Supplementary material for: Influence of land cover and climate on the occupancy of avian distributions along a tropical montane gradient

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Contents

1 Introduction

This is supplementary material for a project in preparation that models occupancy for birds in the Nilgiri hills. The main project can be found here: https://github.com/pratikunterwegs/eBirdOccupancy.

1.1 Attribution

Please contact the following in case of interest in the project.

- Vijay Ramesh (lead author)
  - PhD student, Columbia University
- Pratik Gupte (repo maintainer)
  - PhD student, University of Groningen
- Morgan Tingley (PI)

2 Distance to roads

2.1 Prepare libraries

```r
# load libraries
library(reticulate)
library(sf)
library(dplyr)
library(scales)
library(readr)
library(purrr)

library(ggplot2)
library(ggthemes)
library(ggspatial)
library(scico)

# round any function
round_any <- function(x, accuracy = 20000){round(x/accuracy)*accuracy}
# ci function
ci <- function(x){qnorm(0.975)*sd(x, na.rm = TRUE)/sqrt(length(x))}
```

```
# set python path
use_python(”/usr/bin/python3”)
```

Importing python libraries.

```
# import classic python libs
import itertools
from operator import itemgetter
import numpy as np
import matplotlib.pyplot as plt
import math

# libs for dataframes
import pandas as pd

# import libs for geodata
from shapely.ops import nearest_points
import geopandas as gpd
import rasterio

# import ckdtree
from scipy.spatial import cKDTree
from shapely.geometry import Point, MultiPoint, LineString, MultiLineString
```

2.2 Prepare data for processing

```
# read in roads shapefile
roads = gpd.read_file(”data/spatial/roads_studysite_2019/roads_studysite_2019.shp”)
roads.head()

# read in checklist covariates for conversion to gpd
# get unique coordinates, assign them to the df
# convert df to geo-df
chkCovars = pd.read_csv(”data/eBirdChecklistVars.csv”)
unique_locs = chkCovars.drop_duplicates(subset=['longitude','latitude'])[['longitude', 'latitude']]
unique_locs['coordId'] = np.arange(1, unique_locs.shape[0]+1)
chkCovars = chkCovars.merge(unique_locs, on=['longitude', 'latitude'])

unique_locs = gpd.GeoDataFrame(
unique_locs,
geometry=gpd.points_from_xy(unique_locs.longitude, unique_locs.latitude))
unique_locs.crs = {'init' :'epsg:4326'}

# reproject spatials to 43n epsg 32643

roads = roads.to_crs({'init': 'epsg:32643'})
unique_locs = unique_locs.to_crs({'init': 'epsg:32643'})


# function to simplify multilinestrings
def simplify_roads(complex_roads):
    simpleRoads = []
    for i in range(len(complex_roads.geometry)):
        feature = complex_roads.geometry.iloc[i]
        if feature.geom_type == ”LineString”:
            simpleRoads.append(feature)
        elif feature.geom_type == ”MultiLineString”:
            for road_level2 in feature:
                simpleRoads.append(road_level2)
    return simpleRoads


# function to use ckdtrees for nearest point finding
def ckdnearest(gdfA, gdfB):
    A = np.concatenate(
    [np.array(geom.coords) for geom in gdfA.geometry.to_list()])
    simplified_features = simplify_roads(gdfB)
    B = [np.array(geom.coords) for geom in simplified_features]
    B = np.concatenate(B)
    ckd_tree = cKDTree(B)
    dist, idx = ckd_tree.query(A, k=1)
    return dist


# function to use ckdtrees for nearest point finding
def ckdnearest_point(gdfA, gdfB):
    A = np.concatenate(
    [np.array(geom.coords) for geom in gdfA.geometry.to_list()])
    #simplified_features = simplify_roads(gdfB)
    B = np.concatenate(
    [np.array(geom.coords) for geom in gdfB.geometry.to_list()])
    #B = np.concatenate(B)
    ckd_tree = cKDTree(B)
    dist, idx = ckd_tree.query(A, k=[2])
    return dist


# get distance to nearest road
unique_locs['dist_road'] = ckdnearest(unique_locs, roads)

# get distance to nearest other site
unique_locs['nnb'] = ckdnearest_point(unique_locs, unique_locs)

# write to file
unique_locs = pd.DataFrame(unique_locs.drop(columns='geometry'))
unique_locs['dist_road'] = unique_locs['dist_road']
unique_locs['nnb'] = unique_locs['nnb']
unique_locs.to_csv(path_or_buf=”data/locs_dist_to_road.csv”, index=False)

# merge unique locs with chkCovars
chkCovars = chkCovars.merge(unique_locs, on=['latitude', 'longitude', 'coordId'])
```

2.3 Species specific nearest sites

```
# load data and send to python
load(”data_prelim_processing.rdata”)
py$data <- dataGrouped
```

```
# split data by species
datalist = [pd.DataFrame(y) for x, y in data.groupby('scientific_name', as_index=False)]
```

```
# function to get unique vals anc convert to gpd
def convData(somedata):
    somedata = somedata.drop_duplicates(subset=['longitude','latitude'])[['longitude', 'latitude', 'scientif
    unique_locs = gpd.GeoDataFrame(somedata,
                                  geometry=gpd.points_from_xy(somedata.longitude,
                                  somedata.latitude))
    unique_locs.crs = {'init' :'epsg:4326'}
    unique_locs = unique_locs.to_crs({'init': 'epsg:32643'})
    dists = ckdnearest_point(unique_locs, unique_locs)
    unique_locs = pd.DataFrame(unique_locs.drop(columns='geometry'))
    unique_locs['nnb'] = dists
    return unique_locs


# apply function to datalist
datalist = list(map(convData, datalist))
```

2.4 Explicit spatial filter

```
# extract data from python
chkCovars <- py$chkCovars
chkCovars <- st_as_sf(chkCovars, coords = c(”longitude”, ”latitude”)) %>%
  `st_crs<-`(4326) %>%
  st_transform(32643)

# read wg
wg <- st_read(”data/spatial/hillsShapefile/Nil_Ana_Pal.shp”) %>%
  st_transform(32643)

# spatial subset
chkCovars <- chkCovars %>%
  mutate(id = 1:nrow(.)) %>%
  filter(id %in% unlist(st_contains(wg, chkCovars)))
```

2.5 Species specific filter

```
# extract values from python
sp_spec_data <- py$datalist

sp_spec_data <- map(sp_spec_data, function(df){
  df <- as_tibble(df) %>%
    st_as_sf(coords = c(”longitude”, ”latitude”)) %>%
    `st_crs<-`(4326) %>%
    st_transform(32643) %>%
    mutate(id = 1:nrow(.)) %>%
    filter(id %in% unlist(st_contains(wg, .))) %>%
    st_drop_geometry()
})

sp_spec_data <- bind_rows(sp_spec_data)
```

2.6 Plot histogram: distance to roads

```r
# make histogram
hist_roads <- ggplot(chkCovars)+
  geom_histogram(aes(dist_road / 1e3),
                 bins = 20, size=0.2, fill="steelblue")+
  labs(x = "distance to roads (km)", y = "# checklists")+
  scale_x_log10(label=label_number(accuracy = 0.1),
                breaks = c(0.1, 1, 10))+
  scale_y_continuous(label=label_number(scale=0.001, accuracy = 1, suffix = "K"))+
  theme_few()+
  theme(plot.background = element_rect(fill=NA, colour = 1),
        panel.background = element_blank(),
        panel.border = element_blank(), axis.line = element_blank())
```

2.7 Table: Distance to roads

```r
# write the mean and ci95 to file
chkCovars %>%
  st_drop_geometry() %>%
  select(dist_road, nnb) %>%
  tidyr::pivot_longer(cols = c("dist_road", "nnb"),
                      names_to = "variable") %>%
  group_by(variable) %>%
  summarise_at(vars(value),
               list(~mean(.), ~sd(.), ~min(.), ~max(.))) %>%
  write_csv("data/results/distance_roads_sites.csv")

# read in and show
library(magrittr)
readr::read_csv("data/results/distance_roads_sites.csv") %>%
  knitr::kable()
```

variable	mean	sd	min	max
dist_road	390	859	0.279	7637
nnb	297	553	0.137	12850

2.8 Plot histogram: distance to nearest site

```r
# get unique locations
locs <- py$unique_locs

# make histogram of nearest neighbours
hist_sites <-
  ggplot(locs)+
  geom_histogram(aes(nnb / 1e3),
                 bins = 100, size=0.2, fill="steelblue")+
  labs(x = "dist. nearest site (km)", y = "# sites")+
  # scale_x_log10(label=label_number(accuracy = 0.1),
  #               breaks = c(0.1, 1, 10))+
  coord_cartesian(xlim=c(0,10))+
  scale_y_continuous(label=label_number(scale=0.001, accuracy = 1, suffix = "K"))+
  theme_few()+
  theme(plot.background = element_rect(fill=NA, colour = 1),
        panel.background = element_blank(),
        panel.border = element_blank(), axis.line = element_blank())
```

2.9 Plot species specific histograms: distance to nearest site

```
# plot histograms by species
hist_sites_sp <-
  ggplot(sp_spec_data)+
  geom_histogram(aes(nnb / 1e3),
                 bins = 100, size=0.2, fill=”steelblue”)+
  labs(x = ”dist. nearest site (km)”, y = ”# sites”)+
  # scale_x_log10(label=label_number(accuracy = 0.1),
  #               breaks = c(0.1, 1, 10))+
  facet_wrap(~scientific_name)+
  scale_x_log10()+
  #coord_cartesian(xlim=c(0,10))+
  scale_y_continuous(label=label_number(scale=0.001, accuracy = 1, suffix = ”K”))+
  theme_few()+
  theme(plot.background = element_rect(fill=NA, colour = 1),
        panel.background = element_blank(),
        panel.border = element_blank(), axis.line = element_blank())

ggsave(hist_sites_sp, filename = ”figs/fig_nnb_species.png”)
```

2.10 Table: Species specific nearest site

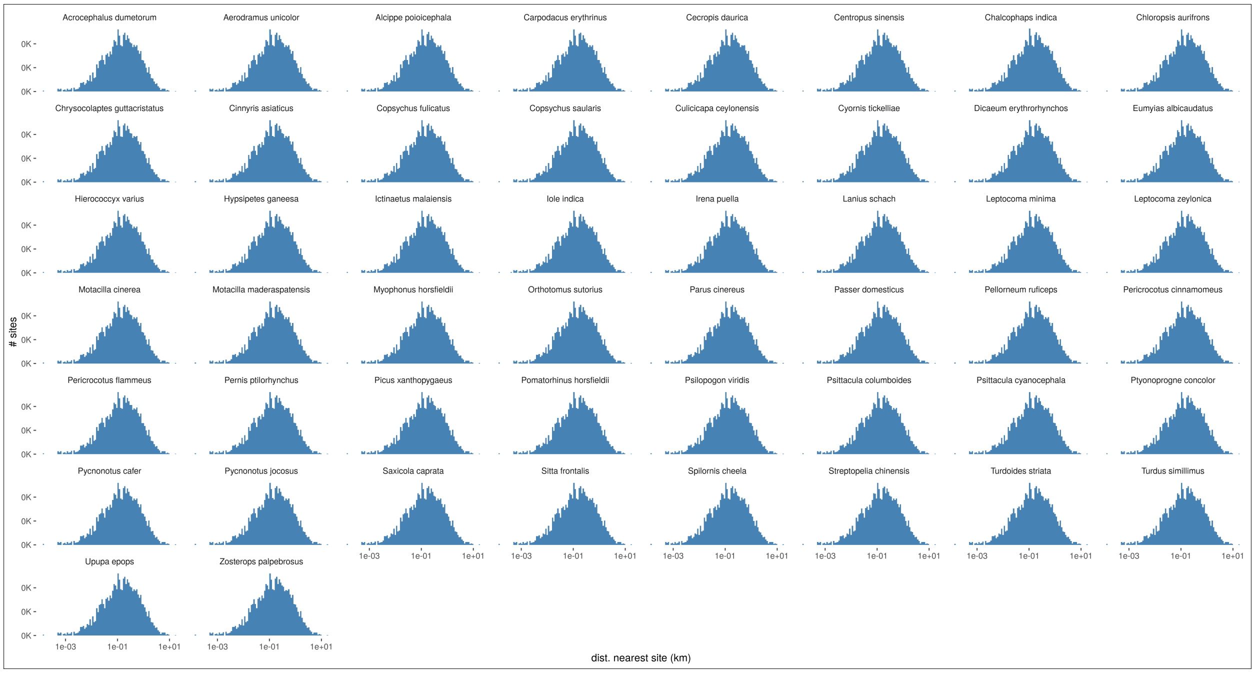
```
# write the mean and ci95 to file
sp_spec_data %>%
  group_by(scientific_name) %>%
  summarise_at(vars(nnb),
               list(~mean(.), ~sd(.), ~ci(.), ~min(.), ~max(.))) %>%
  write_csv(”data/results/dist_nnb_species_specific.csv”)

# show table of distance to nearest site for each species
readr::read_csv(”data/results/dist_nnb_species_specific.csv”) %>%
  knitr::kable()
```

scientific_name	mean	sd	ci	min	max
Alcippe poioicephala	417	808	25.0	0.137	16461
Carpodacus erythrinus	416	808	25.0	0.137	16461
Centropus sinensis	417	808	25.0	0.137	16461
Chalcophaps indica	417	808	25.0	0.137	16461
Chloropsis aurifrons	417	809	25.0	0.137	16461
Chrysocolaptes guttacristatus	417	808	25.0	0.137	16461
Cinnyris asiaticus	417	808	25.0	0.137	16461
Copsychus fulicatus	417	808	25.0	0.137	16461
Copsychus saularis	417	808	25.0	0.137	16461
Culicicapa ceylonensis	417	808	25.0	0.137	16461
Cyornis tickelliae	417	808	25.0	0.137	16461
Dicaeum erythrorhynchos	416	808	25.0	0.137	16461
Eumyias albicaudatus	417	808	25.0	0.137	16461
Hierococcyx varius	417	808	25.0	0.137	16461
Hypsipetes ganeesa	417	808	25.0	0.137	16461
Iole indica	418	810	25.1	0.137	16461
Irena puella	417	808	25.0	0.137	16461
Lanius schach	417	808	25.0	0.137	16461
Leptocoma minima	417	808	25.0	0.137	16461
Leptocoma zeylonica	417	808	25.0	0.137	16461
Motacilla maderaspatensis	417	808	25.0	0.137	16461
Myophonus horsfieldii	417	808	25.0	0.137	16461
Orthotomus sutorius	417	808	25.0	0.137	16461
Parus cinereus	417	808	25.0	0.137	16461
Passer domesticus	417	808	25.0	0.137	16461
Pellorneum ruficeps	417	808	25.0	0.137	16461
Pericrocotus cinnamomeus	417	808	25.0	0.137	16461
Pericrocotus flammeus	417	808	25.0	0.137	16461
Picus xanthopygaeus	417	808	25.0	0.137	16461
Pomatorhinus horsfieldii	417	808	25.0	0.137	16461
Psilopogon viridis	417	808	25.0	0.137	16461
Psittacula columboides	417	808	25.0	0.137	16461
Psittacula cyanocephala	417	808	25.0	0.137	16461
Pycnonotus cafer	417	808	25.0	0.137	16461
Pycnonotus jocosus	417	808	25.0	0.137	16461
Saxicola caprata	417	808	25.0	0.137	16461
Sitta frontalis	417	808	25.0	0.137	16461
Streptopelia chinensis	417	808	25.0	0.137	16461
Turdoides striata	418	810	25.1	0.137	16461
Turdus simillimus	417	808	25.0	0.137	16461
Upupa epops	417	808	25.0	0.137	16461
Zosterops palpebrosus	417	808	25.0	0.137	16461

Histograms showing the species-specific distances to nearest neighbouring site.

```r
knitr::include_graphics("figs/fig_nnb_species.png")
```



2.11 Plot map: points on roads

```
roads <- st_read(”data/spatial/roads_studysite_2019/roads_studysite_2019.shp”) %>%
  st_transform(32643)
points <- chkCovars %>%
  bind_cols(as_tibble(st_coordinates(.))) %>%
  st_drop_geometry() %>%
  mutate(X = round_any(X, 2500), Y = round_any(Y, 2500))

points <- count(points, X,Y)

# add land
library(rnaturalearth)
land <- ne_countries(scale = 50, type = ”countries”, continent = ”asia”,
                     country = ”india”,
                     returnclass = c(”sf”)) %>%
  st_transform(32643)

bbox <- st_bbox(wg)

# plot on maps
ggplot()+
  geom_sf(data = land, fill = ”grey90”, col = NA)+
  geom_sf(data = wg, fill= NA, col = 1)+
  annotation_custom(grob = hist_roads %>% ggplotGrob(),
                    xmin = bbox[”xmax”] - (bbox[”xmax”] - bbox[”xmin”])/2.5,
                    xmax = bbox[”xmax”],
                    ymin = bbox[”ymax”] - (bbox[”ymax”] - bbox[”ymin”])/3,
                    ymax = bbox[”ymax”])+
  geom_tile(data=points, aes(X,Y,fill=n), col = ”grey90”)+

  geom_sf(data=roads, size=0.2, col=”steelblue”)+
  # scale_colour_manual(values = "steelblue", labels = "roads")+

  scale_fill_scico(trans = "log10", palette = "lajolla", values=c(0, 1))+
  annotation_north_arrow(location = "br", which_north = "true",
                         pad_x = unit(0.1, "in"), pad_y = unit(0.5, "in"),
                         style = north_arrow_fancy_orienteering) +
  annotation_scale(location = "br", width_hint = 0.4, text_cex = 1) +

  theme_few()+
  theme(legend.position = c(0.9,0.55),
        legend.background = element_blank(),
        legend.key = element_rect(fill="grey90"),
        axis.title = element_blank(),
        panel.background = element_rect(fill="lightblue"))+
  coord_sf(expand = FALSE, xlim = bbox[c("xmin", "xmax")], ylim = bbox[c("ymin", "ymax")])+
  labs(fill = "checklists", colour=NULL)

# save figure
ggsave(filename = "figs/fig_distRoads.png", device = png())
dev.off()

# transform points to utm
locs <- locs %>%
  st_as_sf(coords=c("longitude", "latitude")) %>%
  `st_crs<-`(4326) %>%
  st_transform(32643)

# add nnb to locations
ggplot()+
  geom_sf(data = land, fill = "grey90", col = NA)+
  geom_sf(data = wg, fill= NA, col = 1)+
  annotation_custom(grob = hist_sites %>% ggplotGrob(),
                    xmin = bbox["xmax"] - (bbox["xmax"] - bbox["xmin"])/2.5,
                    xmax = bbox["xmax"],
                    ymin = bbox["ymax"] - (bbox["ymax"] - bbox["ymin"])/3,
                    ymax = bbox["ymax"])+
  geom_sf(data=roads, size=0.2, col="steelblue")+
  geom_sf(data=locs, aes(col=nnb/1000))+

  scale_colour_scico(palette = "oslo", values=c(0, 1), direction = -1, limits = c(0, 5),
                     na.value = "indianred")+

  annotation_north_arrow(location = "br", which_north = "true",
                         pad_x = unit(0.1, "in"), pad_y = unit(0.5, "in"),
                         style = north_arrow_fancy_orienteering) +
  annotation_scale(location = "br", width_hint = 0.4, text_cex = 1) +

  theme_few()+
  theme(legend.position = c(0.9,0.55),
        legend.background = element_blank(),
        legend.key = element_rect(fill="grey90"),
        axis.title = element_blank(),
        panel.background = element_rect(fill="lightblue"))+
  coord_sf(expand = FALSE, xlim = bbox[c("xmin", "xmax")], ylim = bbox[c("ymin", "ymax")])+
```