Climate-projected distributional shifts and refugia for North American ecoregions

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Climate model projections suggest major North American biome shifts in response to anthropogenic climate change (Rehfeldt et al. 2012). Such shifts could have profound influences on native flora and fauna, many of which would have to move long distances to track their climatic niches. To evaluate potential ecosystem changes at a somewhat finer scale, I projected the change in climate space for level III ecoregions (Commission for Environmental Cooperation 1997) as surrogates for multiple associated species and ecological communities. First, I developed a random forest model (Breiman 2001) to predict ecoregion class from bioclimatic variables. I used 10-km interpolated climate data for the 1971-2000 normal period, available from Natural Resources Canada (McKenney et al. 2011)

R Code for this portion follows:

library(randomForest)  
library(raster)  
  
#eco = project directory  
#datLL = data frame of lat-lon sample points for which to extract climate variables ("CECEcoregionSampleLL.csv"")  
#cececo = data frame with ecoregion names ("CECecoregions.csv")  
#ecolevel3r = ecoregion raster with a Lambert azimuthal equal-area projection ("ceclev3idlaz.tif")  
#ecolevel3s = ecoregion shapefile with a Lambert azimuthal equal-area projection ("NA\_CEC\_Eco\_Level3\_lazea.shp")  
lazea <- CRS("+proj=laea +lat\_0=45 +lon\_0=-100 +x\_0=0 +y\_0=0 +datum=WGS84 +units=m +no\_defs +ellps=WGS84 +towgs84=0,0,0")  
  
#cur = directory containing grids representing derived climate variables  
setwd(cur)  
clim <- list.files(cur, pattern =".asc$")  
curclim<-stack(clim)  
  
temp <- raster(clim[1])  
ID <- as.data.frame(rasterToPoints(temp))  
names(ID)[3] <- "ID4km"  
ID$ID <- row.names(ID)  
IDR <- raster(ncols=ncol(temp), nrows=nrow(temp), xmn=xmin(temp), xmx=xmax(temp), ymn=ymin(temp), ymx=ymax(temp))  
IDRR <- rasterize(as.matrix(ID[,1:2]), IDR, as.numeric(ID[,4]))  
  
curclim <- addLayer(curclim,IDRR)  
  
sampleclim<-cbind(datLL,extract(curclim,as.matrix(cbind(datLL[,3],datLL[,4]))))  
sc <- na.omit(sampleclim)  
names(sc)[ncol(sc)] <- "IDgrid"  
sc$NA\_L3CODE <- as.factor(as.character(sc$NA\_L3CODE))  
lu <- as.data.frame(levels(sc$NA\_L3CODE))  
lu$level <- row.names(lu)  
names(lu)[1] <- "NA\_L3CODE"  
  
setwd(eco)  
eco.rf <- randomForest(y=sc$NA\_L3CODE, x=sc[,5:(ncol(sc)-1)],importance = TRUE, proximity = TRUE, data=sc)  
eco1.rf <- randomForest(y=sc$NA\_L3CODE, x=sc[,5:23],importance = TRUE, proximity = TRUE, data=sc)  
round(importance(eco1.rf), 2)  
varImpPlot(eco1.rf)   
ecocurr <- predict(curclim,eco1.rf)  
ecocurrlaz <- round(projectRaster(ecocurr, ecolevel3r, method='ngb'),0)  
writeRaster(ecocurrlaz,filename="current1\_lazea.tif",datatype='INT4S',format="GTiff",overwrite=TRUE)  
curfreq <- freq(ecocurrlaz)  
ecolu <- merge(lu,curfreq,by.x="level",by.y="value")  
names(ecolu)[3] <- "curr"

This model was then used to project ecoregions onto future mid-century (2041-2070) and end-of-century (2071-2100) climate conditions. Climate projections were based on 10-km downscaled climate anomalies (McKenney et al. 2011) generated by four widely-used GCMs from the Coupled Model Intercomparison Project, Phase 5 (CMIP5, Taylor et al. 2012): CanESM2, CESM1-CAM5, HadGEM2-ES, and MIROC-ESM. These particular GCMs were selected for downscaling by the Canadian Forest Service based on availability of key variables such as solar radiation, wind speed and humidity, as well as temperature and precipitation to support various forest modeling efforts (McKenney et al., 2013). We used representative concentration pathway (RCP) 8.5, to represent the 21st century conditions that are to be expected without dramatic reductions in greenhouse gas emissions or technological fixes (Fuss et al. 2014).

The following code generates projections for each GCM and time period and reprojects the results to an equal-area projection.

#fut = directory containing grids representing derived future climate variables  
gcm <- c("canesm2","cesm1cam5","hadgem2es","mirocesm")  
rcp <- c("rcp45","rcp85")  
time <- c("2041-2070","2071-2100")  
for (i in gcm) {  
 for (j in rcp) {  
 for (k in time) {  
 w <- paste(fut,i,"/",j,"/",k,"/",sep="")  
 setwd(w)  
 futclim <- list.files(w,pattern=".asc$")  
 s <-stack(futclim[1:99])  
 p <- predict(s,eco1.rf)  
 plaz <- round(projectRaster(p,ecolevel3r,method='ngb'),0)  
 writeRaster(plaz, filename=paste(eco,j,k,i,"1",sep="\_"),datatype='INT4S',format="GTiff", overwrite=TRUE)  
 }  
 }   
 }

Next, I identified the most frequently-predicted Level-III ecoregion (Table 1) at each pixel location (i.e, the mode) for RCP 4.5 and RCP 8.5.

groups <- c("rcp45\_2041-2070","rcp45\_2071-2100","rcp85\_2041-2070","rcp85\_2071-2100")  
setwd(eco)  
for (i in groups) {  
 g <- list.files(eco,pattern=i)  
 g1 <- grep(pattern=".tif$",g,value=TRUE)  
 gs <- stack(g1)  
 m <- overlay(gs, fun = modal)   
 futfreq <- as.data.frame(freq(m))  
 names(futfreq)[2] <- i  
 ecolu <- merge(ecolu,futfreq,by.x="level",by.y="value")  
 writeRaster(m, filename=paste(eco,i,"mode",sep="\_"),datatype='INT4S',format="GTiff", overwrite=TRUE)  
 }  
ecolu1 <- merge(unique(cececo[,c(2:4)]),ecolu[,2:7],by="NA\_L3CODE")  
write.csv(ecolu1,file="ecoregion\_change.summary.csv",row.names=FALSE)

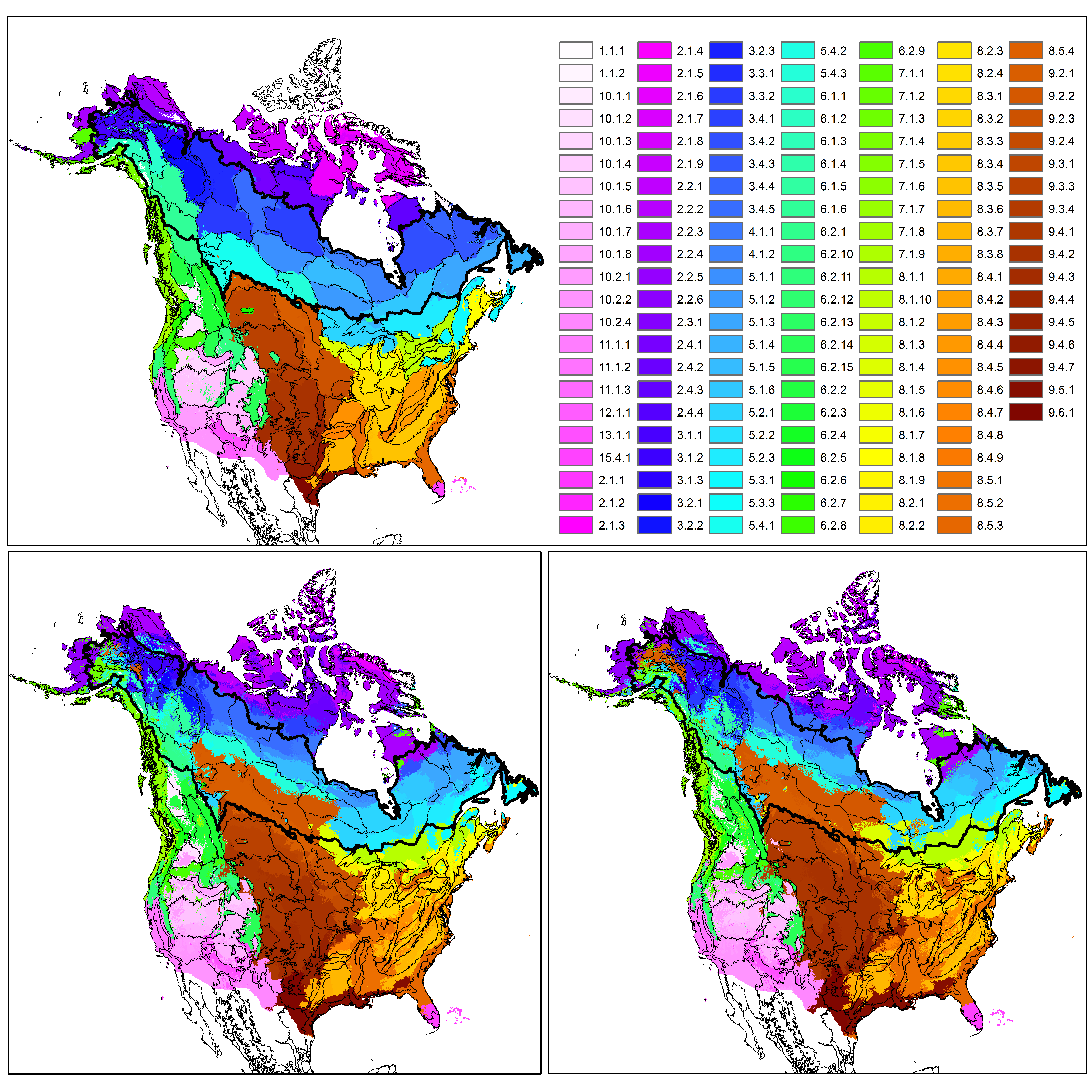


Figure 1. Model-predicted (a) baseline, (b) mid-century, and (c) end-of-century changes in North American ecoregions for RCP 4.5. Boreal and western forested regions are shown in green and blue-green shades; arctic ecoregions are in purple shades; prairie/parkland ecoregions are in red-brown shades; and temperate forest ecoregions are in light green, yellow, and orange shades (see Table 1 for full list of ecoregions). Boreal ecoregions are also outlined in black.

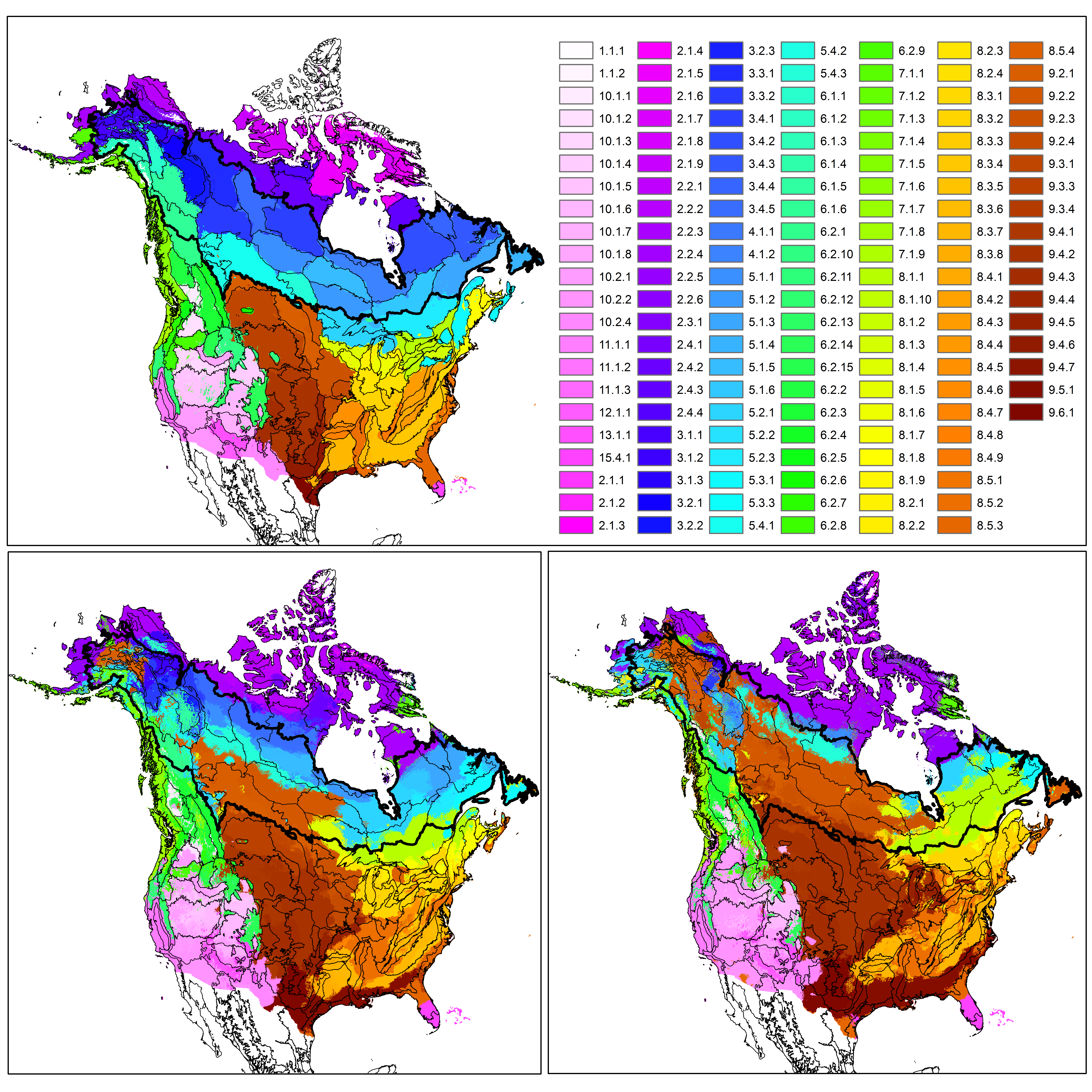


Figure 2. Model-predicted (a) baseline, (b) mid-century, and (c) end-of-century changes in North American ecoregions for RCP 8.5. Boreal and western forested regions are shown in green and blue-green shades; arctic ecoregions are in purple shades; prairie/parkland ecoregions are in red-brown shades; and temperate forest ecoregions are in light green, yellow, and orange shades (see Table 1 for full list of ecoregions). Boreal ecoregions are also outlined in black.

I then calculated the change in area (16 km2 pixels) for each Level III ecoregion:

Table 1. Model-projected changes by ecoregion:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| NA\_L3CODE | NA\_L3NAME | curr | rcp45\_2041.2070 | rcp45\_2071.2100 | rcp85\_2041.2070 | rcp85\_2071.2100 |
| 1.1.2 | Baffin and Torngat Mountains | 5785 | 5197 | 2250 | 1965 | 393 |
| 10.1.1 | Thompson-Okanogan Plateau | 3839 | 5693 | 3589 | 3376 | 2862 |
| 10.1.2 | Columbia Plateau | 5036 | 5531 | 4827 | 5101 | 5167 |
| 10.1.3 | Northern Basin and Range | 9141 | 1445 | 334 | 647 | 11 |
| 10.1.4 | Wyoming Basin | 8515 | 1245 | 560 | 448 | 363 |
| 10.1.5 | Central Basin and Range | 16892 | 15798 | 14737 | 13595 | 5904 |
| 10.1.6 | Colorado Plateaus | 8002 | 14825 | 14476 | 14470 | 15813 |
| 10.1.7 | Arizona/New Mexico Plateau | 8877 | 12827 | 11906 | 10181 | 5301 |
| 10.1.8 | Snake River Plain | 4042 | 5396 | 6074 | 5801 | 1949 |
| 10.2.1 | Mojave Basin and Range | 7766 | 10443 | 13446 | 16203 | 32738 |
| 10.2.2 | Sonoran Desert | 7208 | 13908 | 16462 | 17540 | 27624 |
| 10.2.4 | Chihuahuan Desert | 10202 | 15753 | 14807 | 14405 | 12389 |
| 11.1.1 | California Coastal Sage, Chaparral, and Oak Woodlands | 5946 | 8910 | 10364 | 10810 | 19407 |
| 11.1.2 | Central California Valley | 3208 | 2566 | 2364 | 2829 | 1070 |
| 11.1.3 | Southern and Baja California Pine-Oak Mountains | 1794 | 1249 | 1059 | 998 | 1014 |
| 12.1.1 | Madrean Archipelago | 3214 | 4902 | 4809 | 5281 | 6232 |
| 13.1.1 | Arizona/New Mexico Mountains | 7069 | 5884 | 6871 | 6695 | 7784 |
| 15.4.1 | Southern Florida Coastal Plain | 2542 | 4479 | 5451 | 5394 | 7981 |
| 2.1.4 | Lancaster and Borden Peninsula Plateaus | 5018 | 321 | 118 | 152 | 9 |
| 2.1.5 | Foxe Uplands | 25575 | 4649 | 4173 | 3141 | 1985 |
| 2.1.6 | Baffin Uplands | 7702 | 1641 | 919 | 1122 | 984 |
| 2.1.7 | Gulf of Boothia and Foxe Basin Plains | 11438 | 400 | 128 | 51 | 75 |
| 2.1.9 | Banks Island and Amundsen Gulf Lowlands | 11202 | 16289 | 9323 | 8539 | 68 |
| 2.2.1 | Arctic Coastal Plain | 4145 | 12223 | 13419 | 13942 | 2073 |
| 2.2.2 | Arctic Foothills | 8286 | 37118 | 49520 | 57446 | 46094 |
| 2.2.3 | Subarctic Coastal Plains | 6951 | 38956 | 51348 | 55642 | 96698 |
| 2.2.4 | Seward Peninsula | 3685 | 14046 | 12792 | 12515 | 4386 |
| 2.2.5 | Bristol Bay-Nushagak Lowlands | 4289 | 15780 | 18318 | 17968 | 23889 |
| 2.3.1 | Brooks Range/Richardson Mountains | 9438 | 4093 | 2236 | 2351 | 1008 |
| 2.4.1 | Amundsen Plains | 19528 | 26123 | 12571 | 5358 | 3879 |
| 2.4.2 | Aberdeen Plains | 20284 | 7377 | 6876 | 5852 | 175 |
| 2.4.3 | Central Ungava Peninsula and Ottawa and Belcher Islands | 12708 | 989 | 2019 | 2766 | 2328 |
| 3.1.1 | Interior Forested Lowlands and Uplands | 12314 | 11610 | 12324 | 7956 | 1647 |
| 3.1.2 | Interior Bottomlands | 8480 | 12243 | 12947 | 11485 | 3740 |
| 3.3.2 | Hay and Slave River Lowlands | 18066 | 16530 | 18785 | 16477 | 2894 |
| 3.4.2 | La Grande Hills and New Quebec Central Plateau | 23362 | 2721 | 289 | 7 | 687 |
| 3.4.3 | Smallwood Uplands | 17695 | 3650 | 1900 | 1628 | 59 |
| 3.4.5 | Coppermine River and Tazin Lake Uplands | 17076 | 31218 | 27986 | 32173 | 1788 |
| 4.1.1 | Coastal Hudson Bay Lowland | 5247 | 6216 | 9476 | 4593 | 213 |
| 4.1.2 | Hudson Bay and James Bay Lowlands | 19015 | 7396 | 1772 | 3408 | 5321 |
| 5.1.1 | Athabasca Plain and Churchill River Upland | 17427 | 8784 | 9403 | 7999 | 5953 |
| 5.1.2 | Lake Nipigon and Lac Seul Upland | 14113 | 7979 | 10656 | 10468 | 5219 |
| 5.1.3 | Central Laurentians and Mecatina Plateau | 22320 | 22361 | 19161 | 19597 | 825 |
| 5.1.4 | Newfoundland Island | 9737 | 7967 | 7865 | 7326 | 3273 |
| 5.1.5 | Hayes River Upland and Big Trout Lake | 16227 | 10627 | 11089 | 13205 | 1022 |
| 5.1.6 | Abitibi Plains and Riviere Rupert Plateau | 18020 | 9554 | 5260 | 5975 | 1 |
| 5.2.1 | Northern Lakes and Forests | 19174 | 34982 | 36572 | 39567 | 42851 |
| 5.2.2 | Northern Minnesota Wetlands | 2774 | 36 | 176 | 17 | 2 |
| 5.2.3 | Algonquin/Southern Laurentians | 19758 | 19809 | 13374 | 14844 | 4684 |
| 5.3.1 | Northern Appalachian and Atlantic Maritime Highlands | 13784 | 22199 | 21696 | 21793 | 14885 |
| 5.4.1 | Mid-Boreal Uplands and Peace-Wabaska Lowlands | 26281 | 13199 | 7792 | 9977 | 2322 |
| 5.4.2 | Clear Hills and Western Alberta Upland | 8944 | 987 | 610 | 824 | 114 |
| 5.4.3 | Mid-Boreal Lowland and Interlake Plain | 8591 | 21433 | 22801 | 23930 | 17692 |
| 6.1.1 | Interior Highlands and Klondike Plateau | 9208 | 3124 | 2530 | 1914 | 106 |
| 6.1.2 | Alaska Range | 6968 | 3714 | 2627 | 2487 | 971 |
| 6.1.4 | Wrangell and St. Elias Mountains | 2554 | 1378 | 1049 | 831 | 10 |
| 6.1.5 | Watson Highlands | 13655 | 10757 | 7553 | 6807 | 162 |
| 6.1.6 | Yukon-Stikine Highlands/Boreal Mountains and Plateaus | 10586 | 5786 | 3741 | 3753 | 353 |
| 6.2.1 | Skeena-Omineca-Central Canadian Rocky Mountains | 9171 | 8552 | 8820 | 9990 | 2291 |
| 6.2.10 | Middle Rockies | 10794 | 6030 | 3226 | 2347 | 410 |
| 6.2.11 | Klamath Mountains | 3253 | 3694 | 3332 | 3254 | 2232 |
| 6.2.12 | Sierra Nevada | 3604 | 3118 | 3606 | 3832 | 2868 |
| 6.2.13 | Wasatch and Uinta Mountains | 4243 | 813 | 238 | 623 | 63 |
| 6.2.14 | Southern Rockies | 9092 | 7227 | 6959 | 6111 | 3052 |
| 6.2.15 | Idaho Batholith | 3999 | 3728 | 3623 | 3928 | 2089 |
| 6.2.2 | Chilcotin Ranges and Fraser Plateau | 6500 | 1795 | 1049 | 1413 | 84 |
| 6.2.3 | Columbia Mountains/Northern Rockies | 11119 | 22325 | 24278 | 24061 | 22864 |
| 6.2.4 | Canadian Rockies | 6511 | 1408 | 919 | 661 | 61 |
| 6.2.5 | North Cascades | 2717 | 3194 | 3353 | 2192 | 1064 |
| 6.2.6 | Cypress Upland | 837 | 556 | 282 | 395 | 885 |
| 6.2.7 | Cascades | 2859 | 2817 | 3091 | 3011 | 3540 |
| 6.2.8 | Eastern Cascades Slopes and Foothills | 3449 | 1616 | 861 | 741 | 200 |
| 6.2.9 | Blue Mountains | 4304 | 6120 | 6600 | 6467 | 3588 |
| 7.1.1 | Ahklun and Kilbuck Mountains | 3741 | 5592 | 9927 | 8813 | 9255 |
| 7.1.2 | Alaska Peninsula Mountains | 4630 | 2073 | 1724 | 1409 | 1309 |
| 7.1.3 | Cook Inlet | 2343 | 7889 | 6718 | 5350 | 2189 |
| 7.1.4 | Pacific Coastal Mountains | 8158 | 5032 | 3887 | 3482 | 1811 |
| 7.1.5 | Coastal Western Hemlock-Sitka Spruce Forests | 10176 | 13692 | 12519 | 12684 | 4999 |
| 7.1.6 | Pacific and Nass Ranges | 7173 | 8014 | 7731 | 9747 | 3648 |
| 7.1.7 | Strait of Georgia/Puget Lowland | 3380 | 3809 | 4980 | 5047 | 12675 |
| 7.1.8 | Coast Range | 3878 | 3847 | 3489 | 3851 | 3272 |
| 7.1.9 | Willamette Valley | 1129 | 2525 | 3088 | 2721 | 3538 |
| 8.1.1 | Eastern Great Lakes Lowlands | 10611 | 27854 | 39218 | 39742 | 58844 |
| 8.1.10 | Erie Drift Plain | 2274 | 307 | 62 | 6 | 54 |
| 8.1.2 | Lake Erie Lowland | 4095 | 890 | 1202 | 1076 | 937 |
| 8.1.3 | Northern Allegheny Plateau | 3060 | 36 | 2 | 4 | 130 |
| 8.1.4 | North Central Hardwood Forests | 6153 | 7501 | 12214 | 11052 | 6399 |
| 8.1.6 | Southern Michigan/Northern Indiana Drift Plains | 4974 | 1858 | 404 | 229 | 281 |
| 8.1.7 | Northeastern Coastal Zone | 3483 | 16109 | 16031 | 17106 | 9656 |
| 8.1.8 | Acadian Plains and Hills | 6882 | 1089 | 364 | 793 | 797 |
| 8.1.9 | Maritime Lowlands | 3379 | 564 | 4 | 15 | 706 |
| 8.2.1 | Southeastern Wisconsin Till Plains | 2639 | 1175 | 973 | 1252 | 6440 |
| 8.2.2 | Huron/Erie Lake Plains | 3393 | 4880 | 5070 | 3660 | 4186 |
| 8.2.3 | Central Corn Belt Plains | 5253 | 1871 | 1709 | 2247 | 4536 |
| 8.2.4 | Eastern Corn Belt Plains | 5195 | 8044 | 6701 | 5080 | 614 |
| 8.3.1 | Northern Piedmont | 2266 | 2042 | 2428 | 875 | 220 |
| 8.3.2 | Interior River Valleys and Hills | 7204 | 18471 | 22834 | 32181 | 41053 |
| 8.3.3 | Interior Plateau | 7863 | 4882 | 4497 | 3481 | 1847 |
| 8.3.4 | Piedmont | 10363 | 2622 | 1337 | 895 | 173 |
| 8.3.5 | Southeastern Plains | 15521 | 9623 | 12471 | 8427 | 3111 |
| 8.3.6 | Mississippi Valley Loess Plains | 4937 | 811 | 522 | 1506 | 1092 |
| 8.3.7 | South Central Plains | 9328 | 20114 | 18219 | 24925 | 36606 |
| 8.3.8 | East Central Texas Plains | 3242 | 8719 | 9141 | 10183 | 11699 |
| 8.4.1 | Ridge and Valley | 5920 | 904 | 578 | 203 | 422 |
| 8.4.2 | Central Appalachians | 4867 | 832 | 448 | 138 | 119 |
| 8.4.3 | Western Allegheny Plateau | 4778 | 947 | 617 | 703 | 13 |
| 8.4.4 | Blue Ridge | 3021 | 1863 | 2013 | 2268 | 7292 |
| 8.4.5 | Ozark Highlands | 6249 | 8596 | 4947 | 5703 | 5052 |
| 8.4.6 | Boston Mountains | 1336 | 310 | 668 | 292 | 230 |
| 8.4.7 | Arkansas Valley | 1969 | 3349 | 3055 | 2012 | 659 |
| 8.4.8 | Ouachita Mountains | 1619 | 2407 | 1589 | 1016 | 710 |
| 8.4.9 | Southwestern Appalachians | 3253 | 312 | 274 | 230 | 523 |
| 8.5.1 | Middle Atlantic Coastal Plain | 7953 | 4024 | 7165 | 1763 | 5204 |
| 8.5.2 | Mississippi Alluvial Plain | 8327 | 28746 | 33976 | 31813 | 33331 |
| 8.5.3 | Southern Coastal Plain | 10023 | 14455 | 12420 | 11986 | 12766 |
| 8.5.4 | Atlantic Coastal Pine Barrens | 1540 | 6493 | 9429 | 7146 | 10878 |
| 9.2.1 | Aspen Parkland/Northern Glaciated Plains | 19219 | 43285 | 40756 | 47938 | 53002 |
| 9.2.2 | Lake Manitoba and Lake Agassiz Plain | 7004 | 31809 | 43943 | 43028 | 71014 |
| 9.2.3 | Western Corn Belt Plains | 13086 | 15829 | 14529 | 15256 | 36825 |
| 9.2.4 | Central Irregular Plains | 7590 | 12209 | 7936 | 12002 | 2564 |
| 9.3.1 | Northwestern Glaciated Plains | 22953 | 15444 | 13530 | 12853 | 23046 |
| 9.3.3 | Northwestern Great Plains | 22220 | 26844 | 24463 | 22722 | 4034 |
| 9.3.4 | Nebraska Sand Hills | 5161 | 281 | 272 | 251 | 40 |
| 9.4.1 | High Plains | 17009 | 25323 | 27925 | 26333 | 13500 |
| 9.4.2 | Central Great Plains | 14563 | 39122 | 52642 | 46814 | 122654 |
| 9.4.3 | Southwestern Tablelands | 12148 | 19747 | 18592 | 20378 | 21736 |
| 9.4.4 | Flint Hills | 2576 | 46 | 33 | 5 | 79 |
| 9.4.5 | Cross Timbers | 5772 | 10147 | 11004 | 10631 | 26257 |
| 9.4.6 | Edwards Plateau | 5712 | 155 | 44 | 39 | 14 |
| 9.4.7 | Texas Blackland Prairies | 3141 | 1303 | 1032 | 1451 | 4601 |
| 9.5.1 | Western Gulf Coastal Plain | 5505 | 14913 | 20089 | 20010 | 39523 |
| 9.6.1 | Southern Texas Plains/Interior Plains and Hills with Xerophytic Shrub and Oak Forest | 2942 | 13180 | 15724 | 17877 | 25204 |

I also specifically summarized changes for boreal ecoregions (5.4, 5.1, 3.4, 3.3, 3.2, 3.1, and 6.1):

Table 2. Model-projected changes by boreal ecoregion:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| NA\_L3CODE | NA\_L3NAME | curr | rcp45\_2041.2070 | rcp45\_2071.2100 | rcp85\_2041.2070 | rcp85\_2071.2100 |
| 3.1.1 | Interior Forested Lowlands and Uplands | 12314 | 11610 | 12324 | 7956 | 1647 |
| 3.1.2 | Interior Bottomlands | 8480 | 12243 | 12947 | 11485 | 3740 |
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| 3.4.3 | Smallwood Uplands | 17695 | 3650 | 1900 | 1628 | 59 |
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| 5.1.1 | Athabasca Plain and Churchill River Upland | 17427 | 8784 | 9403 | 7999 | 5953 |
| 5.1.2 | Lake Nipigon and Lac Seul Upland | 14113 | 7979 | 10656 | 10468 | 5219 |
| 5.1.3 | Central Laurentians and Mecatina Plateau | 22320 | 22361 | 19161 | 19597 | 825 |
| 5.1.4 | Newfoundland Island | 9737 | 7967 | 7865 | 7326 | 3273 |
| 5.1.5 | Hayes River Upland and Big Trout Lake | 16227 | 10627 | 11089 | 13205 | 1022 |
| 5.1.6 | Abitibi Plains and Riviere Rupert Plateau | 18020 | 9554 | 5260 | 5975 | 1 |
| 5.4.1 | Mid-Boreal Uplands and Peace-Wabaska Lowlands | 26281 | 13199 | 7792 | 9977 | 2322 |
| 5.4.2 | Clear Hills and Western Alberta Upland | 8944 | 987 | 610 | 824 | 114 |
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| 6.1.1 | Interior Highlands and Klondike Plateau | 9208 | 3124 | 2530 | 1914 | 106 |
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| 6.1.4 | Wrangell and St. Elias Mountains | 2554 | 1378 | 1049 | 831 | 10 |
| 6.1.5 | Watson Highlands | 13655 | 10757 | 7553 | 6807 | 162 |
| 6.1.6 | Yukon-Stikine Highlands/Boreal Mountains and Plateaus | 10586 | 5786 | 3741 | 3753 | 353 |

This translates into 34% and 83% losses of boreal climate space by 2041-2070 and 2071-2100, respectively, based on RCP 8.5; or 27% and 34% losses based on RCP 4.5

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