output4 continents-sr

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2020/8/18

## Load the packages

Load some packages for manipulating and modelling the data

library(maps)  
library(devtools)  
library(predictsFunctions)  
library(StatisticalModels)  
library(raster)  
library(dplyr)  
library(tidyr)  
library(lme4)  
library(car)  
library(DHARMa)  
library(MuMIn)  
library(Hmisc)  
library(ggplot2)  
library(gstat)  
library(scatterplot3d)

## Read in and process the diversity data

diversity <- readRDS("/Users/dd/Desktop/PREDICTS data/database.rds")  
diversity <- mutate(diversity,   
 Measurement = Effort\_corrected\_measurement,  
 Sampling\_effort = Rescaled\_sampling\_effort)

An optional step to merge any sites that are within the same land-use type and that have identical coordinates, start and end dates.

diversity <- MergeSites(diversity, silent = TRUE)

## Calculate the diversity metrics

sites <- diversity %>%  
   
 # add Diversity\_metric\_is\_valid column  
 mutate(Diversity\_metric\_is\_valid = TRUE) %>%  
   
 # calculate SiteMetrics   
 SiteMetrics(extra.cols = c("SSB", "SSBS", "Predominant\_land\_use", "UN\_region"))

## Computing site metrics for 2906994 measurements  
## The data contain 480 sources, 666 studies and 22678 sites  
## Computing site-level values  
## Computing total abundance  
## Computing species richness  
## Assembling site-level values

sites <- sites %>%  
   
 mutate(  
   
 # collapse primary forest and non-forest together into primary vegetation as these aren't well distinguished  
 Predominant\_land\_use = recode\_factor(Predominant\_land\_use,   
 "Primary forest" = "Primary vegetation",   
 "Primary non-forest" = "Primary vegetation"),  
   
 # indeterminate secondary veg and cannot decide get NA  
 Predominant\_land\_use = na\_if(Predominant\_land\_use, "Secondary vegetation (indeterminate age)"),  
 Predominant\_land\_use = na\_if(Predominant\_land\_use, "Cannot decide"),  
   
 # set reference levels  
 Predominant\_land\_use = factor(Predominant\_land\_use),  
 Predominant\_land\_use = relevel(Predominant\_land\_use, ref = "Primary vegetation")  
 )

## Model site-level diversity

Step 1: collinearity

source("/Users/dd/HighstatLib10.R")  
corvif(sites[ , c("Species\_richness", "UN\_region")])

##   
##   
## Variance inflation factors  
##   
## GVIF Df GVIF^(1/2Df)  
## Species\_richness 1.006039 1 1.003015  
## UN\_region 1.006039 4 1.000753

Step 2: complete cases

model\_data <- drop\_na(sites, Species\_richness, Predominant\_land\_use, UN\_region)

Step 3: starting/maximal model

m4 <- glmer(Species\_richness ~ Predominant\_land\_use\*UN\_region + (1|SS) + (1|SSB), data = model\_data, family = poisson)

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :  
## Model failed to converge with max|grad| = 0.00776637 (tol = 0.002, component 1)

m5 <- glmer(Species\_richness ~ Predominant\_land\_use\*UN\_region + (1|SS) + (1|SSB) + (1|SSBS), data = model\_data, family = poisson)

## Warning in (function (fn, par, lower = rep.int(-Inf, n), upper = rep.int(Inf, :  
## failure to converge in 10000 evaluations

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :  
## Model failed to converge with max|grad| = 0.0340254 (tol = 0.002, component 1)

# compare the models using Akaike's Information Criterion (AIC)  
AIC(m4,m5)

## df AIC  
## m4 42 129291.4  
## m5 43 118795.9

# have a look at the significance of the terms  
Anova(m5)

## Analysis of Deviance Table (Type II Wald chisquare tests)  
##   
## Response: Species\_richness  
## Chisq Df Pr(>Chisq)   
## Predominant\_land\_use 614.6314 7 <2e-16 \*\*\*  
## UN\_region 3.9212 4 0.4168   
## Predominant\_land\_use:UN\_region 392.0405 28 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

# look at the model estimates of our mimumum adequate model (which in our case is also our maximal model)  
summary(m5)

## Generalized linear mixed model fit by maximum likelihood (Laplace  
## Approximation) [glmerMod]  
## Family: poisson ( log )  
## Formula: Species\_richness ~ Predominant\_land\_use \* UN\_region + (1 | SS) +   
## (1 | SSB) + (1 | SSBS)  
## Data: model\_data  
##   
## AIC BIC logLik deviance df.resid   
## 118795.9 119136.7 -59354.9 118709.9 20392   
##   
## Scaled residuals:   
## Min 1Q Median 3Q Max   
## -3.4994 -0.4452 -0.0150 0.3341 5.8508   
##   
## Random effects:  
## Groups Name Variance Std.Dev.  
## SSBS (Intercept) 0.08340 0.2888   
## SSB (Intercept) 0.04009 0.2002   
## SS (Intercept) 1.49629 1.2232   
## Number of obs: 20435, groups: SSBS, 20435; SSB, 2182; SS, 647  
##   
## Fixed effects:  
## Estimate  
## (Intercept) 2.461665  
## Predominant\_land\_useYoung secondary vegetation -0.137214  
## Predominant\_land\_useIntermediate secondary vegetation -0.075541  
## Predominant\_land\_useMature secondary vegetation -0.210673  
## Predominant\_land\_usePlantation forest -0.189717  
## Predominant\_land\_usePasture -0.517579  
## Predominant\_land\_useCropland -0.342174  
## Predominant\_land\_useUrban -0.178977  
## UN\_regionAmericas 0.116175  
## UN\_regionAsia 0.382923  
## UN\_regionEurope 0.161913  
## UN\_regionOceania 0.111458  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAmericas 0.066044  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAmericas 0.108876  
## Predominant\_land\_useMature secondary vegetation:UN\_regionAmericas 0.292030  
## Predominant\_land\_usePlantation forest:UN\_regionAmericas 0.006932  
## Predominant\_land\_usePasture:UN\_regionAmericas 0.406304  
## Predominant\_land\_useCropland:UN\_regionAmericas 0.218369  
## Predominant\_land\_useUrban:UN\_regionAmericas -0.054401  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAsia -0.248987  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAsia -0.008394  
## Predominant\_land\_useMature secondary vegetation:UN\_regionAsia 0.244250  
## Predominant\_land\_usePlantation forest:UN\_regionAsia -0.236216  
## Predominant\_land\_usePasture:UN\_regionAsia 0.183981  
## Predominant\_land\_useCropland:UN\_regionAsia -0.289478  
## Predominant\_land\_useUrban:UN\_regionAsia -0.142429  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionEurope 0.019773  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionEurope -0.447436  
## Predominant\_land\_useMature secondary vegetation:UN\_regionEurope 0.085057  
## Predominant\_land\_usePlantation forest:UN\_regionEurope -0.143008  
## Predominant\_land\_usePasture:UN\_regionEurope 0.307644  
## Predominant\_land\_useCropland:UN\_regionEurope 0.021210  
## Predominant\_land\_useUrban:UN\_regionEurope -0.288866  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionOceania 0.001047  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionOceania -0.027607  
## Predominant\_land\_useMature secondary vegetation:UN\_regionOceania 0.405952  
## Predominant\_land\_usePlantation forest:UN\_regionOceania -0.043062  
## Predominant\_land\_usePasture:UN\_regionOceania 0.345199  
## Predominant\_land\_useCropland:UN\_regionOceania 0.280090  
## Predominant\_land\_useUrban:UN\_regionOceania 0.193813  
## Std. Error  
## (Intercept) 0.132684  
## Predominant\_land\_useYoung secondary vegetation 0.039704  
## Predominant\_land\_useIntermediate secondary vegetation 0.040224  
## Predominant\_land\_useMature secondary vegetation 0.053824  
## Predominant\_land\_usePlantation forest 0.025978  
## Predominant\_land\_usePasture 0.049764  
## Predominant\_land\_useCropland 0.027007  
## Predominant\_land\_useUrban 0.091305  
## UN\_regionAmericas 0.156012  
## UN\_regionAsia 0.180118  
## UN\_regionEurope 0.168193  
## UN\_regionOceania 0.207756  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAmericas 0.049562  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAmericas 0.048587  
## Predominant\_land\_useMature secondary vegetation:UN\_regionAmericas 0.067000  
## Predominant\_land\_usePlantation forest:UN\_regionAmericas 0.041760  
## Predominant\_land\_usePasture:UN\_regionAmericas 0.054573  
## Predominant\_land\_useCropland:UN\_regionAmericas 0.039263  
## Predominant\_land\_useUrban:UN\_regionAmericas 0.104934  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAsia 0.055376  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAsia 0.058049  
## Predominant\_land\_useMature secondary vegetation:UN\_regionAsia 0.079102  
## Predominant\_land\_usePlantation forest:UN\_regionAsia 0.040704  
## Predominant\_land\_usePasture:UN\_regionAsia 0.146173  
## Predominant\_land\_useCropland:UN\_regionAsia 0.061407  
## Predominant\_land\_useUrban:UN\_regionAsia 0.202454  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionEurope 0.062416  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionEurope 0.053764  
## Predominant\_land\_useMature secondary vegetation:UN\_regionEurope 0.065564  
## Predominant\_land\_usePlantation forest:UN\_regionEurope 0.056157  
## Predominant\_land\_usePasture:UN\_regionEurope 0.058878  
## Predominant\_land\_useCropland:UN\_regionEurope 0.054164  
## Predominant\_land\_useUrban:UN\_regionEurope 0.107651  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionOceania 0.059184  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionOceania 0.072279  
## Predominant\_land\_useMature secondary vegetation:UN\_regionOceania 0.249955  
## Predominant\_land\_usePlantation forest:UN\_regionOceania 0.086672  
## Predominant\_land\_usePasture:UN\_regionOceania 0.056131  
## Predominant\_land\_useCropland:UN\_regionOceania 0.091243  
## Predominant\_land\_useUrban:UN\_regionOceania 0.165376  
## z value  
## (Intercept) 18.553  
## Predominant\_land\_useYoung secondary vegetation -3.456  
## Predominant\_land\_useIntermediate secondary vegetation -1.878  
## Predominant\_land\_useMature secondary vegetation -3.914  
## Predominant\_land\_usePlantation forest -7.303  
## Predominant\_land\_usePasture -10.401  
## Predominant\_land\_useCropland -12.670  
## Predominant\_land\_useUrban -1.960  
## UN\_regionAmericas 0.745  
## UN\_regionAsia 2.126  
## UN\_regionEurope 0.963  
## UN\_regionOceania 0.536  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAmericas 1.333  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAmericas 2.241  
## Predominant\_land\_useMature secondary vegetation:UN\_regionAmericas 4.359  
## Predominant\_land\_usePlantation forest:UN\_regionAmericas 0.166  
## Predominant\_land\_usePasture:UN\_regionAmericas 7.445  
## Predominant\_land\_useCropland:UN\_regionAmericas 5.562  
## Predominant\_land\_useUrban:UN\_regionAmericas -0.518  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAsia -4.496  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAsia -0.145  
## Predominant\_land\_useMature secondary vegetation:UN\_regionAsia 3.088  
## Predominant\_land\_usePlantation forest:UN\_regionAsia -5.803  
## Predominant\_land\_usePasture:UN\_regionAsia 1.259  
## Predominant\_land\_useCropland:UN\_regionAsia -4.714  
## Predominant\_land\_useUrban:UN\_regionAsia -0.704  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionEurope 0.317  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionEurope -8.322  
## Predominant\_land\_useMature secondary vegetation:UN\_regionEurope 1.297  
## Predominant\_land\_usePlantation forest:UN\_regionEurope -2.547  
## Predominant\_land\_usePasture:UN\_regionEurope 5.225  
## Predominant\_land\_useCropland:UN\_regionEurope 0.392  
## Predominant\_land\_useUrban:UN\_regionEurope -2.683  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionOceania 0.018  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionOceania -0.382  
## Predominant\_land\_useMature secondary vegetation:UN\_regionOceania 1.624  
## Predominant\_land\_usePlantation forest:UN\_regionOceania -0.497  
## Predominant\_land\_usePasture:UN\_regionOceania 6.150  
## Predominant\_land\_useCropland:UN\_regionOceania 3.070  
## Predominant\_land\_useUrban:UN\_regionOceania 1.172  
## Pr(>|z|)  
## (Intercept) < 2e-16  
## Predominant\_land\_useYoung secondary vegetation 0.000548  
## Predominant\_land\_useIntermediate secondary vegetation 0.060380  
## Predominant\_land\_useMature secondary vegetation 9.07e-05  
## Predominant\_land\_usePlantation forest 2.81e-13  
## Predominant\_land\_usePasture < 2e-16  
## Predominant\_land\_useCropland < 2e-16  
## Predominant\_land\_useUrban 0.049970  
## UN\_regionAmericas 0.456481  
## UN\_regionAsia 0.033507  
## UN\_regionEurope 0.335718  
## UN\_regionOceania 0.591625  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAmericas 0.182679  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAmericas 0.025034  
## Predominant\_land\_useMature secondary vegetation:UN\_regionAmericas 1.31e-05  
## Predominant\_land\_usePlantation forest:UN\_regionAmericas 0.868160  
## Predominant\_land\_usePasture:UN\_regionAmericas 9.69e-14  
## Predominant\_land\_useCropland:UN\_regionAmericas 2.67e-08  
## Predominant\_land\_useUrban:UN\_regionAmericas 0.604161  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAsia 6.92e-06  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAsia 0.885020  
## Predominant\_land\_useMature secondary vegetation:UN\_regionAsia 0.002016  
## Predominant\_land\_usePlantation forest:UN\_regionAsia 6.50e-09  
## Predominant\_land\_usePasture:UN\_regionAsia 0.208154  
## Predominant\_land\_useCropland:UN\_regionAsia 2.43e-06  
## Predominant\_land\_useUrban:UN\_regionAsia 0.481737  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionEurope 0.751396  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionEurope < 2e-16  
## Predominant\_land\_useMature secondary vegetation:UN\_regionEurope 0.194525  
## Predominant\_land\_usePlantation forest:UN\_regionEurope 0.010879  
## Predominant\_land\_usePasture:UN\_regionEurope 1.74e-07  
## Predominant\_land\_useCropland:UN\_regionEurope 0.695360  
## Predominant\_land\_useUrban:UN\_regionEurope 0.007289  
## Predominant\_land\_useYoung secondary vegetation:UN\_regionOceania 0.985883  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionOceania 0.702501  
## Predominant\_land\_useMature secondary vegetation:UN\_regionOceania 0.104354  
## Predominant\_land\_usePlantation forest:UN\_regionOceania 0.619303  
## Predominant\_land\_usePasture:UN\_regionOceania 7.75e-10  
## Predominant\_land\_useCropland:UN\_regionOceania 0.002143  
## Predominant\_land\_useUrban:UN\_regionOceania 0.241215  
##   
## (Intercept) \*\*\*  
## Predominant\_land\_useYoung secondary vegetation \*\*\*  
## Predominant\_land\_useIntermediate secondary vegetation .   
## Predominant\_land\_useMature secondary vegetation \*\*\*  
## Predominant\_land\_usePlantation forest \*\*\*  
## Predominant\_land\_usePasture \*\*\*  
## Predominant\_land\_useCropland \*\*\*  
## Predominant\_land\_useUrban \*   
## UN\_regionAmericas   
## UN\_regionAsia \*   
## UN\_regionEurope   
## UN\_regionOceania   
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAmericas   
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAmericas \*   
## Predominant\_land\_useMature secondary vegetation:UN\_regionAmericas \*\*\*  
## Predominant\_land\_usePlantation forest:UN\_regionAmericas   
## Predominant\_land\_usePasture:UN\_regionAmericas \*\*\*  
## Predominant\_land\_useCropland:UN\_regionAmericas \*\*\*  
## Predominant\_land\_useUrban:UN\_regionAmericas   
## Predominant\_land\_useYoung secondary vegetation:UN\_regionAsia \*\*\*  
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionAsia   
## Predominant\_land\_useMature secondary vegetation:UN\_regionAsia \*\*   
## Predominant\_land\_usePlantation forest:UN\_regionAsia \*\*\*  
## Predominant\_land\_usePasture:UN\_regionAsia   
## Predominant\_land\_useCropland:UN\_regionAsia \*\*\*  
## Predominant\_land\_useUrban:UN\_regionAsia   
## Predominant\_land\_useYoung secondary vegetation:UN\_regionEurope   
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionEurope \*\*\*  
## Predominant\_land\_useMature secondary vegetation:UN\_regionEurope   
## Predominant\_land\_usePlantation forest:UN\_regionEurope \*   
## Predominant\_land\_usePasture:UN\_regionEurope \*\*\*  
## Predominant\_land\_useCropland:UN\_regionEurope   
## Predominant\_land\_useUrban:UN\_regionEurope \*\*   
## Predominant\_land\_useYoung secondary vegetation:UN\_regionOceania   
## Predominant\_land\_useIntermediate secondary vegetation:UN\_regionOceania   
## Predominant\_land\_useMature secondary vegetation:UN\_regionOceania   
## Predominant\_land\_usePlantation forest:UN\_regionOceania   
## Predominant\_land\_usePasture:UN\_regionOceania \*\*\*  
## Predominant\_land\_useCropland:UN\_regionOceania \*\*   
## Predominant\_land\_useUrban:UN\_regionOceania   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

##   
## Correlation matrix not shown by default, as p = 40 > 12.  
## Use print(x, correlation=TRUE) or  
## vcov(x) if you need it

## convergence code: 0  
## Model failed to converge with max|grad| = 0.0340254 (tol = 0.002, component 1)  
## failure to converge in 10000 evaluations

source("/Users/dd/Desktop/R script/PlotErrBar\_interactions.R")  
source("/Users/dd/Desktop/R script/J-Yidi.R")

## Plot the results

PlotErrBar\_interactions(model = m5  
 , resp = "Species\_richness"  
 , Effect1 = "Predominant\_land\_use"  
 , Effect2 = "UN\_region"  
 , off= -0.4  
 , off\_increment = 0.2  
 , legend = TRUE  
 , leg.pos = "topright"  
 , blackwhite = FALSE  
 , ylims = c(-0.9,0.9)  
 , srttxt =30)

## Loading required package: roquefort

## Warning in library(package, lib.loc = lib.loc, character.only = TRUE,  
## logical.return = TRUE, : there is no package called 'roquefort'

