libraries

library(GWmodel) ### GW models

library(sf) library(dplyr) library(remotes) library(rgdal) library(rgeos)

library(sp) ## Data management library(spdep) ## Spatial autocorrelation library(gstat) ## Geostatistics library(RColorBrewer) ## Visualization library(classInt) ## Class intervals library(raster) ## spatial data library(gridExtra) # Multiple plot library(ggplot2) # Multiple plot

library(tmap) library(tmaptools)

library(tidyverse) library(here) library(janitor) library(stringr) library(corrplot) library(here)

install.packages("vtable") library(vtable)

define data folder

what data folder are you in?

getwd()

"/Users/elika_sinha/Documents/UCL/11. Dissertation/Term3"

setwd("/Users/elika_sinha/Documents/UCL/11. Dissertation/Term3")

setting directory to folder

what data folder are you in?

getwd()

"/Users/elika_sinha/Documents/UCL/11. Dissertation/Term3/Datasets/Final_cleanData"

here::here() here()

reading csv file

CIA <- read.csv(here::here("Datasets", "Final_cleanData", "CIA_Explore.csv"), header = TRUE, sep = ",", encoding = "latin1")

class(CIA)

summary (CIA)

Datatypelist <- CIA %>% summarise_all(class) %>% pivot_longer(everything(), names_to="All_variables", values_to="Variable_class")

Datatypelist

selecting columns for pca

for all- level 1 and 2

group1 <- CIA[,c("Total.households","Median.Income","LonAmALL","Noise_IncidentALL", "Crime_all", "Licensing_all","geometry", "CIA_Composite")] summary(group1)

class(group1)

level 3 total households

group2 <- CIA[,c("Total.households", "USUALRES","HHOLDRES","POPDEN","HHOLDS", "AVHHOLDSZ","geometry")]

summary(group2)

class(group2)

level 3 income

group3 <- CIA[,c("Median.Income", "Mean.Income","geometry", "Mode.Income", "Lower.Quartile")] summary(group3)

class(group3)

level 3 crime

group4 <- CIA[,c("geometry", "Crime_all", "Damage_incident", "Burglary_incident", "Disorder_incident", "Fraud_incident", "Robbery_incident", "SexRelated_incident", "Violence_incident", "WeaponPossession_incident")] summary(group4)

class(group4)

level 3 noise

group5 <- CIA[,c("geometry", "Noise_IncidentALL", "Animal", "Building.Site", "Commercial.Premises", "Email.Complaint..1d.", "Formal.complaints", "Non.Noise.Complaint..45m.", "Non.Noise.Complaint..4d.", "Proactive.Noise", "Property.Alarm", "Residential.Premises", "Street", "VIP.complaint")] summary(group5)

class(group5)

level 3 licensing

group6 <- CIA[,c("geometry", "Licensing_all", "GACLGE", "GAVESS", "LIMSTL", "LIPSL", "PT011", "PT019", "PT031", "PT049", "PT056", "PT057", "PT060", "PT061", "PT062", "PT065", "PT070", "PT074", "PT075", "PT082", "PT086", "PT100", "PT104", "PT106", "PT122", "PT135", "PT137", "PT138", "PT139", "PT140", "PT152", "PT154", "PT155", "PT165", "PT189", "PT195", "PT196", "PT199", "PT203", "PT204", "PT209", "PT225", "PT226", "PT227", "PT232", "PT234", "PT243", "PT249", "PT253", "PT259", "PT260", "PT270", "PT279", "PT284", "PT288", "PT293", "PT303", "PT304", "PT409", "PT417", "PT437", "PT439", "PT442", "PT500", "PT504", "PT508", "PT993", "PT995", "PT998", "PT999", "RT061", "RT199", "RT226", "RT234", "RT303", "SEV")] summary(group6)

class(group6)

carrying out pca for group1

moving geometry to end of group

group1 <- group1 %>% relocate(geometry, .after = last_col()) group2 <- group2 %>% relocate(geometry, .after = last_col()) group3 <- group3 %>% relocate(geometry, .after = last_col()) group4 <- group4 %>% relocate(geometry, .after = last_col()) group5 <- group5 %>% relocate(geometry, .after = last_col()) group6 <- group6 %>% relocate(geometry, .after = last_col())

summary statistics

st(group1) st(group2) st(group3) st(group4) st(group5) st(group6)

scaling width of columns specified

GROUP101.scaled <- scale(as.matrix(group1[1:6])) summary(GROUP101.scaled)

GROUP102.scaled <- scale(as.matrix(group1[7])) summary(GROUP102.scaled)

GROUP201.scaled <- scale(as.matrix(group2[2:6])) summary(GROUP201.scaled)

GROUP301.scaled <- scale(as.matrix(group3[2:4])) summary(GROUP301.scaled)

GROUP401.scaled <- scale(as.matrix(group4[2:9])) summary(GROUP401.scaled)

GROUP501.scaled <- scale(as.matrix(group5[2:9])) summary(GROUP501.scaled)

GROUP601.scaled <- scale(as.matrix(group6[2:75])) summary(GROUP601.scaled)

what is the length of this dataframe?

n1 <- length(GROUP101.scaled[,1]) n1

n2 <- length(GROUP102.scaled[,1]) n2

n3 <- length(GROUP201.scaled[,1]) n3

n4 <- length(GROUP301.scaled[,1]) n4

n5 <- length(GROUP401.scaled[,1]) n5

n6 <- length(GROUP501.scaled[,1]) n6

n7 <- length(GROUP601.scaled[,1]) n7

key steps for conducting pca

pca1 <- princomp(GROUP101.scaled,cor=F,scores=T)
pca1 pca1$scores

GROUP101.scaled_matrix <- cbind(GROUP101.scaled,pca1$scores)

head(GROUP101.scaled_matrix) pca1$loadings

pca2 <- princomp(GROUP102.scaled,cor=F,scores=T)
pca2 pca2$scores

GROUP102.scaled_matrix <- cbind(GROUP102.scaled,pca2$scores)

head(GROUP102.scaled_matrix) pca2$loadings

pca3 <- princomp(GROUP201.scaled,cor=F,scores=T)
pca3 pca3$scores

GROUP201.scaled_matrix <- cbind(GROUP201.scaled,pca3$scores)

head(GROUP201.scaled_matrix) pca3$loadings

pca4 <- princomp(GROUP301.scaled,cor=F,scores=T)
pca4 pca4$scores

GROUP301.scaled_matrix <- cbind(GROUP301.scaled,pca4$scores)

head(GROUP301.scaled_matrix) pca4$loadings

pca5 <- princomp(GROUP401.scaled,cor=F,scores=T)
pca5 pca5$scores

GROUP401.scaled_matrix <- cbind(GROUP401.scaled,pca5$scores)

head(GROUP401.scaled_matrix) pca5$loadings

pca6 <- princomp(GROUP501.scaled,cor=F,scores=T)
pca6 pca6$scores

GROUP501.scaled_matrix <- cbind(GROUP501.scaled,pca5$scores)

head(GROUP501.scaled_matrix) pca6$loadings

pca7 <- princomp(GROUP601.scaled,cor=F,scores=T)
pca7 pca7$scores

GROUP601.scaled_matrix <- cbind(GROUP601.scaled,pca7$scores)

head(GROUP601.scaled_matrix) pca7$loadings

to plot box plot to see spread for each component- level 1 and 2

pc1 <- pca1$scores[,1] boxplot(pc1,horizontal = TRUE) pc2 <- pca1$scores[,2] boxplot(pc2,horizontal = TRUE) pc3 <- pca1$scores[,3] boxplot(pc3,horizontal = TRUE) pc4 <- pca1$scores[,4] boxplot(pc4,horizontal = TRUE) pc5 <- pca1$scores[,5] boxplot(pc5,horizontal = TRUE) pc6 <- pca1$scores[,6] boxplot(pc5,horizontal = TRUE) pc7 <- pca1$scores[,7] boxplot(pc5,horizontal = TRUE)

new data frame containing components (7) as well as scaled z-scores for the 7 chosen variables

GROUP101.scaled_matrix view(GROUP101.scaled_matrix) class(GROUP101.scaled_matrix)

GROUP102.scaled_matrix view(GROUP102.scaled_matrix) class(GROUP102.scaled_matrix)

GROUP201.scaled_matrix view(GROUP201.scaled_matrix) class(GROUP201.scaled_matrix)

GROUP301.scaled_matrix view(GROUP301.scaled_matrix) class(GROUP301.scaled_matrix)

GROUP401.scaled_matrix view(GROUP401.scaled_matrix) class(GROUP401.scaled_matrix)

GROUP501.scaled_matrix view(GROUP501.scaled_matrix) class(GROUP501.scaled_matrix)

GROUP601.scaled_matrix view(GROUP601.scaled_matrix) class(GROUP601.scaled_matrix)

converting from matrix to data frame

GROUP101_scaled_frame=as.data.frame(GROUP101.scaled_matrix)

GROUP102_scaled_frame=as.data.frame(GROUP102.scaled_matrix)

GROUP201_scaled_frame=as.data.frame(GROUP201.scaled_matrix)

GROUP301_scaled_frame=as.data.frame(GROUP301.scaled_matrix)

GROUP401_scaled_frame=as.data.frame(GROUP401.scaled_matrix)

GROUP501_scaled_frame=as.data.frame(GROUP501.scaled_matrix)

GROUP601_scaled_frame=as.data.frame(GROUP601.scaled_matrix)

print data frame data

print(GROUP101_scaled_frame) class(GROUP101_scaled_frame)

print(GROUP102_scaled_frame) class(GROUP102_scaled_frame)

print(GROUP201_scaled_frame) class(GROUP201_scaled_frame)

print(GROUP301_scaled_frame) class(GROUP301_scaled_frame)

print(GROUP401_scaled_frame) class(GROUP401_scaled_frame)

print(GROUP501_scaled_frame) class(GROUP501_scaled_frame)

print(GROUP601_scaled_frame) class(GROUP601_scaled_frame)

map PCA results

PCA_map101 <- cbind(group1, GROUP101_scaled_frame) PCA_map201 <- PCA_map101[,c(10:20)] G_sf <- st_as_sf(group1, wkt = "geometry", crs = st_crs(27700)) G_sp <- as_Spatial(G_sf) PCA_map1 <- cbind(G_sp, PCA_map201) class(PCA_map1)

PCA_map102 <- cbind(group1, GROUP102_scaled_frame) PCA_map202 <- PCA_map102[,c(9:10)]

PCA_map2 <- cbind(G_sp, PCA_map202) class(PCA_map2)

PCA_map201 <- cbind(group2, GROUP201_scaled_frame) PCA_map202 <- PCA_map201[,c(7:17)] PCA_map3 <- cbind(G_sp, PCA_map202) class(PCA_map3)

PCA_map301 <- cbind(group3, GROUP301_scaled_frame) PCA_map302 <- PCA_map301[,c(6:11)] PCA_map4 <- cbind(G_sp, PCA_map302) class(PCA_map4)

PCA_map401 <- cbind(group4, GROUP401_scaled_frame) PCA_map402 <- PCA_map401[,c(11:26)] PCA_map5 <- cbind(G_sp, PCA_map402) class(PCA_map5)

PCA_map501 <- cbind(group5, GROUP501_scaled_frame) PCA_map502 <- PCA_map501[,c(15:30)] PCA_map6 <- cbind(G_sp, PCA_map502) class(PCA_map6)

PCA_map601 <- cbind(group6, GROUP601_scaled_frame) PCA_map602 <- PCA_map601[,c(76:224)] PCA_map7 <- cbind(G_sp, PCA_map602) class(PCA_map7)

mapping results map1 and map2

tm_shape(PCA_map1) + tm_fill(col = "Comp.1", palette = "YlOrBr", midpoint = NA)

tm_shape(PCA_map1) + tm_fill(col = "Comp.2", palette = "YlGnBu", midpoint = NA)

tm_shape(PCA_map1) + tm_fill(col = "Comp.3", palette = "RdPu", midpoint = NA)

tm_shape(PCA_map1) + tm_fill(col = "Comp.4", palette = "PuBuGn", midpoint = NA)

tm_shape(PCA_map1) + tm_fill(col = "Comp.5", palette = "YlOrRd", midpoint = NA)

tm_shape(PCA_map1) + tm_fill(col = "Comp.6", palette = "YlGn", midpoint = NA)

tm_shape(PCA_map2) + tm_fill(col = "Comp.1", palette = "PuBuGn", midpoint = NA)

mapping results 3

tm_shape(PCA_map3) + tm_fill(col = "Comp.1", palette = "YlOrBr", midpoint = NA)

tm_shape(PCA_map3) + tm_fill(col = "Comp.2", palette = "YlGnBu", midpoint = NA)

tm_shape(PCA_map3) + tm_fill(col = "Comp.3", palette = "RdPu", midpoint = NA)

tm_shape(PCA_map3) + tm_fill(col = "Comp.4", palette = "PuBuGn", midpoint = NA)

tm_shape(PCA_map3) + tm_fill(col = "Comp.5", palette = "YlOrRd", midpoint = NA)

mapping results 4

tm_shape(PCA_map4) + tm_fill(col = "Comp.1", palette = "YlOrBr", midpoint = NA)

tm_shape(PCA_map4) + tm_fill(col = "Comp.2", palette = "YlGnBu", midpoint = NA)

tm_shape(PCA_map4) + tm_fill(col = "Comp.3", palette = "RdPu", midpoint = NA)

mapping results 5

tm_shape(PCA_map5) + tm_fill(col = "Comp.1", palette = "YlOrBr", midpoint = NA)

tm_shape(PCA_map5) + tm_fill(col = "Comp.2", palette = "YlGnBu", midpoint = NA)

tm_shape(PCA_map5) + tm_fill(col = "Comp.3", palette = "RdPu", midpoint = NA)

tm_shape(PCA_map5) + tm_fill(col = "Comp.4", palette = "PuBuGn", midpoint = NA)

tm_shape(PCA_map5) + tm_fill(col = "Comp.5", palette = "YlOrRd", midpoint = NA)

tm_shape(PCA_map5) + tm_fill(col = "Comp.6", palette = "YlGn", midpoint = NA)

tm_shape(PCA_map5) + tm_fill(col = "Comp.7", palette = "RdYlGn", midpoint = NA)

tm_shape(PCA_map5) + tm_fill(col = "Comp.8", palette = "RdYlBu", midpoint = NA)

mapping results 6

tm_shape(PCA_map6) + tm_fill(col = "Comp.1", palette = "YlOrBr", midpoint = NA)

tm_shape(PCA_map6) + tm_fill(col = "Comp.2", palette = "YlGnBu", midpoint = NA)

tm_shape(PCA_map6) + tm_fill(col = "Comp.3", palette = "RdPu", midpoint = NA)

tm_shape(PCA_map6) + tm_fill(col = "Comp.4", palette = "PuBuGn", midpoint = NA)

tm_shape(PCA_map6) + tm_fill(col = "Comp.5", palette = "YlOrRd", midpoint = NA)

tm_shape(PCA_map6) + tm_fill(col = "Comp.6", palette = "YlGn", midpoint = NA)

tm_shape(PCA_map6) + tm_fill(col = "Comp.7", palette = "RdYlGn", midpoint = NA)

tm_shape(PCA_map6) + tm_fill(col = "Comp.8", palette = "RdYlBu", midpoint = NA)

mapping results 7

tm_shape(PCA_map7) + tm_fill(col = "Comp.1", palette = "YlOrBr", midpoint = NA)

tm_shape(PCA_map7) + tm_fill(col = "Comp.2", palette = "YlGnBu", midpoint = NA)

tm_shape(PCA_map7) + tm_fill(col = "Comp.3", palette = "RdPu", midpoint = NA)

tm_shape(PCA_map7) + tm_fill(col = "Comp.4", palette = "PuBuGn", midpoint = NA)

tm_shape(PCA_map7) + tm_fill(col = "Comp.5", palette = "YlOrRd", midpoint = NA)

tm_shape(PCA_map7) + tm_fill(col = "Comp.6", palette = "YlGn", midpoint = NA)

tm_shape(PCA_map7) + tm_fill(col = "Comp.7", palette = "RdYlGn", midpoint = NA)

tm_shape(PCA_map7) + tm_fill(col = "Comp.8", palette = "RdYlBu", midpoint = NA)

to bind the data frame and project pca on geography

creating a data frame of the scaled data

class(group1$geometry)

geometry1 <- (group1$geometry) coords1 <- st_as_sfc(geometry1) class(coords1)

coords1 geometry is re-projected as spatial

coords1_sp <- as_Spatial(coords1, cast = TRUE) class(coords1_sp) summary(coords1_sp) plot(coords1_sp)

colnames(GROUP101_scaled_frame)

colnames(GROUP102_scaled_frame)

GROUP103.scaled <- scale(as.matrix(group1[1:7])) summary(GROUP103.scaled)

converting to spatial points (/polygons) data frame for gwpca - although mapping for polygons both examples display spatial point df

SPDF1 <- SpatialPointsDataFrame(coords=coords1_sp, data=as.data.frame(GROUP103.scaled))

summary (SPDF1) class(SPDF1) SPDF1

nrow(SPDF1) ncol(SPDF1)

#

SPDF2 <- SpatialPointsDataFrame(coords=coords1_sp, data=as.data.frame(GROUP201.scaled))

summary (SPDF2) class(SPDF2) SPDF2

nrow(SPDF2) ncol(SPDF2)

```
#
SPDF3 <- SpatialPointsDataFrame(coords=coords1_sp, data=as.data.frame(GROUP301.scaled))
summary (SPDF3) class(SPDF3) SPDF3
nrow(SPDF3) ncol(SPDF3)
#
SPDF4 <- SpatialPointsDataFrame(coords=coords1_sp, data=as.data.frame(GROUP401.scaled))
summary (SPDF4) class(SPDF4) SPDF4
nrow(SPDF4) ncol(SPDF4)
#
SPDF5 <- SpatialPointsDataFrame(coords=coords1_sp, data=as.data.frame(GROUP501.scaled))
summary (SPDF5) class(SPDF5) SPDF5
nrow(SPDF5) ncol(SPDF5)
#
SPDF6 <- SpatialPointsDataFrame(coords=coords1_sp, data=as.data.frame(GROUP601.scaled))
summary (SPDF6) class(SPDF6) SPDF6
nrow(SPDF6) ncol(SPDF6)
```

bandwidth selection 1

```
bw_gwpca1 <- bw.gwpca(SPDF1, vars = colnames(SPDF1@data), k = 7, robust = FALSE, adaptive = TRUE)
```

bandwidth selection 2

```
bw_gwpca2 <- bw.gwpca(SPDF2, vars = colnames(SPDF2@data), k = 5, robust = FALSE, adaptive = TRUE)
```

bandwidth selection 3

```
bw_gwpca3 <- bw.gwpca(SPDF3, vars = colnames(SPDF3@data), k = 3, robust = FALSE, adaptive = TRUE)
```

bandwidth selection 4

```
bw_gwpca4 <- bw.gwpca(SPDF4, vars = colnames(SPDF4@data), k = 8, robust = FALSE, adaptive = TRUE)
```

bandwidth selection 5

```
bw_gwpca5 <- bw.gwpca(SPDF5, vars = colnames(SPDF5@data), k = 8, robust = FALSE, adaptive = TRUE)
```

bandwidth selection 6

```
bw_gwpca6 <- bw.gwpca(SPDF6, vars = colnames(SPDF6@data), k = 8, robust = FALSE, adaptive = TRUE)
```

Calculating gwpca

although selected bandwidth, here setting specific relative bandwidth for continuity and uniformity

```
gwpca1 <- gwpca(SPDF1,vars=colnames(SPDF1@data),bw=1000000,k=7,scores=T) gwpca1
summ(gwpca1)
class(gwpca1) #### gwpca is a complex object with pca, gwpca, scores and projections packed
```

```
# gwpca2 <- gwpca(SPDF2,vars=colnames(SPDF2@data),bw=1000000,k=5,scores=T) gwpca2
class(gwpca2)
# gwpca3 <- gwpca(SPDF3,vars=colnames(SPDF3@data),bw=1000000,k=3,scores=T) gwpca3
class(gwpca3)
# gwpca4 <- gwpca(SPDF4,vars=colnames(SPDF4@data),bw=1000000,k=8,scores=T) gwpca4
class(gwpca4)
# gwpca5 <- gwpca(SPDF5,vars=colnames(SPDF5@data),bw=1000000,k=8,scores=T) gwpca5
class(gwpca5)
# gwpca6 <- gwpca(SPDF6,vars=colnames(SPDF6@data),bw=1000000,k=8,scores=T) gwpca6
class(gwpca6)
```

---

saving output files

```
sink('gwpca1.txt') gwpca1 sink()
sink('gwpca2.txt') gwpca2 sink()
sink('gwpca3.txt') gwpca3 sink()
sink('gwpca4.txt') gwpca4 sink()
sink('gwpca5.txt') gwpca5 sink()
sink('gwpca6.txt') gwpca6 sink()
#
local.loadings <- gwpca1$loadings [, , 1] # for 1st component only? all components separately? local.loadings
class(local.loadings)
local.loadings2 <- gwpca1$loadings [, , 2] # for 2nd component only? all components separately? local.loadings2
```

here we extract the scores from the complex gwpca object

```
gwpca_scores1 <- gwpca1$gwpca.scores gwpca_scores1
class(gwpca_scores1) nrow(gwpca_scores1)
as.data.frame(gwpca_scores1)
```

```
gwpca_scores2 <- gwpca2$gwpca.scores gwpca_scores2
class(gwpca_scores2) nrow(gwpca_scores2)
as.data.frame(gwpca_scores2)
```

```
gwpca_scores3 <- gwpca3$gwpca.scores gwpca_scores3
class(gwpca_scores3) nrow(gwpca_scores3)
as.data.frame(gwpca_scores3)
```

```
gwpca_scores4 <- gwpca4$gwpca.scores gwpca_scores4
```

class(gwpca_scores4) nrow(gwpca_scores4)

as.data.frame(gwpca_scores4)

---

gwpca_scores5 <- gwpca5$gwpca.scores gwpca_scores5

class(gwpca_scores5) nrow(gwpca_scores5)

as.data.frame(gwpca_scores5)

---

gwpca_scores6 <- gwpca6$gwpca.scores gwpca_scores6

class(gwpca_scores6) nrow(gwpca_scores6)

as.data.frame(gwpca_scores6)

to plot box plot to see spread for each component of level 1 and 2

gwpc1 <- local.loadings[,1] boxplot(gwpc1,horizontal = TRUE) gwpc2 <- local.loadings[,2] boxplot(gwpc2,horizontal = TRUE) gwpc3 <- local.loadings[,3] boxplot(gwpc3,horizontal = TRUE) gwpc4 <- local.loadings[,4] boxplot(gwpc4,horizontal = TRUE) gwpc5 <- local.loadings[,5] boxplot(gwpc5,horizontal = TRUE) gwpc6 <- local.loadings[,6] boxplot(gwpc6,horizontal = TRUE) gwpc7 <- local.loadings[,7] boxplot(gwpc7,horizontal = TRUE)

mapping gwpca

geom1 <- st_as_sf(group1, wkt = "geometry", crs = st_crs(27700)) geom2 <- st_as_sf(group2, wkt = "geometry", crs = st_crs(27700)) geom3 <- st_as_sf(group3, wkt = "geometry", crs = st_crs(27700)) geom4 <- st_as_sf(group4, wkt = "geometry", crs = st_crs(27700)) geom5 <- st_as_sf(group5, wkt = "geometry", crs = st_crs(27700)) geom6 <- st_as_sf(group6, wkt = "geometry", crs = st_crs(27700))

sum(is.na(gwpca_scores1))

df <-gwpca_scores1

gwpca_map1 <- cbind(geom1,gwpca_scores1) class(gwpca_map1)

gwpca_map2 <- cbind(geom2,gwpca_scores2) class(gwpca_map2)

gwpca_map3 <- cbind(geom3,gwpca_scores3) class(gwpca_map3)

gwpca_map4 <- cbind(geom4,gwpca_scores4) class(gwpca_map4)

gwpca_map5 <- cbind(geom5,gwpca_scores5) class(gwpca_map5)

gwpca_map6 <- cbind(geom6,gwpca_scores6) class(gwpca_map6)

chop unwanted columns

gwpca_map101 <- gwpca_map1[,c(8:14)]

gwpca_map102 <- gwpca_map2[,c(7:11)]

gwpca_map103 <- gwpca_map3[,c(5:7)]

gwpca_map104 <- gwpca_map4[,c(10:17)]

gwpca_map105 <- gwpca_map5[,c(14:21)]

gwpca_map106 <- gwpca_map6[,c(8:14)]

mapping results 1

```
tm_shape(gwpca_map101) + tm_fill( col = "X1", palette = "YlOrBr", midpoint = NA )
tm_shape(gwpca_map101) + tm_fill( col = "X2", palette = "YlGnBu", midpoint = NA )
tm_shape(gwpca_map101) + tm_fill( col = "X3", palette = "RdPu", midpoint = NA )
tm_shape(gwpca_map101) + tm_fill( col = "X4", palette = "PuBuGn", midpoint = NA )
tm_shape(gwpca_map101) + tm_fill( col = "X5", palette = "YlOrRd", midpoint = NA )
tm_shape(gwpca_map101) + tm_fill( col = "X6", palette = "YlGn", midpoint = NA )
tm_shape(gwpca_map101) + tm_fill( col = "X7", palette = "RdYlBu", midpoint = NA )
```

mapping results 2

```
tm_shape(gwpca_map102) + tm_fill( col = "X1", palette = "YlOrBr", midpoint = NA )
tm_shape(gwpca_map102) + tm_fill( col = "X2", palette = "YlGnBu", midpoint = NA )
tm_shape(gwpca_map102) + tm_fill( col = "X3", palette = "RdPu", midpoint = NA )
tm_shape(gwpca_map102) + tm_fill( col = "X4", palette = "PuBuGn", midpoint = NA )
tm_shape(gwpca_map102) + tm_fill( col = "X5", palette = "YlOrRd", midpoint = NA )
```

mapping results 3

```
tm_shape(gwpca_map103) + tm_fill( col = "X1", palette = "YlOrBr", midpoint = NA )
tm_shape(gwpca_map103) + tm_fill( col = "X2", palette = "YlGnBu", midpoint = NA )
tm_shape(gwpca_map103) + tm_fill( col = "X3", palette = "RdPu", midpoint = NA )
```

mapping results 4

```
tm_shape(gwpca_map104) + tm_fill( col = "X1", palette = "YlOrBr", midpoint = NA )
tm_shape(gwpca_map104) + tm_fill( col = "X2", palette = "YlGnBu", midpoint = NA )
tm_shape(gwpca_map104) + tm_fill( col = "X3", palette = "RdPu", midpoint = NA )
tm_shape(gwpca_map104) + tm_fill( col = "X4", palette = "PuBuGn", midpoint = NA )
tm_shape(gwpca_map104) + tm_fill( col = "X5", palette = "YlOrRd", midpoint = NA )
tm_shape(gwpca_map104) + tm_fill( col = "X6", palette = "YlGn", midpoint = NA )
tm_shape(gwpca_map104) + tm_fill( col = "X7", palette = "BuGn", midpoint = NA )
```

mapping results 5

```
tm_shape(gwpca_map105) + tm_fill( col = "X1", palette = "YlOrBr", midpoint = NA )
tm_shape(gwpca_map105) + tm_fill( col = "X2", palette = "YlGnBu", midpoint = NA )
tm_shape(gwpca_map105) + tm_fill( col = "X3", palette = "RdPu", midpoint = NA )
tm_shape(gwpca_map105) + tm_fill( col = "X4", palette = "PuBuGn", midpoint = NA )
tm_shape(gwpca_map105) + tm_fill( col = "X5", palette = "YlOrRd", midpoint = NA )
tm_shape(gwpca_map105) + tm_fill( col = "X6", palette = "YlGn", midpoint = NA )
tm_shape(gwpca_map105) + tm_fill( col = "X7", palette = "BuGn", midpoint = NA )
tm_shape(gwpca_map105) + tm_fill( col = "X8", palette = "RdYlBu", midpoint = NA )
```

mapping results 6

```
tm_shape(gwpca_map106) + tm_fill( col = "X1", palette = "YlOrBr", midpoint = NA )

tm_shape(gwpca_map106) + tm_fill( col = "X2", palette = "YlGnBu", midpoint = NA )

tm_shape(gwpca_map106) + tm_fill( col = "X3", palette = "RdPu", midpoint = NA )

tm_shape(gwpca_map106) + tm_fill( col = "X4", palette = "PuBuGn", midpoint = NA )

tm_shape(gwpca_map105) + tm_fill( col = "X5", palette = "YlOrRd", midpoint = NA )

tm_shape(gwpca_map106) + tm_fill( col = "X6", palette = "YlGn", midpoint = NA )

tm_shape(gwpca_map106) + tm_fill( col = "X7", palette = "BuGn", midpoint = NA )

tm_shape(gwpca_map106) + tm_fill( col = "Comp.8", palette = "RdYlBu", midpoint = NA )
```

calculating variation gwpca

```
prop.var1 <- function(gwpca1.obj, n.components) { return((rowSums(gwpca1.obj$var[, 1:n.components])
/rowSums(gwpca1.obj$var)) * 100) }

var.gwpca1 <- prop.var(gwpca1, 7)

var.gwpca1

group1$var.gwpca1 <- var.gwpca1

var.gwpca1

prop.var2 <- function(gwpca2.obj, n.components) { return((rowSums(gwpca2.obj$var[, 1:n.components])
/rowSums(gwpca2.obj$var)) * 100) }

var.gwpca2 <- prop.var(gwpca2, 7)

var.gwpca2

group2$var.gwpca1 <- var.gwpca2

var.gwpca2

prop.var3 <- function(gwpca3.obj, n.components) { return((rowSums(gwpca3.obj$var[, 1:n.components])
/rowSums(gwpca3.obj$var)) * 100) }

var.gwpca3 <- prop.var(gwpca3, 7)

var.gwpca3

group3$var.gwpca3 <- var.gwpca3

var.gwpca3

prop.var4 <- function(gwpca4.obj, n.components) { return((rowSums(gwpca4.obj$var[, 1:n.components])
/rowSums(gwpca4.obj$var)) * 100) }

var.gwpca4 <- prop.var(gwpca4, 7)

var.gwpca4

group4$var.gwpca4 <- var.gwpca4

var.gwpca4

prop.var5 <- function(gwpca5.obj, n.components) { return((rowSums(gwpca5.obj$var[, 1:n.components])
/rowSums(gwpca5.obj$var)) * 100) }

var.gwpca5 <- prop.var(gwpca5, 7)

var.gwpca5

group5$var.gwpca5 <- var.gwpca5
```

```
var.gwpca5

prop.var6 <- function(gwpca6.obj, n.components) { return((rowSums(gwpca6.obj$var[, 1:n.components])
/rowSums(gwpca6.obj$var)) * 100) }

var.gwpca6 <- prop.var(gwpca6, 7)

var.gwpca6

group6$var.gwpca6 <- var.gwpca6

var.gwpca6
```

end