Pavo muticus in mainland South-east Asia: applications for landscape conservation and management. Oryx 54, 30–39.

Theresa, M.N., Frank, W.D., 2015. Can Orchards Help Connect Mediterranean Ecosystems? Animal Movement Data Alter Conservation Priorities. Am. Midl. Nat. 174, 105–116.
TMD, 2022, Thai Meteorological Department.
Tu, H.-M., Fan, M.-W., Ko, J.C.-J., 2020. Different Habitat Types Affect Bird Richness and Evenness. Sci. Rep. 10, 1221.
Win, L., Sukumal, N., Shwe, N.M., Savini, T., 2023. Teak plantations are complementary habitat for Green Peafowl within the fragmented Bago Yoma range, south-central Myanmar. Ornithol. Appl. 125 duac051.
Withaningsih, S., Parikesit, Rizka Fatharani, A., 2020. Diversity of bird species in the coffee agroforestry landscape: Case study in the Pangalengan Sub-district, Bandung District, West Java, Indonesia. Biodiversitas Journal of Biological Diversity, p. 21.
Yen, S.-C., Ju, Y.-T., Shaner, P.-J.L., Chen, H.L., 2019. Spatial and temporal relationship between native mammals and free-roaming dogs in a protected area surrounded by a metropolis. Sci. Rep. 9, 8161.
Zabel, F., Delzeit, R., Schneider, J.M., Seppelt, R., Mauser, W., Václavík, T., 2019. Global impacts of future cropland expansion and intensification on agricultural markets and biodiversity. Nat. Commun. 10, 2844.