# final

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### *ERROR Found*

In this document, there is a recurring syntax error present in several code blocks. The error arises from the absence of the language identifier `{r}` within the code blocks, preventing the code from being properly interpreted as R code.

In the original document, the language identifier `{r}` was written like this:

```

# sample code
```

To resolve this issue, we made sure that all code blocks are preceded by the language identifier `{r}` to indicate that they contain R code.

```r
# sample code
```

## How to Create a 3D Population Density Map in R

### *1. Install library Packages:*

You need to install the necessary packages. Run the following commands in your R console. Try to install them one by one, it might library restarting the R-session several times.

```r
install.packages("sf", dependencies=TRUE)
install.packages("tmap", dependencies=TRUE)
install.packages("mapview", dependencies=TRUE)
install.packages("stars", dependencies=TRUE)
install.packages("rayshader", dependencies=TRUE)
install.packages("MetBrewer", dependencies=TRUE)
install.packages("rayrender")
install.packages("extrafont", dependencies=TRUE)
install.packages("magick", dependencies=TRUE)
```

### *2. Load Packages and Set Options:*

Load the library libraries and set the RGL options:

```
options(rgl.useNULL = FALSE)
library(tidyverse)

## ── Attaching core tidyverse packages ──────────────────────── tidyverse
2.0.0 ──
## ✓ dplyr     1.1.4     ✓ readr     2.1.5
## ✓ forcats   1.0.0     ✓ stringr   1.5.1
## ✓ ggplot2   3.5.0     ✓ tibble    3.2.1
## ✓ lubridate 1.9.3     ✓ tidyr     1.3.1
## ✓ purrr     1.0.2
## ── Conflicts ──────────────────────────────────────────
tidyverse_conflicts() ──
## ✕ dplyr::filter() masks stats::filter()
## ✕ dplyr::lag()    masks stats::lag()
## ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all
conflicts to become errors

library(sf)

## Linking to GEOS 3.11.2, GDAL 3.8.2, PROJ 9.3.1; sf_use_s2() is TRUE

library(tmap)

## Breaking News: tmap 3.x is retiring. Please test v4, e.g. with
## remotes::install_github('r-tmap/tmap')

library(ggplot2)
library(mapview)
library(stars)

## Loading required package: abind

library(rayshader)
library(MetBrewer)
library(colorspace)
library(rayrender)

##
## Attaching package: 'rayrender'
##
## The following object is masked from 'package:rayshader':
##
##     run_documentation
##
## The following object is masked from 'package:ggplot2':
##
##     arrow

library(magick)
```

```
## Linking to ImageMagick 6.9.12.98
## Enabled features: cairo, freetype, fftw, ghostscript, heic, lcms, pango,
raw, rsvg, webp
## Disabled features: fontconfig, x11

library(extrafont)

## Registering fonts with R
```

### *3. Load and Transform Data:*

You'll need to load the population data and administrative boundaries for the Philippines, transforming them into a suitable coordinate system. The data is downloaded from Kontur Population.

```
# population data of Myanmar
MM_hex <- st_read("data/kontur_population_MM_20231101.gpkg") %>%
st_transform(3106)

## Reading layer `population' from data source
##   `C:\Users\User\Downloads\data\kontur_population_MM_20231101.gpkg'
##   using driver `GPKG'
## Simple feature collection with 212821 features and 2 fields
## Geometry type: POLYGON
## Dimension:     XY
## Bounding box:  xmin: 10259660 ymin: 1078258 xmax: 11261570 ymax: 3303433
## Projected CRS: WGS 84 / Pseudo-Mercator

# administrative boundaries of Myanmar
MM_admin <- st_read("data/kontur_boundaries_MM_20230628.gpkg") %>%
st_transform(3106)

## Reading layer `boundaries' from data source
##   `C:\Users\User\Downloads\data\kontur_boundaries_MM_20230628.gpkg'
##   using driver `GPKG'
## Simple feature collection with 488 features and 6 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: 92.17292 ymin: 9.526084 xmax: 101.1701 ymax: 28.54784
## Geodetic CRS:  WGS 84
```

### *4. Check and Create Boundaries:*

Inspect the 'name_en' column and create the boundary for the Philippines. Use the filter option to plot specific districts and divisions on the map.

```
distinct_names <- MM_admin %>% distinct(name_en)
print(distinct_names)

##                                 name_en
## 1                               Myanmar
## 2                                  <NA>
## 3                          Bago Region
## 4                              Rakhine
## 5            Naypyitaw Union Territory
## 6                            Mon State
## 7                             Mandalay
## 8                               Magway
## 9                          Kayin State
## 10                         Kayah State
## 11                        Kachin State
## 12                                Chin
## 13                          Ayeyarwady
## 14                              Yangon
## 15                  Tanintharyi Region
## 16                          Shan State
## 17                      Sagaing Region
## 18     Pa Laung Self-Administered Zone
## 19         Pa'O Self-Administered Zone
## 20         Danu Self-Administered Zone
## 21         Naga Self-Administered Zone
## 22       Wa Self-Administered Division
## 23                    South Shan State
## 24                    North Shan State
## 25                     East Shan State
## 26                    West Bago Region
## 27                    East Bago Region
## 28            Wa State Southern region
## 29          Wa State (Northern Region)
## 30           Nam Deeg Special District
## 31                    Kyaukme District
## 32                   Kyaukpyu District
## 33                    Kyaukse District
## 34                             Labutta
## 35                    Langhko District
## 36                     Lashio District
## 37                  Laukkaing District
## 38                     Loikaw District
## 39                     Loilen District
## 40                     Magway District
## 41                   Mandalay District
## 42                     Matman District
## 43                              Maubin
## 44                   Maungdaw District
## 45                    Mawlaik District
## 46                 Mawlamyine District
## 47                   Meiktila District
## 48                      Minbu District
## 49                      Mindat District
## 50                     Mohnyin District
## 51                   Mong Hsat District
## 52                      Monywa District
## 53                    Mrauk-U District
## 54                      Mu Se District
## 55                           Myaungmya
## 56                   Myawaddy District
## 57                      Myeik District
## 58                  Myitkyina District
## 59                   Myingyan District
## 60                   Nyaung-U District
## 61                    Pakokku District
## 62                             Pathein
## 63                      Putao District
## 64                              Pyapon
## 65                       Pyay District
## 66               Pyin Oo Lwin District
## 67                    Sagaing District
## 68                     Shwebo District
## 69                     Sittwe District
## 70                  Tachileik District
## 71                Mong Hpayak District
## 72                       Tamu District
## 73                   Taunggyi District
## 74                    Taungoo District
## 75                    Thandwe District
## 76                     Thaton District
## 77                Tharrawaddy District
## 78                     Thayet District
## 79                   Yamethin District
## 80                   Yinmabin District
## 81                       Bago District
## 82                   Bawlakhe District
## 83                      Bhamo District
## 84                      Dawei District
## 85                      Falam District
## 86                     Gangaw District
## 87                      Hakha District
## 88                            Hinthada
## 89                  Kawthoung District
## 90                        Yangon South
## 91           Pangkham Special District
## 92                   Kengtung District
## 93                         Yangon West
## 94                         Yangon East
## 95                     Hkamti District
## 96                        Yangon North
## 97                     Hopang District
## 98                   Dekkhina District
## 99                    Ottara District
## 100                    Hpa-An District
## 101                   Kanbalu District
## 102                    Hpapun District
## 103                      Kale District
## 104                  Mong Mit District
## 105                     Katha District
## 106                 Kawkareik District
## 107                  Mōung Nēng County
## 108                    Mongpauk County
## 109                    Mongmaoe County
## 110                  Yinmabin Township
## 111                   Ywangan Township
## 112                 Zabuthiri Township
## 113                              Zalun
## 114                Zeyarthiri Township
## 115                     Zigon Township
## 116                   Pinlebu Township
## 117                  Pinlaung Township
## 118                   Pindaya Township
## 119                               Phyu
## 120                     Pekon Township
## 121                   Paungde Township
## 122                 Paungbyin Township
## 123                     Paung Township
## 124                   Pauktaw Township
## 125                 Paukkaung Township
## 126                      Pauk Township
## 127                Patheingyi Township
## 128                           Pantanaw
## 129                  Pangwaun Township
## 130                  Pangsang Township
## 131                   Paletwa Township
## 132                      Pale Township
## 133                     Palaw Township
## 134                   Pakokku Township
## 135                             Ahlone
## 136                 Amarapura Township
## 137                       Ann Township
## 138                   Aunglan Township
## 139             Aungmyethazan Township
## 140                    Ayadaw Township
## 141                      Bago Township
## 142                              Bahan
## 143                   Banmauk Township
## 144                  Bawlakhe Township
## 145                     Bhamo Township
## 146                     Bilin Township
## 147                             Bogale
## 148                   Bokpyin Township
## 149                   Budalin Township
## 150                Buthidaung Township
## 151             Chanayethazan Township
## 152              Chanmyathazi Township
## 153                     Chauk Township
## 154                  Chaung-U Township
## 155                 Chaungzon Township
## 156                    Chipwi Township
## 157                           Cocokyun
## 158                              Dagon
## 159                    Daik-U Township
## 160                               Dala
## 161                            Danubyu
## 162                             Dawbon
## 163                     Dawei Township
## 164                             Dedaye
## 165             Dekkhinathiri Township
## 166                    Demoso Township
## 167                              Einme
## 168                     Falam Township
## 169                    Gangaw Township
## 170                       Gwa Township
## 171                Gyobingauk Township
## 172                     Hakha Township
## 173                    Hkamti Township
## 174                             Hlaing
## 175                 Hlaingbwe Township
## 176                Hlaingtharya (East)
## 177                              Hlegu
## 178                             Hmawbi
## 179                   Homalin Township
## 180                             Hopang
## 181                    Hopong Township
## 182                    Hpa-An Township
## 183                   Hpakant Township
## 184                  Hpasawng Township
## 185                    Hpruso Township
## 186                    Hsenwi Township
## 187                 Hsi Hseng Township
## 188                    Hsipaw Township
## 189                 Htantabin Township
## 190                          Htantabin
## 191                     Indaw Township
## 192                             Ingapu
## 193                Injangyang Township
## 194                             Insein
## 195                     Kalaw Township
## 196                     Kalay Township
## 197                    Kalewa Township
## 198                           Kamaryut
## 199                     Kamma Township
## 200                   Kanbalu Township
## 201                        Kangyidaunt
## 202                      Kani Township
## 203                 Kanpetlet Township
## 204                     Katha Township
## 205                      Kawa Township
## 206                             Kawhmu
## 207                 Kawkareik Township
## 208                    Kawlin Township
## 209                 Kawthoung Township
## 210                              Kayan
## 211                  Kengtung Township
## 212              Kawnglanghpu Township
## 213                    Khin-U Township
## 214                            Konkyan
## 215                         Kungyangon
## 216                   Kunhing Township
## 217                   Kunlong Township
## 218                    Kutkai Township
## 219                           Kyaiklat
## 220                Kyaikmaraw Township
## 221                   Kyaikto Township
## 222              Kyainseikgyi Township
## 223                            Kyangin
## 224                  Kyaukkyi Township
## 225                   Kyaukme Township
## 226              Kyaukpadaung Township
## 227                  Kyaukpyu Township
## 228                   Kyaukse Township
## 229                          Kyauktada
## 230                 Kyauktaga Township
## 231                           Kyauktan
## 232                  Kyauktaw Township
## 233                          Kyaunggon
## 234                      Kyeemyindaing
## 235                    Kyethi Township
## 236                           Kyonpyaw
## 237                   Kyunhla Township
## 238                    Kyunsu Township
## 239                      Lahe Township
## 240                   Lai-Hka Township
## 241                   Langhko Township
## 242                           Lanmadaw
## 243                    Lashio Township
## 244                              Latha
## 245                          Laukkaing
## 246                  Launglon Township
## 247                  Lawksawk Township
## 248                     Leshi Township
## 249                          Lemyethna
## 250                  Letpadan Township
## 251                      Lewe Township
## 252                    Loikaw Township
## 253                    Loilem Township
## 254                    Mabein Township
## 255                 Machanbaw Township
## 256                    Madaya Township
## 257                    Magway Township
## 258              Maha Aungmye Township
## 259                  Mahlaing Township
## 260                     Mansi Township
## 261                   Mantong Township
## 262                             Matman
## 263                    Matupi Township
## 264                  Maungdaw Township
## 265                   Mawkmai Township
## 266                   Mawlaik Township
## 267                         Mawlamyine
## 268                     Mawlamyinegyun
## 269                          Mayangone
## 270                  Meiktila Township
## 271                      Mese Township
## 272                     Minbu Township
## 273                    Minbya Township
## 274                    Mindat Township
## 275                    Mindon Township
## 276                 Mingala Taungnyunt
## 277                    Mingin Township
## 278                    Minhla Township
## 279                   Mogaung Township
## 280                     Mogok Township
## 281                   Mohnyin Township
## 282                    Momauk Township
## 283               Mong Hpayak Township
## 284                 Mong Hsat Township
## 285                  Mong Hsu Township
## 286                 Mong Kung Township
## 287                 Mong Khet Township
## 288                   Mong La Township
## 289                   Mongmao Township
## 290                  Mong Mit Township
## 291                  Mong Nai Township
## 292                  Mong Pan Township
## 293                 Mong Ping Township
## 294                  Mong Ton Township
## 295                   Mongyai Township
## 296                 Mong Yang Township
## 297                Mong Yawng Township
## 298                     Monyo Township
## 299                    Monywa Township
## 300                 Ponnagyun Township
## 301                     Mudon Township
## 302                   Manaung Township
## 303                      Muse Township
## 304                    Myaing Township
## 305                           Myanaung
## 306                    Myaung Township
## 307                    Myebon Township
## 308                     Myeik Township
## 309                  Myingyan Township
## 310                    Myinmu Township
## 311                 Myitkyina Township
## 312                   Myittha Township
## 313                   Myothit Township
## 314                   Namhkam Township
## 315                   Namhsan Township
## 316                     Namtu Township
## 317                   Nansang Township
## 318                    Nanyun Township
## 319                   Narphan Township
## 320                   Natmauk Township
## 321                   Natogyi Township
## 322                  Nattalin Township
## 323                 Nawnghkio Township
## 324                  Nawngmun Township
## 325                     Ngape Township
## 326                           Ngapudaw
## 327                    Ngazun Township
## 328                     North Okkalapa
## 329                  Nyaung-U Township
## 330                          Nyaungdon
## 331               Nyaunglebin Township
## 332                Nyaungshwe Township
## 333                     Okpho Township
## 334                    Oktwin Township
## 335               Ottarathiri Township
## 336                            Pabedan
## 337                  Pandaung Township
## 338                     South Okkalapa
## 339                        Thingangyun
## 340                         Pazundaung
## 341                         Botahtaung
## 342                      Dagon Seikkan
## 343                        South Dagon
## 344                         East Dagon
## 345                        North Dagon
## 346                   Mrauk-U Township
## 347                     Putao Township
## 348                  Pwintbyu Township
## 349                   Pyawbwe Township
## 350                      Pyay Township
## 351               Pyigyidagun Township
## 352                  Pyinmana Township
## 353                Pyinoolwin Township
## 354                    Ramree Township
## 355                Rathedaung Township
## 356                   Sagaing Township
## 357                     Salin Township
## 358                  Salingyi Township
## 359                          Sanchaung
## 360                       Saw Township
## 361                   Seikgyikanaungto
## 362                  Seikphyu Township
## 363                    Shadaw Township
## 364                    Shwebo Township
## 365                 Shwedaung Township
## 366                    Shwegu Township
## 367                  Shwegyin Township
## 368                        Shwepyithar
## 369                 Sidoktaya Township
## 370                Sinbaungwe Township
## 371                     Singu Township
## 372                 Sintgaing Township
## 373                    Sittwe Township
## 374                 Sumprabum Township
## 375                   Tabayin Township
## 376                    Tada-U Township
## 377                            Taikkyi
## 378                              Tamwe
## 379                     Tanai Township
## 380                   Tangyan Township
## 381               Tanintharyi Township
## 382                    Tatkon Township
## 383              Taungdwingyi Township
## 384                  Taunggyi Township
## 385                   Taungoo Township
## 386                  Taungtha Township
## 387                      Taze Township
## 388                     Tedim Township
## 389                           Thabaung
## 390               Thabeikkyin Township
## 391                            Thaketa
## 392                 Thanatpin Township
## 393              Thanbyuzayat Township
## 394              Thandaunggyi Township
## 395                   Thandwe Township
## 396                           Thanlyin
## 397                 Thantlang Township
## 398                    Thaton Township
## 399               Tharrawaddy Township
## 400                    Thayet Township
## 401              Thayetchaung Township
## 402                     Thazi Township
## 403                    Thegon Township
## 404                            Thongwa
## 405                  Tigyaing Township
## 406                     Tilin Township
## 407                   Tonzang Township
## 408                   Toungup Township
## 409                   Hsawlaw Township
## 410                            Twantay
## 411                           Waingmaw
## 412                             Wakema
## 413                       Waw Township
## 414                    Wetlet Township
## 415                   Wundwin Township
## 416                    Wuntho Township
## 417                  Yamethin Township
## 418                             Yankin
## 419                                 Ye
## 420                      Ye-U Township
## 421                     Yebyu Township
## 422                   Yedashe Township
## 423                              Yegyi
## 424                        Yenangyaung
## 425                   Yesagyo Township
## 426                  Great Coco Island
## 427                Hlaingtharya (West)
## 428                Pobbathiri Township
## 429                             Narwee
## 430           Kaung Ming Sang District
## 431                    Banwai District
## 432                  Man Doun District
## 433                  Mansiang District
## 434                  Yawnglin District
## 435                 Nar Kawng District
## 436                Noung Kied District
## 437               Nam Hkan Wu District
## 438                   Panyang District
## 439                           Hkun Mar
## 440                  Mongpauk District
## 441                     Hotao District
## 442                            Longtan
## 443 Monghpen Economic Development Zone
## 444                   Namhpai District
## 445                 Mong Ning District
## 446                         Yiang Chen
## 447                   Yingpan District
## 448                    Lianhe District
## 449                  Glong Ba District
## 450                       San Chi Ward
## 451                    Htein Thit Ward
## 452                   Byaw Taw Wa Ward
## 453                      Sin Seik Ward
## 454                     Kyauk Maw Ward
## 455                  Pein Hne Taw Ward
## 456                       Ka Nyon Ward
## 457                        Za Yit Ward
## 458                       Bon Maw Ward
## 459                  Kyet Sa Pyin Ward
## 460                     Daung Ngu Ward
## 461                 Thin Baw Seik Ward
## 462              Ah Nauk Myo Twin Ward
## 463                Ta Laing Htein Ward
## 464                       Oe Loke Ward
## 465                     Kaing Daw Kwin

# Creating BD Boundary
MM_boundary <- MM_admin %>%
  st_geometry %>%
  st_union %>%
  st_sf %>%
  st_make_valid()
```

*5. Plot Boundaries for Verification:*

Visualize the hex data and boundaries to ensure accuracy.

```
names(MM_hex)

## [1] "h3"         "population" "geom"
```

## Revision No. 1

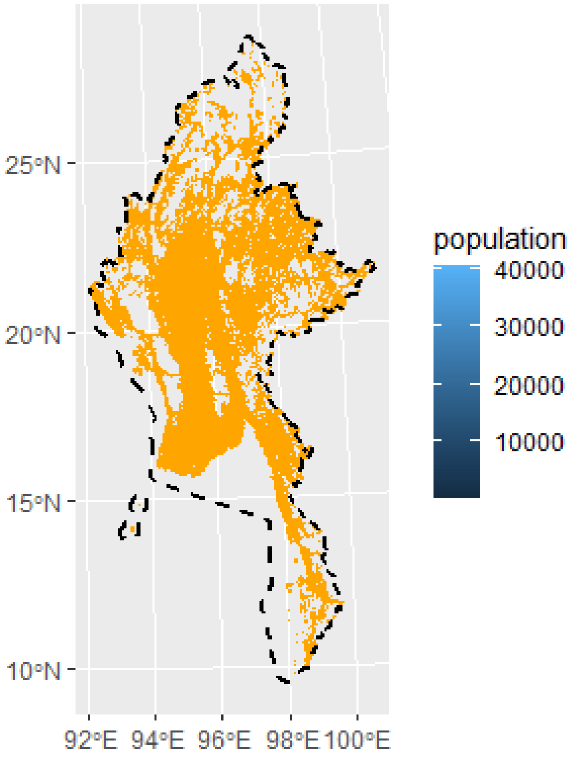
Upon reviewing the original code, we found that the representation of the boundary lines in the plot lacked clarity and distinction. To address this, we revised the code to enhance the styling of the boundary lines in the plot.

We added the `linetype` and `linewidth` parameters in the `geom_sf` function to include boundary lines in the plot.

```
 library(ggplot2)

ggplot(MM_hex) +
  geom_sf(aes(fill = population),
          color = "orange",
          linewidth = 0) +
  geom_sf(
    data = MM_boundary,
    fill = NA,
    color = "black",

    # additional code for boundary lines
    linetype = "dashed",
    linewidth = .8
  )
```



### *6. Calculate Aspect Ratio:*

Determine the aspect ratio for the map based on the bounding box of the boundary.

```
# setting the ph boundary as a bounding box
bbox <- st_bbox(MM_boundary)

# finding the aspect ratio
bottom_left <- st_point(c(bbox[["xmin"]], bbox[["ymin"]])) %>%
  st_sfc(crs = 3106)
bottom_right <- st_point(c(bbox[["xmax"]], bbox[["ymin"]])) %>%
  st_sfc(crs = 3106)
top_left <- st_point(c(bbox[["xmin"]], bbox[["ymax"]])) %>%
  st_sfc(crs = 3106)
top_right <- st_point(c(bbox[["xmin"]], bbox[["ymax"]])) %>%
  st_sfc(crs = 3106)

width <- st_distance(bottom_left, bottom_right)
height <- st_distance(bottom_left, top_left)

if(width > height) {
  w_ratio = 1
  h_ratio = height / width
} else {
  h_ratio = 1.1
  w_ratio = width / height
}
```

### *7. Rasterize Population Data:*

Convert the population data into a raster format suitable for 3D rendering.

- For interactively checking the 3D plot setting the size low will help render in real time.

- To improve the quality of the 3D image when saving, change the settings to a higher resolution.

```
# convert to raster to convert to matrix
size = 3500

pop_raster <- st_rasterize(
  MM_hex,
  nx = floor(size * w_ratio) %>% as.numeric(),
  ny = floor(size * h_ratio) %>% as.numeric()
)

pop_matrix <- matrix(pop_raster$population,
                     nrow = floor(size * w_ratio),
                     ncol = floor(size * h_ratio))
```

### *8. Define Color Palette:*

Select a color palette from the MetBrewer or RColorBrewer library and customize it for your map.

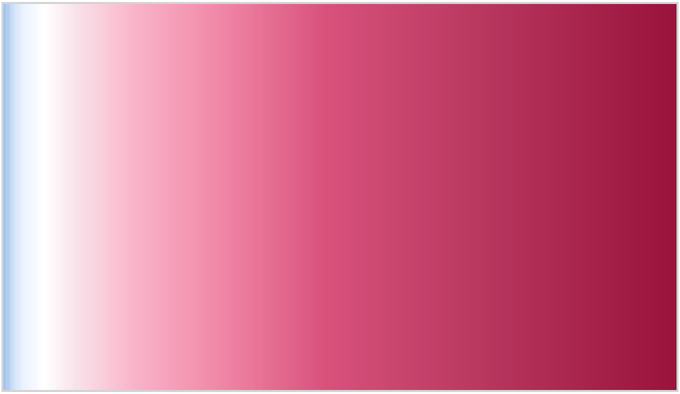
## Revision No. 2

n the original code, the color palette was generated with a `bias of 4.5.` While the colors in the palette seemed fitting for our visualization, we found that the transitions between colors were not as distinct as we had hoped. To address this issue, we decided to change the `bias from 4 to 4.5.`

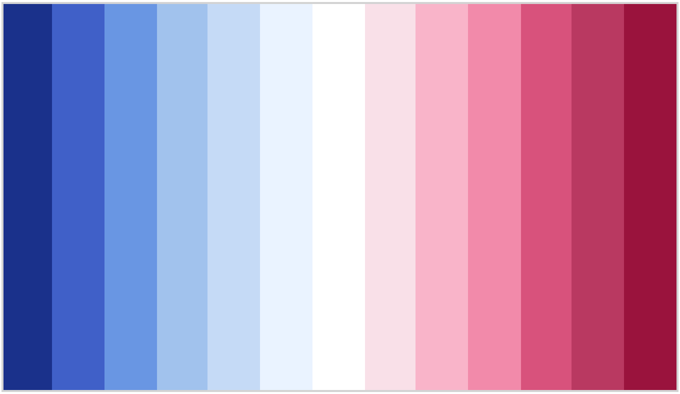
This adjustment creates a color palette with more distinct boundaries between colors and less smooth transitions compared to the original palette. We expect that this change will lead to a perceptible difference in the appearance of the generated color palette, resulting in a better presentation of the population density of our chosen country.

```
# Create color palette from MetBrewer Library
color <- MetBrewer::met.brewer(name="Benedictus", direction = -1)

tx <- grDevices::colorRampPalette(color, bias = 4)(256) # new bias
swatchplot(tx)
```



```r
swatchplot(color)
```



### *9. Render 3D Map:*

Use Rayshader to create a 3D representation of the population density.

## Revision No. 3

In the original code, the `fov` parameter was included in the `plot_3d` function. When we included it, we noticed that it affected the rendering process of the 3D plot. Removing the FOV parameter allowed the rendering process to proceed without the specific FOV setting. We made this decision to optimize rendering efficiency, considering that specifying a FOV may increase computational complexity or rendering time.

Although the `FOV` parameter was removed, the `plot_3d` function still produces a reasonable output. The default angle leaves us satisfied, and we believe that the inclusion of the FOV parameter does not significantly affect the overall presentation of our input

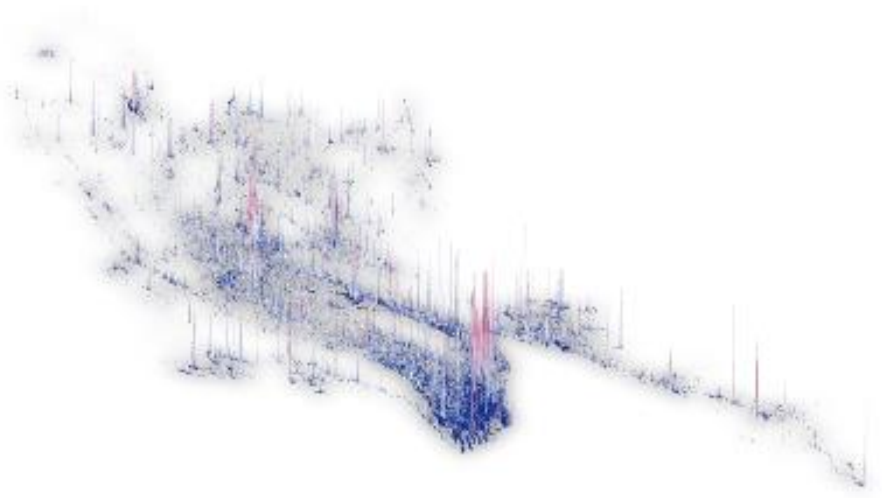
```r
# Close any existing 3D plot before plotting another
rgl::close3d()

pop_matrix %>%
  height_shade(texture = tx) %>%
  plot_3d(heightmap = pop_matrix,
          zscale = 70,
          solid = FALSE,
          shadowdepth = 0,
  )
render_camera(theta = -50, phi = 50, zoom = .7,)

# To interactively view the 3D plot
rgl::rglwidget()
```

```
## Google Chrome was not found. Try setting the `CHROMOTE_CHROME` environment
variable to the executable of a Chromium-based browser, such as Google
Chrome, Chromium or Brave.
```

```
## Warning in snapshot3d(scene = x, width = width, height = height): webshot
=
## TRUE requires the webshot2 package and Chrome browser; using
rgl.snapshot()
## instead
```



### *10. Render in high-quality and Save Image:*

Fine-tune the camera angle and render a high-quality image of the 3D map.

## Revision No. 4

In this current chunk of code, multiple lines of code were originally turned into comments, rendering them inexecutable. We resolved this issue by removing the '#' symbols to revert them back to executable code.

However, after running this chunk multiple times, we encountered issues generating high-quality files due to incompatible parameter values. The original code produced unsuccessful outputs, such as all-black output, all-black output with white dots, or a white dimension with a black base. These issues stemmed from using **`lightcolor = c("white", "white")`** instead of **`lightcolor = c(pop_matrix[2], color)`**, which caused the 3D population density map to not display any color.

To address this, we added **`sample_method = "sobol"`** to achieve a more even coverage of space compared to purely random sequences.

We also made changes to the parameters in the **`render_highquality`** function to resolve these issues. Refer to the comments in the code for the specific changes made.

By incorporating these clarifications, the explanation becomes more accessible and understandable for readers who may not be familiar with the code or its context.

```
Sz# Define the output file path using the glue package
outfile <- glue::glue("C:/Users/HP PAVILION/Documents/data/MM_MAP[5].png")

{
  # Record the start time of the execution
  start_time <- Sys.time()

  # Print the start time in cyan color
  cat(crayon::cyan(start_time), "\n")

  if(!file.exists(outfile)) {
    png::writePNG(matrix(1), target = outfile)
  }

  render_highquality(
    filename = outfile,
    interactive = FALSE,
    lightdirection = 100,    # originally 50,
    lightaltitude = c(70, 90),    # originally c(30,80)
    lightcolor = c(pop_matrix[2], color),   # originally c("white", "white")
    lightintensity = c(600, 100),
    samples = 450,   # originally 550
    sample_method = "sobol",
    width = 1080,    # originally 1980
    height = 920     # originally 1180
  )

  # Record the end time of the execution
  end_time <- Sys.time()

  # Calculate the difference between start and end time
  diff <- end_time - start_time

  # Print the execution time in cyan color
  cat(crayon::cyan(diff), "\n")
}
```

### *11. Annotate the image*

You can add names and more details about your generated visualization.

## Revision No. 5

We slightly enhanced the original code by revising these original lines:

```
install.packages("showtext") library(showtext) install.packages("extrafont")
library(extrafont) font_import(pattern = "Philosopher")
```

We transformed it into a code where it checks whether each package is already installed before attempting to install it. This prevents unnecessary installation processes, saving time and system resources.

While we changed some of the values for font customization, not much were really revised. Some of the original parts of the code were still used in this chunk. Any other changes made were not intently for a different effect but just for preferences in customization.

```
# Check if packages are installed, and install if necessary
if (!requireNamespace("showtext", quietly = TRUE)) {
  install.packages("showtext")
}
if (!requireNamespace("extrafont", quietly = TRUE)) {
  install.packages("extrafont")
}
if (!requireNamespace("magick", quietly = TRUE)) {
  install.packages("magick")
}

# Load required packages
library(showtext)
library(extrafont)
library(magick)

# Import fonts
font_import(pattern = "Philosopher")



# Automatically enable font support
showtext_auto()

# Load Google font
font_add_google("Philosopher", regular = "400", bold = "700")

# Read the SVG image
pop_raster <- image_read("C:/Users/HP PAVILION/Documents/data/MM_MAP[3].png")

# Define text color
```

```
text_color <- "#1e466e" # Adjust as needed
text1_color <- "#376795"

# Annotate the image
pop_raster %>%
  image_annotate("Myanmar",
                 gravity = "northeast",
                 location = "+50+50",
                 color = text_color,
                 size = 150,
                 font = "Philosopher",
                 weight = 800,
                 degrees = 0) %>%

  image_annotate("POPULATION DENSITY MAP",
                 gravity = "northeast",
                 location = "+50+230",
                 color = text_color,
                 size = 30,
                 font = "Philosopher",
                 weight = 500,
                 degrees = 0) %>%

  image_annotate("Visualization by: Culanggo | Felisilda | Casiño | Abainza
\nData @ Kontur Population 2023",
                 gravity = "southwest",
                 location = "+20+20",
                 color = alpha(text1_color, .8),
                 font = "Philosopher",
                 size = 22,
                 degrees = 0) %>%

  image_write("C:/Users/HP PAVILION/Documents/data/MM_MAP[3](ANNOTATED).png",
format = "png", quality = 100)
```