Production Code Draft: '0_LiDAR-FAIB-WSVHA-raster-to-raster-production.R'

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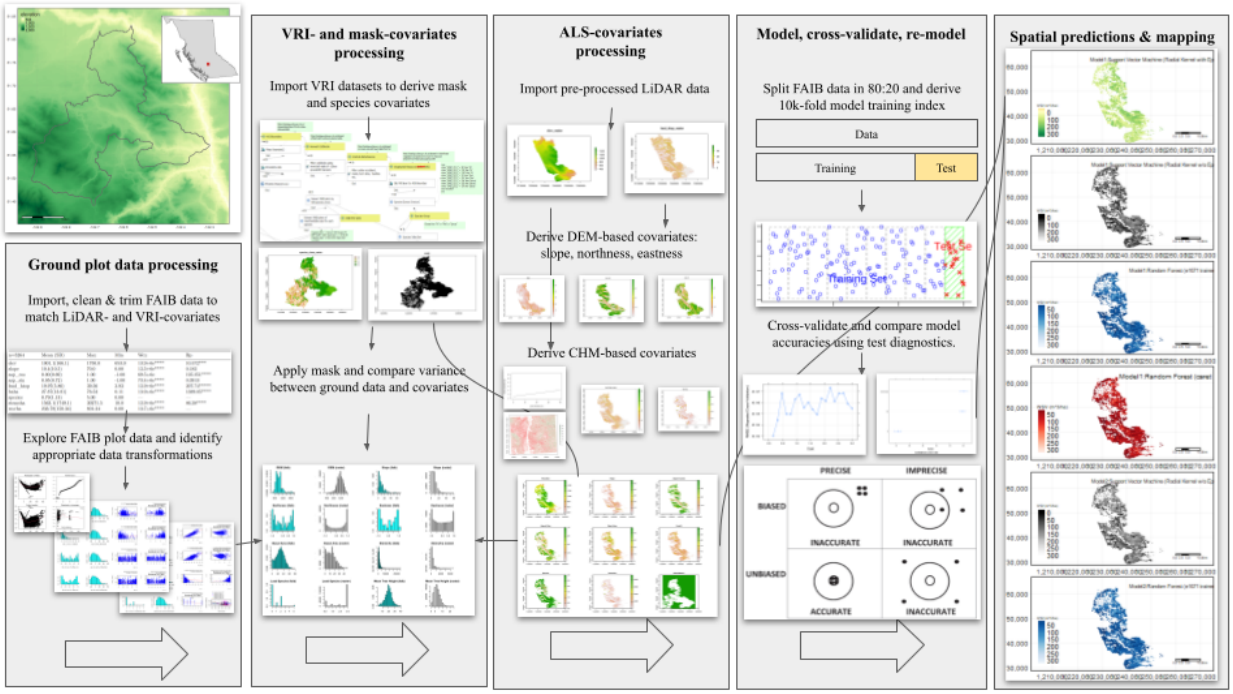
Action

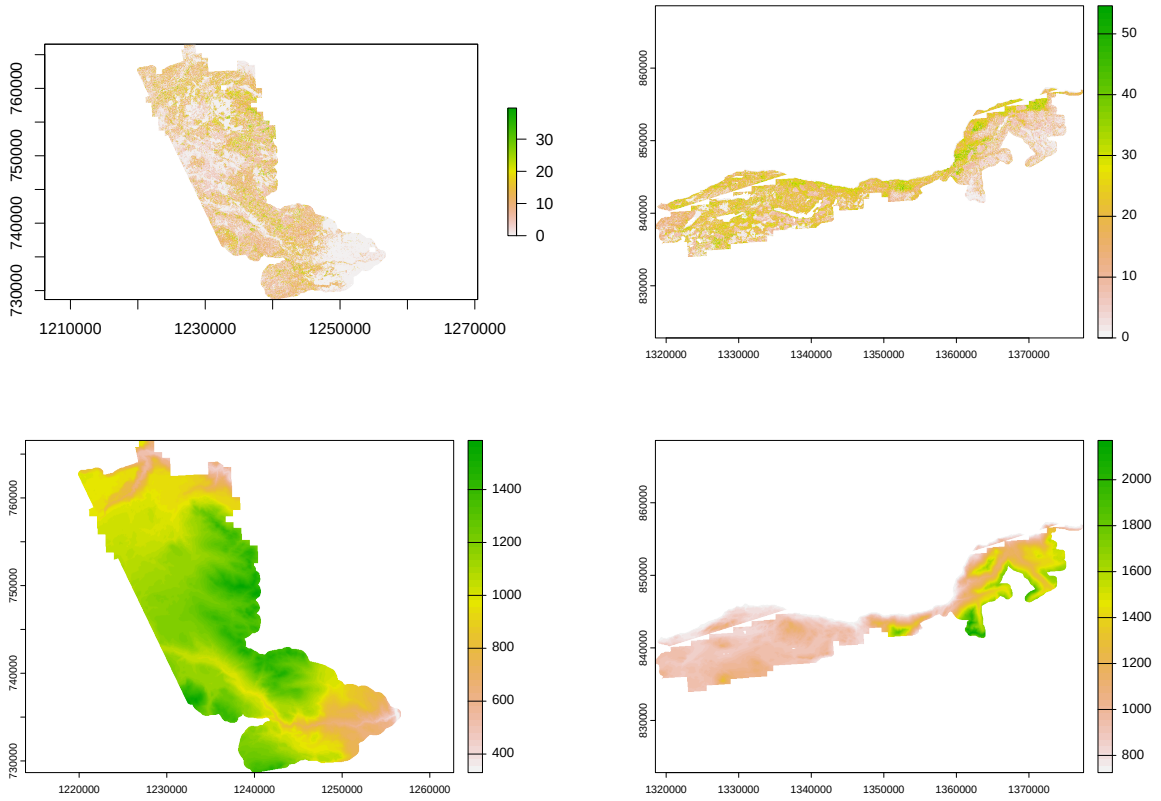
The following markdown report provides a complete run-through and guide of a raster-to-raster workflow to generating Whole Stem Volume (m^3/ha: WSVHA) raster estimates from initial phases of importing liDAR tiles, to deriving stem-detection map and a 95% canopy height model, to generating and masking DEM-based and species covariates, to fitting and training models with faib.csv data, to finally making spatial predictions using raster stack of covariates. The graphical abstract below is offered as reference guide.



Import LiDAR: Load, list and merge chunks

```
zip_file_vh_quesnel = ("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/quesnel_region/VegHt.zip")
zip_file_be_quesnel = ("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/quesnel_region/BareEarth.zip")
zip_dir_vh_quesnel = ("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/quesnel_region")
zip_dir_be_quesnel = ("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/quesnel_region")
unzip(zip_file_vh_quesnel, exdir = zip_dir_vh_quesnel, overwrite = TRUE)
unzip(zip_file_be_quesnel, exdir=zip_dir_be_quesnel, overwrite = TRUE)
unzip_dir_vh_quesnel <- paste0("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/quesnel_region/VegHt")
unzip_dir_be_quesnel <- paste0("/media/seamus128GB_WORKD/EFI-TCC/LiDAR_Data/quesnel_region/BareEarth")
zip_file_vh_gaspard = ("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/gaspard_region/VegHt.zip")
zip_file_be_gaspard = ("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/gaspard_region/BareEarth.zip")
zip_dir_vh_gaspard = ("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/gaspard_region")
zip_dir_be_gaspard = ("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/gaspard_region")
unzip(zip_file_vh_gaspard, exdir=zip_dir_vh_gaspard, overwrite = TRUE)
unzip(zip_file_be_gaspard, exdir=zip_dir_be_gaspard, overwrite = TRUE)
unzip_dir_vh_gaspard <- paste0("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/gaspard_region/VegHt")
unzip_dir_be_gaspard <- paste0("/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/gaspard_region/BareEarth")
filez_vh_quesnel = list.files(unzip_dir_vh_quesnel, full.names = T, all.files = FALSE, pattern = '.tif$
filez_be_quesnel = list.files(unzip_dir_be_quesnel, full.names = T, all.files = FALSE, pattern = '.tif$
filez_vh_gaspard = list.files(unzip_dir_vh_gaspard, full.names = T, all.files = FALSE, pattern = '.tif$
filez_be_gaspard = list.files(unzip_dir_be_gaspard, full.names = T, all.files = FALSE, pattern = '.tif$
lead_htop_raster_list_quesnel <- lapply(filez_vh_quesnel, raster)
lead_htop_raster_list_gaspard <- lapply(filez_vh_gaspard, raster)
elev_raster_list_quesnel <- lapply(filez_be_quesnel, raster)
elev_raster_list_gaspard <- lapply(filez_be_gaspard, raster)
lead_htop_raster_quesnel = do.call(merge, c(lead_htop_raster_list_quesnel, tolerance = 1))
lead_htop_raster_gaspard = do.call(merge, c(lead_htop_raster_list_gaspard, tolerance = 1))
elev_raster_quesnel = do.call(merge, c(elev_raster_list_quesnel, tolerance = 1))
```

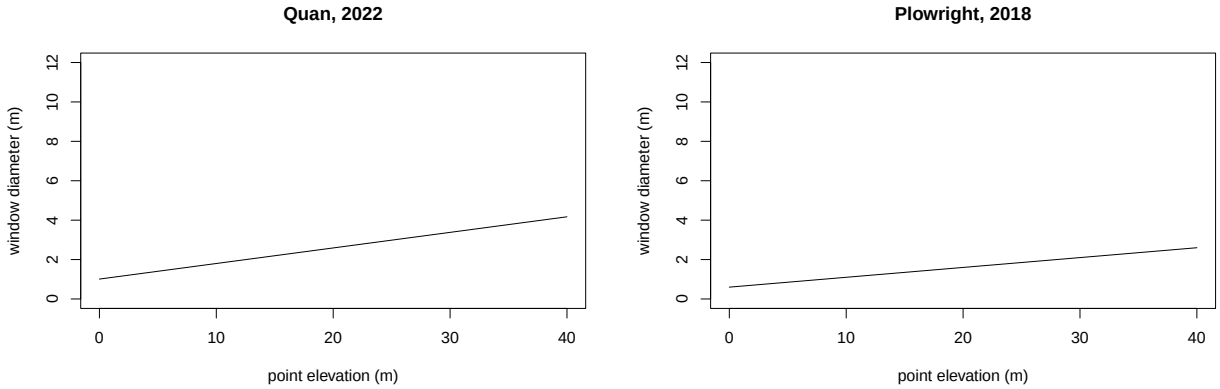
```
elev_raster_gaspard = do.call(merge, c(elev_raster_list_gaspard, tolerance = 1))
writeRaster(lead_htop_raster_quesnel, filename = "/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/quesnel_
writeRaster(lead_htop_raster_gaspard, filename = "/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/gaspard_
writeRaster(elev_raster_quesnel, filename = "/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/quesnel_regio
writeRaster(elev_raster_gaspard, filename = "/media/seamus/128GB_WORKD/EFI-TCC/LiDAR_Data/gaspard_regio
```



CHM-derived covariates: Variable window function

```
kernel <- matrix(1,3,3)
wf_quan<-function(x){
  a=0.179-0.1
  b=0.51+0.5
  y<-a*x+b
  return(y)}
wf_plowright<-function(x){
  a=0.05
  b=0.6
  y<-a*x+b
  return(y)}
heights <- seq(0,40,0.5)
window_quan <- wf_quan(heights)
window_plowright <- wf_plowright(heights)
```

```
plot(heights, window_quan, type = "l",  ylim = c(0,12), xlab="point elevation (m)", ylab="window diamet
plot(heights, window_plowright, type = "l", ylim = c(0,12), xlab="point elevation (m)", ylab="window di
```



CHM-derived covariates: Stem-detection & 95% height

```
lead_htop_raster_1m_smoothed_quesnel = focal(lead_htop_rast_quesnel, w = kernel, fun = median, na.rm = 
lead_htop_raster_1m_smoothed_gaspard = focal(lead_htop_rast_gaspard, w = kernel, fun = median, na.rm = 
ttops_2m_quan_quesnel <- ForestTools::vwf(lead_htop_raster_1m_smoothed_quesnel, wf_quan, 2)
ttops_2m_quan_gaspard = ForestTools::vwf(CHM = lead_htop_raster_1m_smoothed_gaspard, winFun = wf_quan, 
ttops_2m_plowright_quesnel = ForestTools::vwf(CHM = lead_htop_raster_1m_smoothed_quesnel, winFun = wf_pl
ttops_2m_plowright_gaspard = ForestTools::vwf(CHM = lead_htop_raster_1m_smoothed_gaspard, winFun = wf_pl
writeOGR(ttops_2m_quan_quesnel, "/media/seamus/128GB_WORKD/data/vector/stem_maps", "treetops_quan_quesn
writeOGR(ttops_2m_quan_gaspard, "/media/seamus/128GB_WORKD/data/vector/stem_maps", "treetops_quan_gaspa
writeOGR(ttops_2m_plowright_quesnel, "/media/seamus/128GB_WORKD/data/vector/stem_maps", "treetops_plowr
writeOGR(ttops_2m_plowright_gaspard, "/media/seamus/128GB_WORKD/data/vector/stem_maps", "treetops_plowr

quant95 <- function(x, ...)
  quantile(x, c(0.95), na.rm = TRUE)
custFuns <- list(quant95, max)
names(custFuns) <- c("95thQuantile", "Max")

ttops_2m_quan_quesnel <- readOGR(dsn = "/media/seamus/128GB_WORKD/data/vector/stem_maps/treetops_quan_q
ttops_2m_quan_gaspard <- readOGR(dsn = "/media/seamus/128GB_WORKD/data/vector/stem_maps/treetops_quan_g
ttops_2m_Quan_raster_2m1.5m_95th_20cell_quesnel <- ForestTools::sp_summarise(ttops_2m_quan_quesnel, gri
ttops_2m_Quan_raster_2m1.5m_95th_20cell_gaspard <- ForestTools::sp_summarise(ttops_2m_quan_gaspard, gri
ttops_2m_Quan_raster_2m1.5m_95th_100cell_quesnel <- ForestTools::sp_summarise(ttops_2m_quan_quesnel, gr
ttops_2m_Quan_raster_2m1.5m_95th_100cell_gaspard <- ForestTools::sp_summarise(ttops_2m_quan_gaspard, gr
lead_htop_95th_raster_20m_quesnel = ttops_2m_Quan_raster_2m1.5m_95th_20cell_quesnel[["height95thQuantil
lead_htop_95th_raster_20m_gaspard = ttops_2m_Quan_raster_2m1.5m_95th_20cell_gaspard[["height95thQuantil
lead_htop_95th_raster_100m_quesnel = ttops_2m_Quan_raster_2m1.5m_95th_100cell_quesnel[["height95thQuant
lead_htop_95th_raster_100m_gaspard = ttops_2m_Quan_raster_2m1.5m_95th_100cell_gaspard[["height95thQuant
stemsha_L_raster_20m_quesnel = ttops_2m_Quan_raster_2m1.5m_95th_20cell_quesnel[["TreeCount"]]
stemsha_L_raster_20m_gaspard = ttops_2m_Quan_raster_2m1.5m_95th_20cell_gaspard[["TreeCount"]]
stemsha_L_raster_100m_quesnel = ttops_2m_Quan_raster_2m1.5m_95th_100cell_quesnel[["TreeCount"]]
stemsha_L_raster_100m_gaspard = ttops_2m_Quan_raster_2m1.5m_95th_100cell_gaspard[["TreeCount"]]
raster::writeRaster(lead_htop_95th_raster_20m_quesnel, filename = "/media/seamus/128GB_WORKD/data/raste
raster::writeRaster(lead_htop_95th_raster_20m_gaspard, filename = "/media/seamus/128GB_WORKD/data/raste
```

```
raster::writeRaster(lead_htop_95th_raster_100m_quesnel, filename = "/media/seamus/128GB_WORKD/data/raste
raster::writeRaster(lead_htop_95th_raster_100m_gaspard, filename = "/media/seamus/128GB_WORKD/data/raste
raster::writeRaster(stemsha_L_raster_20m_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/
raster::writeRaster(stemsha_L_raster_20m_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/
raster::writeRaster(stemsha_L_raster_100m_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tc
raster::writeRaster(stemsha_L_raster_100m_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tc
```

DEM-derived covariates: Terrain rasters

```
terra::crs(elev_rast_quesnel) = "epsg:3005"
terra::crs(elev_rast_gaspard) = "epsg:3005"
elev_rast_quesnel = terra::aggregate(elev_rast_quesnel, fact = 100, fun = mean)
elev_rast_gaspard = terra::aggregate(elev_rast_gaspard, fact = 100, fun = mean)
slope_rast_quesnel = terra::terrain(elev_rast_quesnel, v="slope", unit="degrees", neighbors=8)
slope_rast_gaspard = terra::terrain(elev_rast_gaspard, v="slope", unit="degrees", neighbors=8)
aspect_rast_quesnel = terra::terrain(elev_rast_quesnel, v="aspect", unit="degrees", neighbors=8)
aspect_rast_gaspard = terra::terrain(elev_rast_gaspard, v="aspect", unit="degrees", neighbors=8)
asp_cos_rast_quesnel = cos((aspect_rast_quesnel*pi)/180)
asp_cos_rast_gaspard = cos((aspect_rast_gaspard*pi)/180)
asp_sin_rast_quesnel = sin((aspect_rast_quesnel*pi)/180)
asp_sin_rast_gaspard = sin((aspect_rast_gaspard*pi)/180)

lead_htop_rast_quesnel = terra::rast(lead_htop_95th_raster_100m_quesnel)
lead_htop_rast_gaspard = terra::rast(lead_htop_95th_raster_100m_gaspard)
stemsha_L_rast_quesnel = terra::rast(stemsha_L_raster_100m_quesnel)
stemsha_L_rast_gaspard = terra::rast(stemsha_L_raster_100m_gaspard)
terra::crs(lead_htop_rast_gaspard) = "epsg:3005"
terra::crs(lead_htop_rast_quesnel) = "epsg:3005"
terra::crs(stemsha_L_rast_gaspard) = "epsg:3005"
terra::crs(stemsha_L_rast_quesnel) = "epsg:3005"

lead_htop_rast_quesnel = terra::resample(lead_htop_rast_quesnel, elev_rast_quesnel)
lead_htop_rast_gaspard = terra::resample(lead_htop_rast_gaspard, elev_rast_gaspard)
stemsha_L_rast_quesnel = terra::resample(stemsha_L_rast_quesnel, elev_rast_quesnel)
stemsha_L_rast_gaspard = terra::resample(stemsha_L_rast_gaspard, elev_rast_gaspard)
elev_rast_quesnel = terra::mask(elev_rast_quesnel, lead_htop_rast_quesnel)
elev_rast_gaspard = terra::mask(elev_rast_gaspard, lead_htop_rast_gaspard)
slope_rast_quesnel = terra::mask(slope_rast_quesnel, lead_htop_rast_quesnel)
slope_rast_gaspard = terra::mask(slope_rast_gaspard, lead_htop_rast_gaspard)
asp_cos_rast_quesnel = terra::mask(asp_cos_rast_quesnel, lead_htop_rast_quesnel)
asp_cos_rast_gaspard = terra::mask(asp_cos_rast_gaspard, lead_htop_rast_gaspard)
asp_sin_rast_quesnel = terra::mask(asp_sin_rast_quesnel, lead_htop_rast_quesnel)
asp_sin_rast_gaspard = terra::mask(asp_sin_rast_gaspard, lead_htop_rast_gaspard)

writeRaster(elev_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates
writeRaster(elev_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates
writeRaster(slope_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariat
writeRaster(slope_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariat
writeRaster(asp_cos_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covaria
writeRaster(asp_cos_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covaria
writeRaster(asp_sin_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covaria
```

```
writeRaster(asp_sin_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covaria
```

Species covariates: VRI rasterization

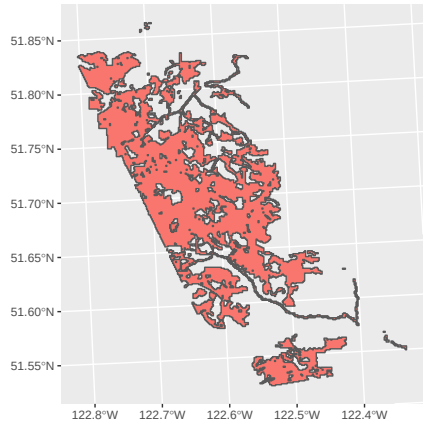
```
lead_htop_sv_quesnel = as.polygons(lead_htop_rast_quesnel)
lead_htop_sv_gaspard = as.polygons(lead_htop_rast_gaspard)
lead_htop_sf_quesnel = sf::st_as_sf(lead_htop_sv_quesnel)
lead_htop_sf_gaspard = sf::st_as_sf(lead_htop_sv_gaspard)
vri_sf = read_sf("/media/seamus/128GB_WORKD/data/vector/vri/vri_bc_2020_rank1.shp")
vri_species = vri_sf[c("SPECIES__1", "SPECIES_CD", "SPECIES_PC")]
vri_species_aoi =  dplyr::filter(
  vri_species, SPECIES__1=='PL' | SPECIES__1=='PLI' | SPECIES__1=='FD' | SPECIES__1=='FDI' |
    SPECIES__1=='SB' | SPECIES__1=='SE' | SPECIES__1=='SW' | SPECIES__1=='SX' |
    SPECIES__1=='CW' | SPECIES__1=='HW' | SPECIES__1=='BL' | SPECIES__1=='LW')
vri_species_aoi_gaspard = vri_species_aoi[!(
  vri_species_aoi$SPECIES__1 == 'FD' & vri_species_aoi$SPECIES_PC >= 50 |
    vri_species_aoi$SPECIES__1 == 'FDI' & vri_species_aoi$SPECIES_PC >=50),]
vri_species_aoi_gaspard$SPECIES__1 = dplyr::recode(
  vri_species_aoi_gaspard$SPECIES__1,
  PL = 0, PLI = 0, SB = 1, SE = 1, SW = 1, SX = 1,
  FD = 2, FDI = 2, CW = 3, HW = 4, BL = 5, LW = 6)
vri_species_aoi_gaspard = dplyr::rename(vri_species_aoi_gaspard, species_class = SPECIES__1)
vri_species_aoi_gaspard = vri_species_aoi_gaspard["species_class"]
vri_species_aoi_sf_gaspard = sf::st_as_sf(vri_species_aoi_gaspard)

vri_species_aoi_quesnel = vri_species_aoi
vri_species_aoi_quesnel$SPECIES__1 = dplyr::recode(vri_species_aoi$SPECIES__1, PL = 0, PLI = 0, SB = 1,
vri_species_aoi_quesnel = dplyr::rename(vri_species_aoi_quesnel, species_class = SPECIES__1)
vri_species_aoi_quesnel = vri_species_aoi_quesnel["species_class"]
vri_species_aoi_sf_quesnel = sf::st_as_sf(vri_species_aoi_quesnel)

vri_species_aoi_quesnel = st_intersection(vri_species_aoi_sf_quesnel, st_make_valid(lead_htop_sf_quesnel
vri_species_aoi_gaspard = st_intersection(vri_species_aoi_sf_gaspard, st_make_valid(lead_htop_sf_gaspard
species_class_rast_quesnel = terra::rasterize(vect(vri_species_aoi_quesnel), lead_htop_rast_quesnel, fi
species_class_rast_gaspard = terra::rasterize(vect(vri_species_aoi_gaspard), lead_htop_rast_gaspard, fi
species_class_rast_quesnel = terra::resample(species_class_rast_quesnel, lead_htop_rast_quesnel)
species_class_rast_gaspard = terra::resample(species_class_rast_gaspard, lead_htop_rast_gaspard)
species_class_raster_quesnel = raster::raster(species_class_rast_quesnel)
species_class_raster_gaspard = raster::raster(species_class_rast_gaspard)
raster::writeRaster(species_class_raster_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc
raster::writeRaster(species_class_raster_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc
```

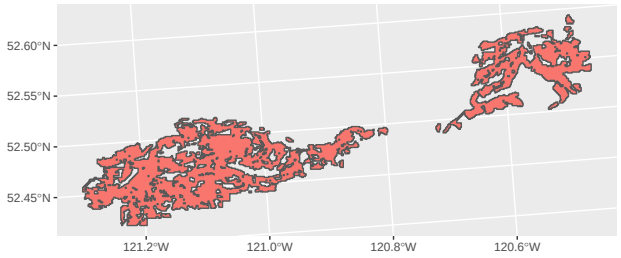
Masking: Generate mask layers

```
mask_burn2017 = sf::read_sf("/media/seamus/128GB_WORKD/data/vector/tcc_mask_layers/TCC_Burn_Severity TC
mask_burn2018 = sf::read_sf("/media/seamus/128GB_WORKD/data/vector/tcc_mask_layers/TCC_Burn_Severity TC
mask_burn2021 = sf::read_sf("/media/seamus/128GB_WORKD/data/vector/tcc_mask_layers/TCC_Burn_Severity TC
mask_burn2017 = mask_burn2017["BurnSev"]
mask_burn2018 = mask_burn2018["BurnSev"]
```

```
mask_burn2021 = mask_burn2021["BurnSev"]
mask_burn2017 = dplyr::filter(mask_burn2017, BurnSev == 'High')
mask_burn2018 = dplyr::filter(mask_burn2018, BurnSev == 'High')
mask_burn2021 = dplyr::filter(mask_burn2021, BurnSev == 'High')
mask_burn2017_quesnel = sf::st_intersection(sf::st_make_valid(mask_burn2017), lead_htop_sf_quesnel)
mask_burn2017_gaspard = sf::st_intersection(sf::st_make_valid(mask_burn2017), lead_htop_sf_gaspard)
mask_burn2018_quesnel = sf::st_intersection(sf::st_make_valid(mask_burn2018), lead_htop_sf_quesnel)
mask_burn2018_gaspard = sf::st_intersection(sf::st_make_valid(mask_burn2018), lead_htop_sf_gaspard)
mask_burn2021_quesnel = sf::st_intersection(sf::st_make_valid(mask_burn2021), lead_htop_sf_quesnel)
mask_burn2021_gaspard = sf::st_intersection(sf::st_make_valid(mask_burn2021), lead_htop_sf_gaspard)
masks_df_quesnel = full_join(as_tibble(mask_burn2017_quesnel), as_tibble(mask_burn2018_quesnel), as_tibl
masks_df_gaspard = full_join(as_tibble(mask_burn2017_gaspard), as_tibble(mask_burn2018_gaspard), as_tibl
masks_sf_quesnel = st_as_sf(masks_df_quesnel) # easier to combine by 'geometry'
masks_sf_gaspard = st_as_sf(masks_df_gaspard) # easier to combine by 'geometry'

mask_clearcut = sf::read_sf("/media/seamus/128GB_WORKD/data/vector/tcc_mask_layers/RSLT_CCRES_CLEAR.shp
mask_clearcut_quesnel = sf::st_intersection(mask_clearcut, st_make_valid(lead_htop_sf_quesnel))
mask_clearcut_gaspard = sf::st_intersection(mask_clearcut, st_make_valid(lead_htop_sf_gaspard))
masks_df_quesnel = full_join(as_tibble(masks_sf_quesnel), as_tibble(mask_clearcut_quesnel), by = 'geome
masks_df_gaspard = full_join(as_tibble(masks_sf_gaspard), as_tibble(mask_clearcut_gaspard), by = 'geome
masks_sf_quesnel = st_as_sf(masks_df_quesnel)
masks_sf_gaspard = st_as_sf(masks_df_gaspard)

mask_blocks = sf::read_sf("/media/seamus/128GB_WORKD/data/vector/tcc_mask_layers/TCC_Blocks_Join.shp")
mask_blocks_quesnel = sf::st_intersection(mask_blocks, st_make_valid(lead_htop_sf_quesnel))
mask_blocks_gaspard = sf::st_intersection(mask_blocks, st_make_valid(lead_htop_sf_gaspard))
masks_df_quesnel = full_join(as_tibble(masks_sf_quesnel), as_tibble(mask_blocks_quesnel), by = 'geometry
masks_df_gaspard = full_join(as_tibble(masks_sf_gaspard), as_tibble(mask_blocks_gaspard), by = 'geometry
masks_sf_quesnel = st_as_sf(masks_df_quesnel)
masks_sf_gaspard = st_as_sf(masks_df_gaspard)

mask_roads_tcc = sf::read_sf("/media/seamus/128GB_WORKD/data/vector/tcc_mask_layers/TCC_Roads.shp")
mask_roads_tcc = sf::st_zm(mask_roads_tcc)
mask_roads_tcc_quesnel = sf::st_intersection(mask_roads_tcc, st_make_valid(lead_htop_sf_quesnel))
mask_roads_tcc_gaspard = sf::st_intersection(mask_roads_tcc, st_make_valid(lead_htop_sf_gaspard))
mask_roads_tcc_quesnel = sf::st_buffer(mask_roads_tcc_quesnel, dist = 15, nQuadSegs = 5, endCapStyle =
mask_roads_tcc_gaspard = sf::st_buffer(mask_roads_tcc_gaspard, dist = 15, nQuadSegs = 5, endCapStyle =

mask_roads_ften = sf::read_sf("/media/seamus/128GB_WORKD/data/vector/tcc_mask_layers/FTEN_Roads_All.shp
mask_roads_ften = sf::st_zm(mask_roads_ften)
mask_roads_ften_quesnel = sf::st_intersection(mask_roads_ften, st_make_valid(lead_htop_sf_quesnel))
mask_roads_ften_gaspard = sf::st_intersection(mask_roads_ften, st_make_valid(lead_htop_sf_gaspard))
mask_roads_ften_quesnel = sf::st_buffer(mask_roads_ften_quesnel, dist = 15, nQuadSegs = 5, endCapStyle
mask_roads_ften_gaspard = sf::st_buffer(mask_roads_ften_gaspard, dist = 15, nQuadSegs = 5, endCapStyle
masks_df_quesnel = full_join(as_tibble(masks_sf_quesnel), as_tibble(mask_roads_tcc_quesnel), as_tibble(
masks_df_gaspard = full_join(as_tibble(masks_sf_gaspard), as_tibble(mask_roads_tcc_gaspard), as_tibble(
masks_sf_quesnel = st_as_sf(masks_df_quesnel)
masks_sf_gaspard = st_as_sf(masks_df_gaspard)
masks_rast_quesnel = rasterize(vect(masks_sf_quesnel), lead_htop_rast_quesnel, touches = TRUE)
masks_rast_gaspard = rasterize(vect(masks_sf_gaspard), lead_htop_rast_gaspard, touches = TRUE)
masks_raster_quesnel = raster::raster(masks_rast_quesnel)
masks_raster_gaspard = raster::raster(masks_rast_gaspard)
writeRaster(masks_raster_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/mask/mask_raste
```

```
writeRaster(masks_raster_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/mask/mask_raste
ggplot(masks_sf_gaspard) + geom_sf(aes(fill = 'red'), show.legend = FALSE)
ggplot(masks_sf_quesnel) + geom_sf(aes(fill = 'red'), show.legend = FALSE)
```





Masking: Apply masking

```
elev_rast_quesnel = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/elev_ras
elev_rast_gaspard = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/elev_ras
slope_rast_quesnel = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/slope_r
slope_rast_gaspard = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/slope_r
asp_cos_rast_quesnel = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/asp_c
asp_cos_rast_gaspard = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/asp_c
asp_sin_rast_quesnel = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/asp_s
asp_sin_rast_gaspard = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/asp_s
lead_htop_rast_quesnel = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/lea
lead_htop_rast_gaspard = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/lea
stemsha_L_rast_quesnel = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/ste
stemsha_L_rast_gaspard = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates/ste
species_class_rast_quesnel = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates
species_class_rast_gaspard = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/unmasked-covariates
masks_rast_quesnel = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc//mask/mask_raster_100m_ques
masks_rast_gaspard = terra::rast("/media/seamus/128GB_WORKD/data/raster/tcc/mask/mask_raster_100m_gaspa
# masking by stem map
lead_htop_rast_quesnel = terra::resample(lead_htop_rast_quesnel, elev_rast_quesnel)
lead_htop_rast_gaspard = terra::resample(lead_htop_rast_gaspard, elev_rast_gaspard)
stemsha_L_rast_quesnel = terra::resample(stemsha_L_rast_quesnel, elev_rast_quesnel)
stemsha_L_rast_gaspard = terra::resample(stemsha_L_rast_gaspard, elev_rast_gaspard)
elev_rast_quesnel = terra::mask(elev_rast_quesnel, lead_htop_rast_quesnel)
elev_rast_gaspard = terra::mask(elev_rast_gaspard, lead_htop_rast_gaspard)
slope_rast_quesnel = terra::mask(slope_rast_quesnel, lead_htop_rast_quesnel)
slope_rast_gaspard = terra::mask(slope_rast_gaspard, lead_htop_rast_gaspard)
asp_cos_rast_quesnel = terra::mask(asp_cos_rast_quesnel, lead_htop_rast_quesnel)
asp_cos_rast_gaspard = terra::mask(asp_cos_rast_gaspard, lead_htop_rast_gaspard)
asp_sin_rast_quesnel = terra::mask(asp_sin_rast_quesnel, lead_htop_rast_quesnel)
asp_sin_rast_gaspard = terra::mask(asp_sin_rast_gaspard, lead_htop_rast_gaspard)
species_class_rast_quesnel = terra::mask(species_class_rast_quesnel, lead_htop_rast_quesnel)
species_class_rast_gaspard = terra::mask(species_class_rast_gaspard, lead_htop_rast_gaspard)
```

```
# masking by mask
masks_rast_quesnel = terra::resample(masks_rast_quesnel, lead_htop_rast_quesnel)
masks_rast_gaspard = terra::resample(masks_rast_gaspard, lead_htop_rast_gaspard)
masks_rast_quesnel = terra::resample(masks_rast_quesnel, elev_rast_quesnel)
masks_rast_gaspard = terra::resample(masks_rast_gaspard, elev_rast_gaspard)
lead_htop_rast_quesnel = mask(lead_htop_rast_quesnel, masks_rast_quesnel, inverse=TRUE)
lead_htop_rast_gaspard = mask(lead_htop_rast_gaspard, masks_rast_gaspard, inverse=TRUE)
elev_rast_quesnel = mask(elev_rast_quesnel, masks_rast_quesnel, inverse=TRUE)
elev_rast_gaspard = mask(elev_rast_gaspard, masks_rast_gaspard, inverse=TRUE)
slope_rast_quesnel = mask(slope_rast_quesnel, masks_rast_quesnel, inverse=TRUE)
slope_rast_gaspard = mask(slope_rast_gaspard, masks_rast_gaspard, inverse=TRUE)
asp_cos_rast_quesnel = mask(asp_cos_rast_quesnel, masks_rast_quesnel, inverse=TRUE)
asp_cos_rast_gaspard = mask(asp_cos_rast_gaspard, masks_rast_gaspard, inverse=TRUE)
asp_sin_rast_quesnel = mask(asp_sin_rast_quesnel, masks_rast_quesnel, inverse=TRUE)
asp_sin_rast_gaspard = mask(asp_sin_rast_gaspard, masks_rast_gaspard, inverse=TRUE)
stemsha_L_rast_quesnel = mask(stemsha_L_rast_quesnel, masks_rast_quesnel, inverse=TRUE)
stemsha_L_rast_gaspard = mask(stemsha_L_rast_gaspard, masks_rast_gaspard, inverse=TRUE)
species_class_rast_quesnel = mask(species_class_rast_quesnel, masks_rast_quesnel, inverse=TRUE)
species_class_rast_gaspard = mask(species_class_rast_gaspard, masks_rast_gaspard, inverse=TRUE)
# masking by species
lead_htop_rast_quesnel = mask(lead_htop_rast_quesnel, species_class_rast_quesnel, inverse=FALSE)
lead_htop_rast_gaspard = mask(lead_htop_rast_gaspard, species_class_rast_gaspard, inverse=FALSE)
elev_rast_quesnel = mask(elev_rast_quesnel, species_class_rast_quesnel, inverse=FALSE)
elev_rast_gaspard = mask(elev_rast_gaspard, species_class_rast_gaspard, inverse=FALSE)
slope_rast_quesnel = mask(slope_rast_quesnel, species_class_rast_quesnel, inverse=FALSE)
slope_rast_gaspard = mask(slope_rast_gaspard, species_class_rast_gaspard, inverse=FALSE)
asp_cos_rast_quesnel = mask(asp_cos_rast_quesnel, species_class_rast_quesnel, inverse=FALSE)
asp_cos_rast_gaspard = mask(asp_cos_rast_gaspard, species_class_rast_gaspard, inverse=FALSE)
asp_sin_rast_quesnel = mask(asp_sin_rast_quesnel, species_class_rast_quesnel, inverse=FALSE)
asp_sin_rast_gaspard = mask(asp_sin_rast_gaspard, species_class_rast_gaspard, inverse=FALSE)
stemsha_L_rast_quesnel = mask(stemsha_L_rast_quesnel, species_class_rast_quesnel, inverse=FALSE)
stemsha_L_rast_gaspard = mask(stemsha_L_rast_gaspard, species_class_rast_gaspard, inverse=FALSE)

writeRaster(elev_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates/
writeRaster(elev_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates/
writeRaster(slope_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates
writeRaster(slope_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates
writeRaster(asp_cos_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariat
writeRaster(asp_cos_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariat
writeRaster(asp_sin_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariat
writeRaster(asp_sin_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariat
writeRaster(species_class_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-co
writeRaster(species_class_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-co
writeRaster(stemsha_L_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covaria
writeRaster(stemsha_L_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covaria
writeRaster(lead_htop_rast_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covaria
writeRaster(lead_htop_rast_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covaria
```

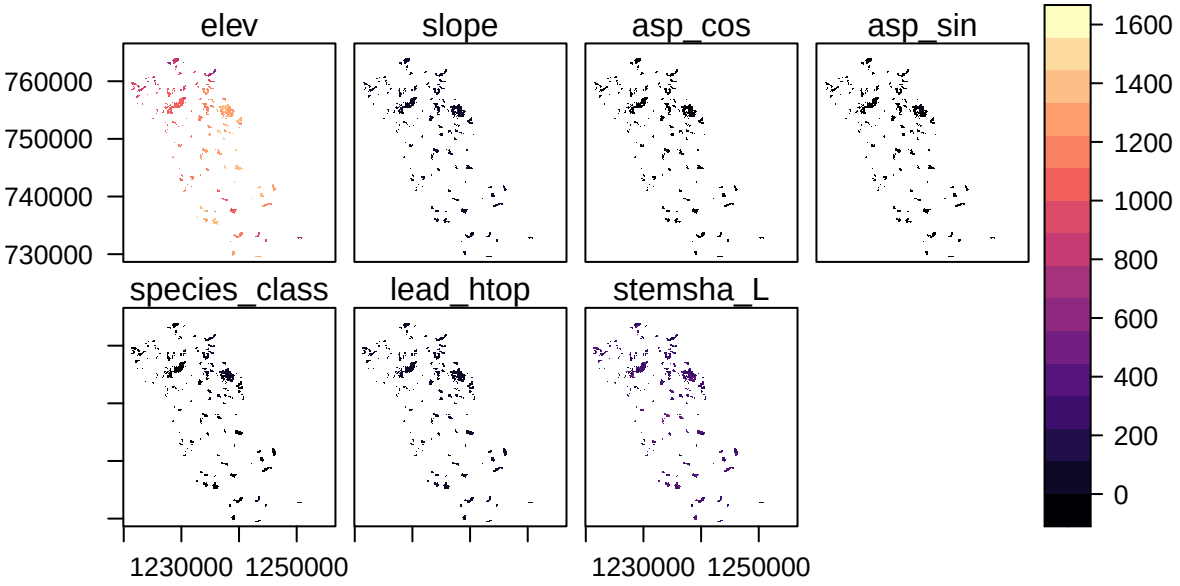
Tidy: Stack covariates

```
#tidy names
names(elev_rast_quesnel) = "elev"
```

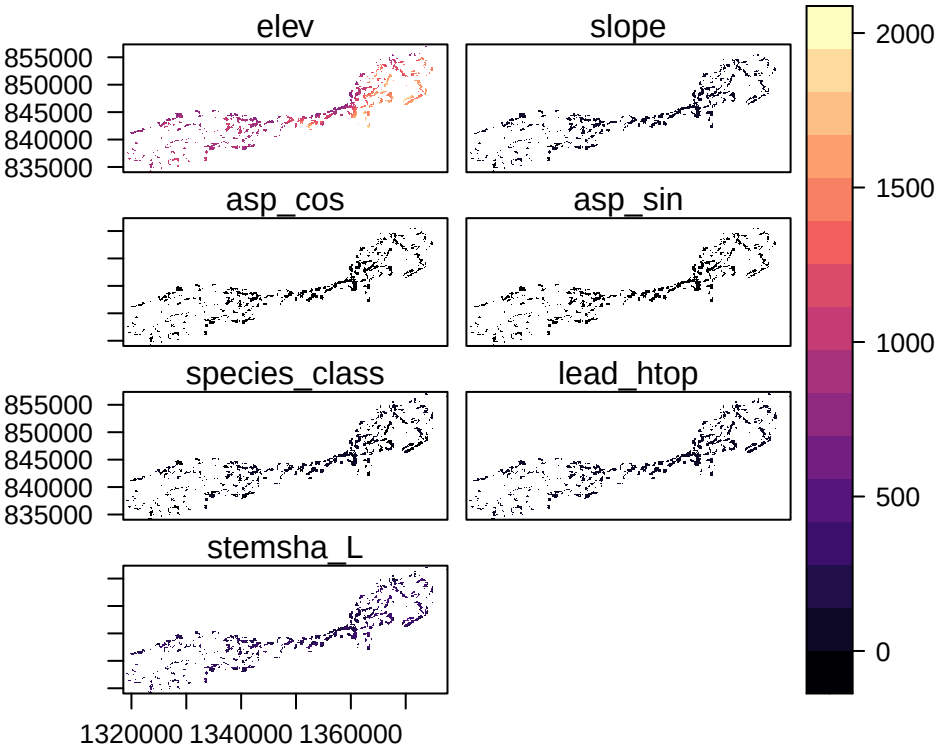
```
names(slope_rast_quesnel) = "slope"
names(asp_cos_rast_quesnel) = "asp_cos"
names(asp_sin_rast_quesnel) = "asp_sin"
names(species_class_rast_quesnel) = "species_class"
names(stemsha_L_rast_quesnel) = "stemsha_L"
names(lead_htop_rast_quesnel) = "lead_htop"

names(elev_rast_gaspard) = "elev"
names(slope_rast_gaspard) = "slope"
names(asp_cos_rast_gaspard) = "asp_cos"
names(asp_sin_rast_gaspard) = "asp_sin"
names(species_class_rast_gaspard) = "species_class"
names(stemsha_L_rast_gaspard) = "stemsha_L"
names(lead_htop_rast_gaspard) = "lead_htop"

elev_raster_quesnel = raster::raster(elev_rast_quesnel)
slope_raster_quesnel = raster::raster(slope_rast_quesnel)
asp_cos_raster_quesnel = raster::raster(asp_cos_rast_quesnel)
asp_sin_raster_quesnel = raster::raster(asp_sin_rast_quesnel)
species_class_raster_quesnel = raster::raster(species_class_rast_quesnel)
stemsha_L_raster_quesnel = raster::raster(stemsha_L_rast_quesnel)
lead_htop_raster_quesnel = raster::raster(lead_htop_rast_quesnel)

elev_raster_gaspard = raster::raster(elev_rast_gaspard)
slope_raster_gaspard = raster::raster(slope_rast_gaspard)
asp_cos_raster_gaspard = raster::raster(asp_cos_rast_gaspard)
asp_sin_raster_gaspard = raster::raster(asp_sin_rast_gaspard)
species_class_raster_gaspard = raster::raster(species_class_rast_gaspard)
stemsha_L_raster_gaspard = raster::raster(stemsha_L_rast_gaspard)
lead_htop_raster_gaspard = raster::raster(lead_htop_rast_gaspard)

elev_raster_list = list(elev_raster_quesnel, elev_raster_gaspard)
slope_raster_list = list(slope_raster_quesnel, slope_raster_gaspard)
asp_cos_raster_list = list(asp_cos_raster_quesnel, asp_cos_raster_gaspard)
asp_sin_raster_list = list(asp_sin_raster_quesnel, asp_sin_raster_gaspard)
species_class_raster_list = list(species_class_raster_quesnel, species_class_raster_gaspard)
stemsha_L_raster_list = list(stemsha_L_raster_quesnel, stemsha_L_raster_gaspard)
lead_htop_raster_list = list(lead_htop_raster_quesnel, lead_htop_raster_gaspard)

elev_raster = do.call(merge, c(elev_raster_list, tolerance = 1))
slope_raster = do.call(merge, c(slope_raster_list, tolerance = 1))
asp_cos_raster = do.call(merge, c(asp_cos_raster_list, tolerance = 1))
asp_sin_raster = do.call(merge, c(asp_sin_raster_list, tolerance = 1))
species_class_raster = do.call(merge, c(species_class_raster_list, tolerance = 1))
stemsha_L_raster = do.call(merge, c(stemsha_L_raster_list, tolerance = 1))
lead_htop_raster = do.call(merge, c(lead_htop_raster_list, tolerance = 1))

writeRaster(elev_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates/elev_ra
writeRaster(slope_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates/slope_
writeRaster(asp_cos_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates/asp_
writeRaster(asp_sin_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates/asp_
writeRaster(species_class_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariate
writeRaster(stemsha_L_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates/st
```

```
writeRaster(lead_htop_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/masked-covariates/l

covs_m1_quesnel = raster::stack(
  elev_raster_quesnel,
  slope_raster_quesnel,
  asp_cos_raster_quesnel,
  asp_sin_raster_quesnel,
  species_class_raster_quesnel,
  lead_htop_raster_quesnel,
  stemsha_L_raster_quesnel)

covs_m1_gaspard = raster::stack(
  elev_raster_gaspard,
  slope_raster_gaspard,
  asp_cos_raster_gaspard,
  asp_sin_raster_gaspard,
  species_class_raster_gaspard,
  lead_htop_raster_gaspard,
  stemsha_L_raster_gaspard)

covs_m2_quesnel = raster::stack(
  elev_raster_quesnel,
  slope_raster_quesnel,
  asp_cos_raster_quesnel,
  asp_sin_raster_quesnel,
  species_class_raster_quesnel,
  lead_htop_raster_quesnel)

covs_m2_gaspard = raster::stack(
  elev_raster_gaspard,
  slope_raster_gaspard,
  asp_cos_raster_gaspard,
  asp_sin_raster_gaspard,
  species_class_raster_gaspard,
  lead_htop_raster_gaspard)

covs_m2 = raster::stack(
  elev_raster,
  slope_raster,
  asp_cos_raster,
  asp_sin_raster,
  lead_htop_raster,
  species_class_raster)

covs_m1 = raster::stack(
  elev_raster,
  slope_raster,
  asp_cos_raster,
  asp_sin_raster,
  lead_htop_raster,
  species_class_raster,
  stemsha_L_raster)
```

```
rasterVis::levelplot(covs_m1_gaspard)
```

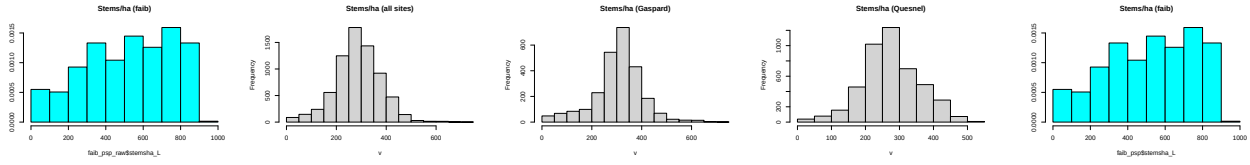



```
rasterVis::levelplot(covs_m1_quesnel)
```



Tidy plot data: Bootstrapped resampling

```
## # A tibble: 691 x 8
##     elev slope   asp_cos asp_sin lead_htop species_class stemsha_L wsvha_L
##    <int> <int>     <dbl>   <dbl>     <dbl>         <dbl>     <dbl>   <dbl>
##  1   793    15 -1.84e-16  -1          23.0             1      770.    303.
##  2   793    15 -1.84e-16  -1          26.0             1      700.    384.
##  3   661     4  3.09e- 1   0.951      23.6             2      817.    338.
##  4   788     5  1.74e- 1   0.985      27.8             2      883.    507.
##  5   903     2  6.98e- 2  -0.998      18.3             1      315.    113.
##  6   903     2  6.98e- 2  -0.998      21.1             1      522.    184.
##  7   903     2  6.98e- 2  -0.998      24.4             1      660.    272.
##  8   903     2  6.98e- 2  -0.998      25.8             1      650.    356.
##  9   903     2  6.98e- 2  -0.998      26.0             2      414.    219.
## 10   825    10 -3.42e- 1  -0.940      18.3             2      335.    126.
## # ... with 681 more rows
```



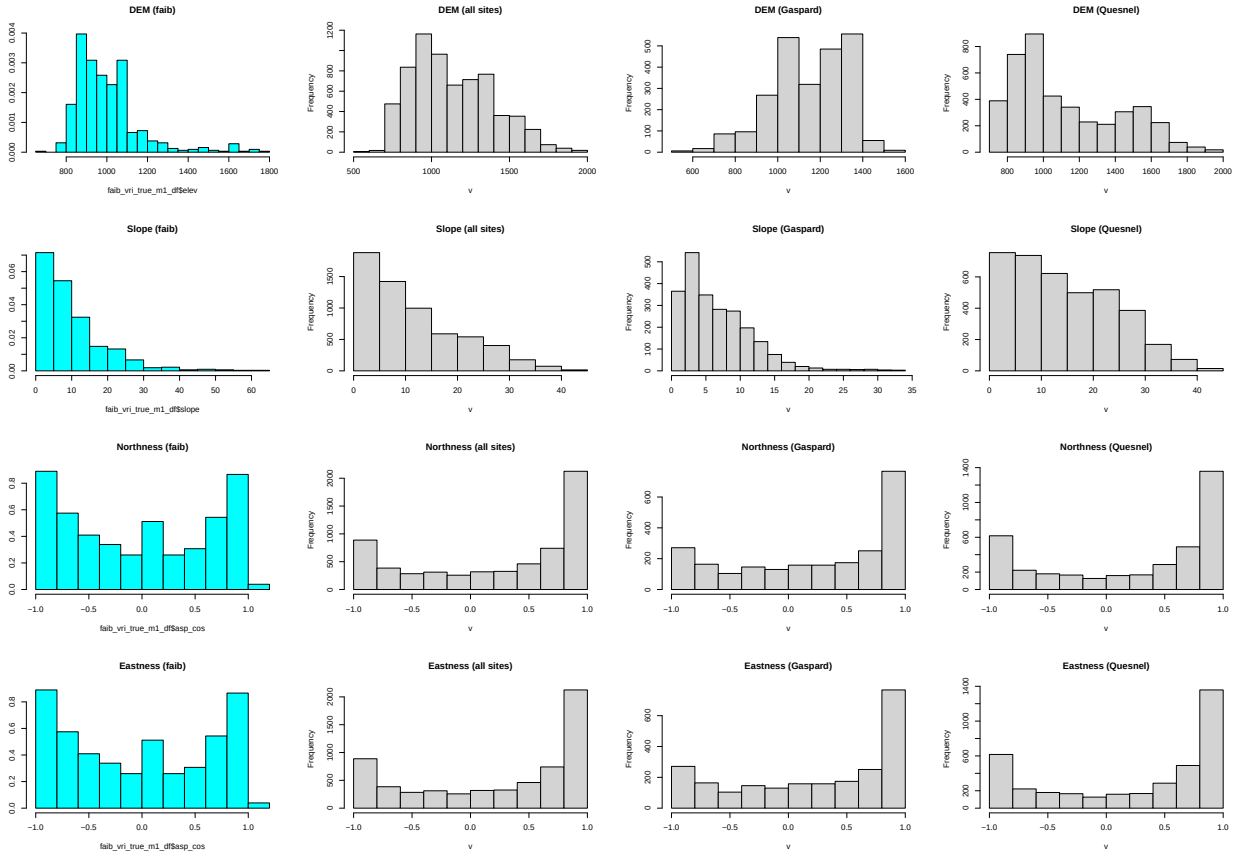
Tidy plot data: Data cleaning & training-test split

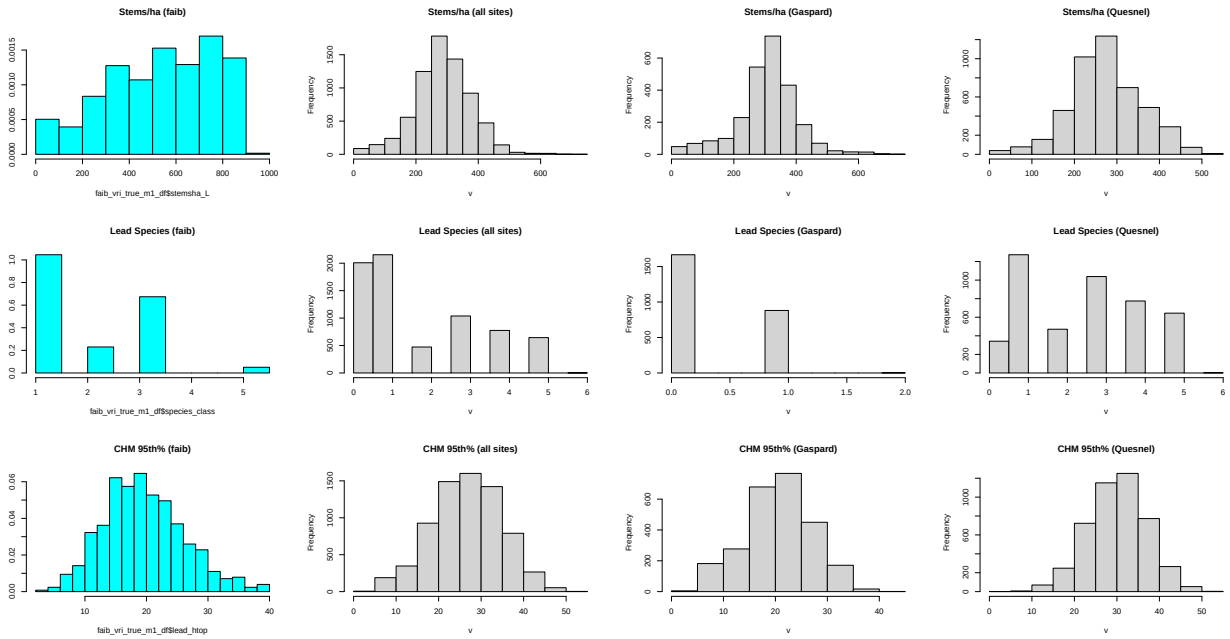
```
faib_psp$elev = as.numeric(faib_psp$elev)
faib_psp$slope = as.numeric(faib_psp$slope)
faib_psp$asp_cos = as.numeric(faib_psp$asp_cos)
faib_psp$asp_sin = as.numeric(faib_psp$asp_sin)
faib_psp$lead_htop = as.numeric(faib_psp$lead_htop)
faib_psp$species_class = as.numeric(faib_psp$species_class)
faib_psp$stemsha_L = as.numeric(faib_psp$stemsha_L)
faib_psp$wsvha_L = as.numeric(faib_psp$wsvha_L)

faib_psp$elev[faib_psp$elev <= 0] = NA
faib_psp$slope[faib_psp$slope <= 0] = NA
faib_psp$lead_htop[faib_psp$lead_htop < 2] = NA
faib_psp$stemsha_L[faib_psp$stemsha_L <= 0] = NA
faib_psp$wsvha_L[faib_psp$wsvha_L <= 0] = NA

faib_vri_true_m1_df = faib_psp[c("elev", "slope", "asp_cos", "asp_sin", "lead_htop", "species_class", "
faib_vri_true_m2_df = faib_psp[c("elev", "slope", "asp_cos", "asp_sin", "lead_htop", "species_class", "
faib_vri_true_m1_df = na.omit(faib_vri_true_m1_df)
faib_vri_true_m2_df = na.omit(faib_vri_true_m2_df)

n <- nrow(faib_vri_true_m1_df)
frac <- 0.8
ix <- sample(n, frac * n)
train_m1 = faib_vri_true_m1_df[ix,]
test_m1 = faib_vri_true_m1_df[-ix,]
train_m2 = faib_vri_true_m2_df[ix,]
test_m2 = faib_vri_true_m2_df[-ix,]

X_train_m1=train_m1[,-8]
X_test_m1=test_m1[,-8]
y_train_m1=train_m1[,8]
y_test_m1=test_m1[,8]

X_train_m2=train_m2[,-7]
X_test_m2=test_m2[,-7]
y_train_m2=train_m2[,7]
y_test_m2=test_m2[,7]

X_m1 = faib_vri_true_m1_df[,-8]
y_m1 = faib_vri_true_m1_df[,8]
X_m2 = faib_vri_true_m2_df[,-7]
y_m2 = faib_vri_true_m2_df[,7]
```

Exploratory data analysis: Visualize distributions

```
truehist(faib_vri_true_m1_df$elev, main="DEM (faib)", maxpixels=22000000)
hist(elev_raster, main="DEM (all sites)", maxpixels=22000000)
hist(elev_raster_gaspard, main="DEM (Gaspard)", maxpixels=22000000)
hist(elev_raster_quesnel, main="DEM (Quesnel)", maxpixels=22000000)
```

```
truehist(faib_vri_true_m1_df$slope, main="Slope (faib)", maxpixels=22000000)
hist(slope_raster, main="Slope (all sites)", maxpixels=22000000)
hist(slope_raster_gaspard, main="Slope (Gaspard)", maxpixels=22000000)
hist(slope_raster_quesnel, main="Slope (Quesnel)", maxpixels=22000000)
truehist(faib_vri_true_m1_df$asp_cos, main="Northness (faib)", maxpixels=22000000)
hist(asp_cos_raster, main="Northness (all sites)", maxpixels=22000000)
hist(asp_cos_raster_gaspard, main="Northness (Gaspard)", maxpixels=22000000)
hist(asp_cos_rast_quesnel, main="Northness (Quesnel)", maxpixels=22000000)
truehist(faib_vri_true_m1_df$asp_cos, main="Eastness (faib)", maxpixels=22000000)
hist(asp_cos_raster, main="Eastness (all sites)", maxpixels=22000000)
hist(asp_cos_raster_gaspard, main="Eastness (Gaspard)", maxpixels=22000000)
hist(asp_cos_rast_quesnel, main="Eastness (Quesnel)", maxpixels=22000000)
truehist(faib_vri_true_m1_df$stemsha_L, main="Stems/ha (faib)", maxpixels=22000000)
hist(stemsha_L_raster, main="Stems/ha (all sites)", maxpixels=22000000)
hist(stemsha_L_raster_gaspard, main="Stems/ha (Gaspard)", maxpixels=22000000)
hist(stemsha_L_raster_quesnel, main="Stems/ha (Quesnel)", maxpixels=22000000)
faib_vri_true_m1_df$species_class = as.numeric(faib_vri_true_m1_df$species_class)
truehist(faib_vri_true_m1_df$species_class, main="Lead Species (faib)", maxpixels=22000000)
hist(species_class_raster, main="Lead Species (all sites)", maxpixels=22000000)
hist(species_class_raster_gaspard, main="Lead Species (Gaspard)", maxpixels=22000000)
hist(species_class_raster_quesnel, main="Lead Species (Quesnel)", maxpixels=22000000)
truehist(faib_vri_true_m1_df$lead_htop, main="CHM 95th% (faib)", maxpixels=22000000)
hist(lead_htop_raster, main="CHM 95th% (all sites)", maxpixels=22000000)
hist(lead_htop_raster_gaspard, main="CHM 95th% (Gaspard)", maxpixels=22000000)
hist(lead_htop_raster_quesnel, main="CHM 95th% (Quesnel)", maxpixels=22000000)
```





Exploratory data analysis: Visualize trends in variance

```
elev_wsvha_lm = lm(wsvha_L ~ elev, data = faib_vri_true_m1_df)
slope_wsvha_lm = lm(wsvha_L ~ slope, data = faib_vri_true_m1_df)
asp_cos_wsvha_lm = lm(wsvha_L ~ asp_cos, data = faib_vri_true_m1_df)
asp_sin_wsvha_lm = lm(wsvha_L ~ asp_sin, data = faib_vri_true_m1_df)
lead_htop_wsvha_lm = lm(wsvha_L ~ lead_htop, data = faib_vri_true_m1_df)
species_class_wsvha_lm = lm(wsvha_L ~ species_class, data = faib_vri_true_m1_df)
stemsha_L_wsvha_lm = lm(wsvha_L ~ stemsha_L, data = faib_vri_true_m1_df)

summary(elev_wsvha_lm)
```

```
##
## Call:
## lm(formula = wsvha_L ~ elev, data = faib_vri_true_m1_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -217.13 -111.13  -47.98   72.19  624.56
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 351.20563   37.89240   9.268  < 2e-16 ***
## elev         -0.17006    0.03742  -4.545 6.58e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 153.9 on 633 degrees of freedom
## Multiple R-squared:  0.0316, Adjusted R-squared:  0.03007
## F-statistic: 20.66 on 1 and 633 DF,  p-value: 6.584e-06
```

```
truehist(faib_vri_true_m1_df$elev)
truehist(elev_wsvha_lm$residuals)
plot(wsvha_L ~ elev, data = faib_vri_true_m1_df,
     main="Linear function showing negative correlation:\nR^2=0.011,  =-0.0954, p<0.0000",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.8, cex.axis=0.8, adj=1,
     ylab = "wsvha_L (m3/ha)", xlab = "DEM")
abline(elev_wsvha_lm, col = "red")
plot(elev_wsvha_lm, which=1,
     main="Residuals showing increasing trend\n clustering at larger fitted values",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.5, cex.axis=0.5, adj=1) # Residuals vs Fitted
summary(slope_wsvha_lm)
```

```
##
## Call:
## lm(formula = wsvha_L ~ slope, data = faib_vri_true_m1_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -183.60 -115.29  -47.90   74.18  619.15
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 185.5195     9.1698  20.232   <2e-16 ***
## slope        -0.4469     0.7050  -0.634    0.526
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 156.3 on 633 degrees of freedom
## Multiple R-squared:  0.0006344,  Adjusted R-squared:  -0.0009444
## F-statistic: 0.4018 on 1 and 633 DF,  p-value: 0.5264
```

```
truehist(faib_vri_true_m1_df$slope)
truehist(slope_wsvha_lm$residuals)
plot(wsvha_L ~ slope, data = faib_vri_true_m1_df,
     main="Linear function showing negative correlation:\nR^2=0.0013,  =-0.5171: p=0.0009",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.8, cex.axis=0.8, adj=1,
     ylab = "wsvha_L (m3/ha)", xlab = "slope")
abline(slope_wsvha_lm, col = "red")
plot(slope_wsvha_lm, which=1,
     main="Residuals showing increasing trend of\nnegative errors near larger fitted values",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.5, cex.axis=0.5, adj=1)
summary(asp_cos_wsvha_lm)
```

```
##
## Call:
## lm(formula = wsvha_L ~ asp_cos, data = faib_vri_true_m1_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -193.04 -117.03  -46.78   75.16  606.31
##
## Coefficients:
```

```
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  181.491      6.199  29.276   <2e-16 ***
## asp_cos       12.635      9.010   1.402    0.161
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 156.2 on 633 degrees of freedom
## Multiple R-squared:  0.003097,   Adjusted R-squared:  0.001522
## F-statistic: 1.966 on 1 and 633 DF,  p-value: 0.1613
```

```
truehist(faib_vri_true_m1_df$asp_cos)
truehist(asp_cos_wsvha_lm$residuals)
plot(wsvha_L ~ asp_cos, data = faib_vri_true_m1_df,
     main="Linear function showing positive correlation:\nR^2=0.005,  =15.197, p<0.000",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.8, cex.axis=0.8, adj=1,
     ylab = "wsvha_L (m3/ha)", xlab = "asp_cos")
abline(asp_cos_wsvha_lm, col = "red")
plot(asp_cos_wsvha_lm, which=1,
     main="Residuals showing almost constant variance",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.5, cex.axis=0.5, adj=1)
summary(asp_sin_wsvha_lm)
```

```
##
## Call:
## lm(formula = wsvha_L ~ asp_sin, data = faib_vri_true_m1_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -180.68 -114.56  -48.57   74.30  618.14
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  181.071      6.268  28.887   <2e-16 ***
## asp_sin        1.658      8.638   0.192    0.848
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 156.4 on 633 degrees of freedom
## Multiple R-squared:  5.818e-05,  Adjusted R-squared:  -0.001522
## F-statistic: 0.03683 on 1 and 633 DF,  p-value: 0.8479
```

```
truehist(faib_vri_true_m1_df$asp_sin)
truehist(asp_sin_wsvha_lm$residuals)
plot(wsvha_L ~ asp_sin, data = faib_vri_true_m1_df,
     main="Linear function showing positive correlation:\nR^2=0.005,  =15.197, p<0.000",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.8, cex.axis=0.8, adj=1,
     ylab = "wsvha_L (m3/ha)", xlab = "asp_sin")
abline(asp_sin_wsvha_lm, col = "red")
plot(asp_sin_wsvha_lm, which=1,
     main="Residuals showing almost constant variance",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.5, cex.axis=0.5, adj=1)
summary(lead_htop_wsvha_lm)
```

```
##
## Call:
## lm(formula = wsvha_L ~ lead_htop, data = faib_vri_true_m1_df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -237.481  -41.807   -4.616   45.469  287.232
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -233.8917     9.1330  -25.61   <2e-16 ***
## lead_htop     21.1705     0.4419   47.91   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 72.72 on 633 degrees of freedom
## Multiple R-squared:  0.7838, Adjusted R-squared:  0.7835
## F-statistic:  2295 on 1 and 633 DF,  p-value: < 2.2e-16
```

```
truehist(faib_vri_true_m1_df$lead_htop)
truehist(lead_htop_wsvha_lm$residuals)
plot(wsvha_L ~ lead_htop, data = faib_vri_true_m1_df,
     main="Linear function shows positive correlation:\n R^2=0.6508,  =20.6829, p<0.0000",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.8, cex.axis=0.8, adj=1,
     ylab = "wsvha_L (m3/ha)", xlab = "lead_htop")
abline(lead_htop_wsvha_lm, col = "red")
plot(lead_htop_wsvha_lm, which=1,
     main="Residuals showing non-constant variance with\n increasing trends at smallest and largest fit
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.5, cex.axis=0.5, adj=1)
summary(stemsha_L_wsvha_lm)
```

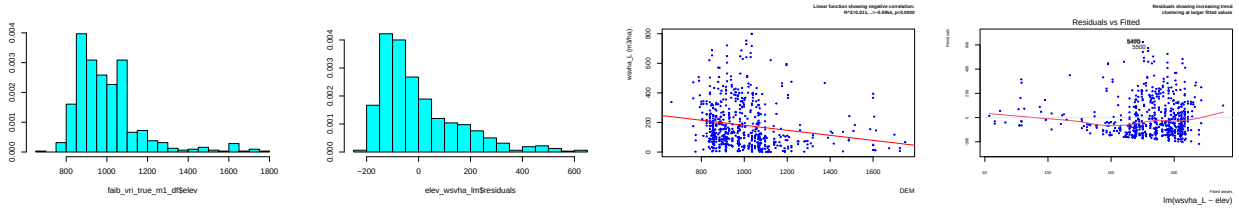
```
##
## Call:
## lm(formula = wsvha_L ~ stemsha_L, data = faib_vri_true_m1_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -194.29  -88.39  -40.98   52.69  599.97
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 21.79199   14.02008   1.554    0.121
## stemsha_L    0.29974    0.02419  12.392   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 140.3 on 633 degrees of freedom
## Multiple R-squared:  0.1952, Adjusted R-squared:  0.194
## F-statistic: 153.6 on 1 and 633 DF,  p-value: < 2.2e-16
```

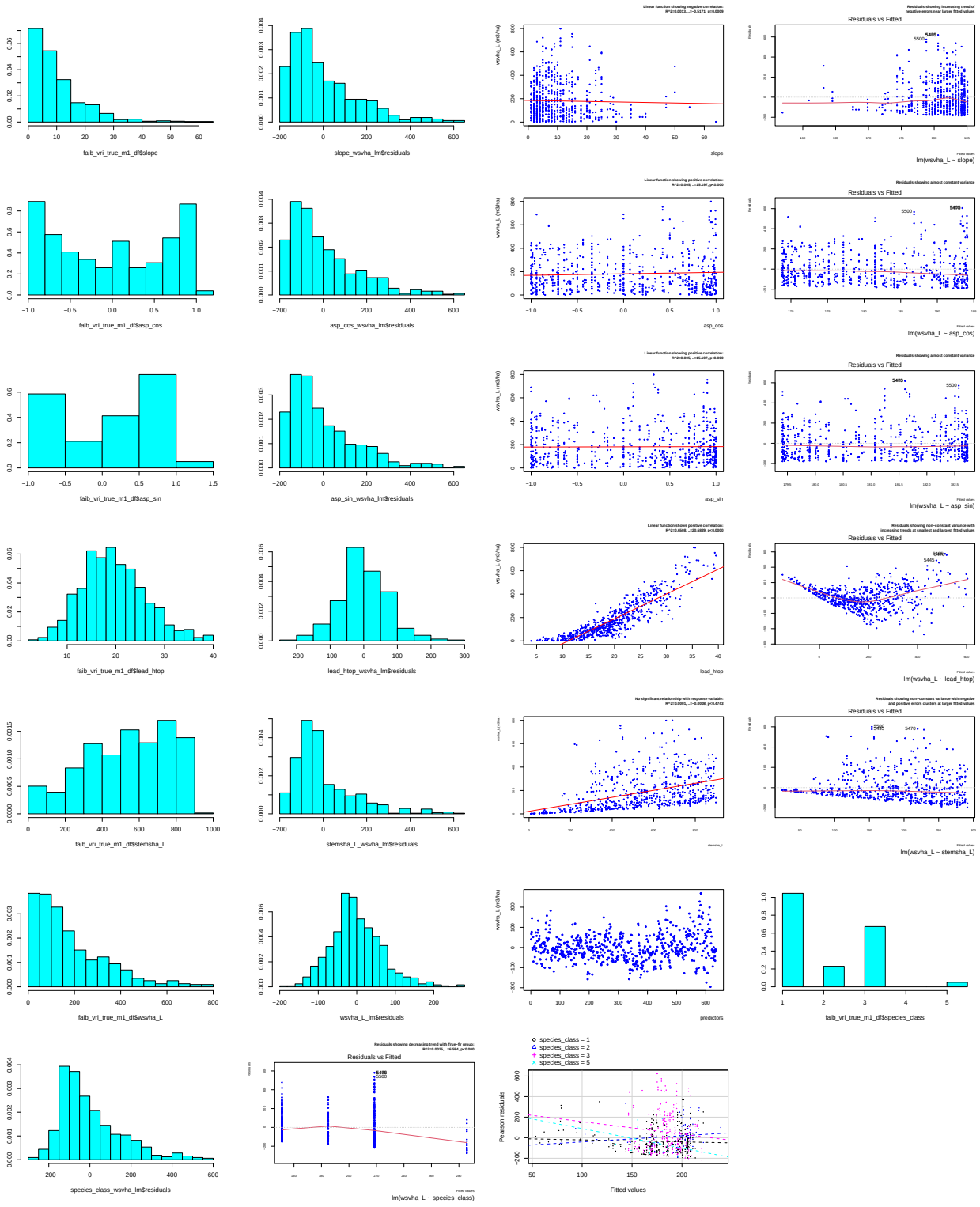
```
truehist(faib_vri_true_m1_df$stemsha_L)
truehist(stemsha_L_wsvha_lm$residuals)
plot(wsvha_L ~ stemsha_L, data = faib_vri_true_m1_df,
```

```
     main="No significant relationship with response variable:\nR^2=0.0001,  =-0.0008, p<0.4743",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.5, cex.axis=0.5, adj=1,
     ylab = "wsvha_L (m3/ha)", xlab = "stemsha_L")
abline(stemsha_L_wsvha_lm, col = "red")
plot(stemsha_L_wsvha_lm, which=1,
     main="Residuals showing non-constant variance with negative\nand positive errors clusters at large
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.5, cex.axis=0.5, adj=1)
wsvha_L_lm = lm(wsvha_L ~ ., data = faib_vri_true_m1_df)
truehist(faib_vri_true_m1_df$wsvha_L)
truehist(wsvha_L_lm$residuals)
plot(wsvha_L_lm$residuals,
     main="",
     col="blue", pch=20, cex=0.8, cex.main=0.8, cex.lab=0.8, cex.axis=0.8, adj=1,
     ylab = "wsvha_L (m3/ha)", xlab = "predictors")
abline(wsvha_L_lm, col="red")
summary(species_class_wsvha_lm)
```

```
##
## Call:
## lm(formula = wsvha_L ~ species_class, data = faib_vri_true_m1_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -275.02 -108.63  -41.67   76.84  581.18
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)    117.692     12.580   9.356  < 2e-16 ***
## species_class   33.627      5.836   5.762  1.3e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 152.5 on 633 degrees of freedom
## Multiple R-squared:  0.04983,    Adjusted R-squared:  0.04833
## F-statistic:  33.2 on 1 and 633 DF,  p-value: 1.301e-08
```

```
faib_vri_true_m1_df$species_class = as.numeric(faib_vri_true_m1_df$species_class)
truehist(faib_vri_true_m1_df$species_class)
truehist(species_class_wsvha_lm$residuals)
plot(species_class_wsvha_lm, which=1,
     main="Residuals showing decreasing trend with True-fir group:\nR^2=0.0025,  =6.584, p<0.000",
     col="blue", pch=20, cex=0.5, cex.main=0.6, cex.lab=0.5, cex.axis=0.5, adj=1)
car::residualPlots(elev_wsvha_lm, terms= ~ 1 | species_class, cex=0.1, pch=19) # plot vs. yhat grouping
```

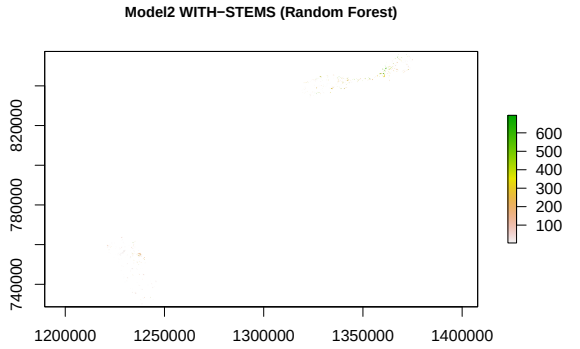


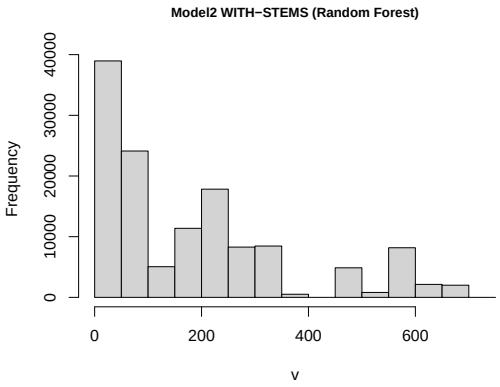


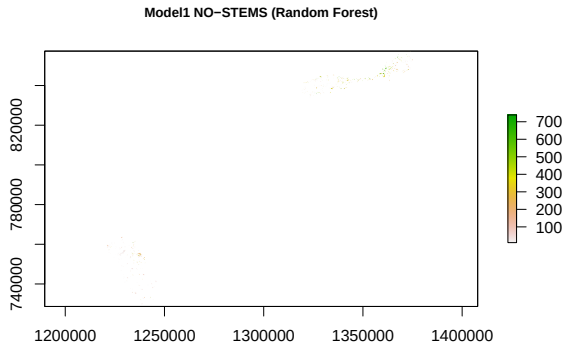
Modelling: Fit, cross-validate and tune models

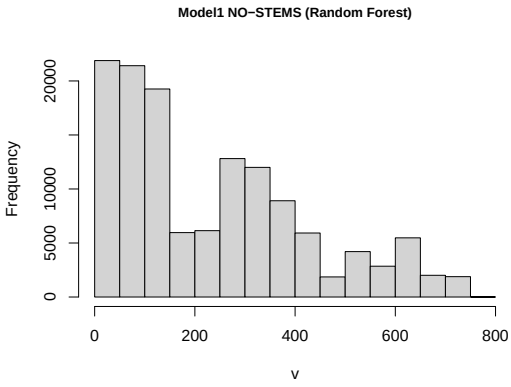
```
tuneResult_rf_m2_full <- tune.randomForest(
  X_m2, y_m2,
  mtry = c(2:10), ntree = 50,
  tunecontrol = tune.control(sampling = "cross", cross = 10),
  preProcess = c("BoxCox","center","scale"))

tuneResult_rf_m1_full <- tune.randomForest(
  X_m1, y_m1,
  mtry = c(2:10), ntree = 50,
  tunecontrol = tune.control(sampling = "cross", cross = 10),
  preProcess = c("BoxCox","center","scale"))

tunedModel_rf_m2_full <- tuneResult_rf_m2_full$best.model
tunedModel_rf_m1_full <- tuneResult_rf_m1_full$best.model
print(summary(tunedModel_rf_m2_full))
print(summary(tunedModel_rf_m1_full))
tunedModel_rf_m2_full
tunedModel_rf_m1_full
save(tunedModel_rf_m2_full, file = "/media/seamus/128GB_WORKD/data/models/tcc-wsvha/wsvha_model2_rndmFo
save(tunedModel_rf_m1_full, file = "/media/seamus/128GB_WORKD/data/models/tcc-wsvha/wsvha_model1_rndmFo
tunedModel_rf_m2 = predict(tunedModel_rf_m2_full, X_m2, y_m2, type = "response")
tunedModel_rf_m1 = predict(tunedModel_rf_m1_full, X_m1, y_m1,type = "response")
tuneResult_rf_m2_train <- tune.randomForest(X_train_m2, y_train_m2, mtry = c(2:10), ntree = 50,
  tunecontrol = tune.control(sampling = "cross", cross = 10), preProcess = c("BoxCox","center","scale"))
tuneResult_rf_m1_train <- tune.randomForest(X_train_m1, y_train_m1, mtry = c(2:10), ntree = 50,
  tunecontrol = tune.control(sampling = "cross", cross = 10), preProcess = c("BoxCox","center","scale"))
tunedModel_rf_m2_train <- tuneResult_rf_m2_train$best.model
tunedModel_rf_m1_train <- tuneResult_rf_m1_train$best.model
tunedModel_rf_m2_test = predict(tunedModel_rf_m2_train, X_test_m2, y_test_m2, type="response")
tunedModel_rf_m1_test = predict(tunedModel_rf_m1_train, X_test_m1, y_test_m1, type="response")
tunedModel_rf_m2_full_MAE = MAE(tunedModel_rf_m2, y_m2)
tunedModel_rf_m2_full_RMSE = RMSE(tunedModel_rf_m2, y_m2)
tunedModel_rf_m1_full_MAE = MAE(tunedModel_rf_m1, y_m2)
tunedModel_rf_m1_full_RMSE = RMSE(tunedModel_rf_m1, y_m2)
tunedModel_rf_m2_test_MAE = MAE(tunedModel_rf_m2_test, y_test_m2)
tunedModel_rf_m2_test_RMSE = RMSE(tunedModel_rf_m2_test, y_test_m2)
tunedModel_rf_m1_test_MAE = MAE(tunedModel_rf_m1_test, y_test_m2)
tunedModel_rf_m1_test_RMSE = RMSE(tunedModel_rf_m1_test, y_test_m2)

R2(tunedModel_rf_m2, y_m2)
MAE(tunedModel_rf_m2, y_m2)
RMSE(tunedModel_rf_m2, y_m2)
MAE(tunedModel_rf_m2_test, y_test_m2)
RMSE(tunedModel_rf_m2_test, y_test_m2)
tunedModel_rf_m2_full_RMSE/tunedModel_rf_m2_test_RMSE
R2(tunedModel_rf_m1, y_m1)
MAE(tunedModel_rf_m1, y_m1)
RMSE(tunedModel_rf_m1, y_m1)
MAE(tunedModel_rf_m1_test, y_test_m1)
RMSE(tunedModel_rf_m1_test, y_test_m1)
tunedModel_rf_m1_full_RMSE/tunedModel_rf_m1_test_RMSE

tuneResult_rf_m2_full$performances
```

```
tuneResult_rf_m1_full$performances
tunedModel_rf_m2_to_raster <- predict(covs_m2, tunedModel_rf_m2_full)
tunedModel_rf_m1_to_raster <- predict(covs_m1, tunedModel_rf_m1_full)
tunedModel_rf_m2_to_raster_gaspard <- predict(covs_m2_gaspard, tunedModel_rf_m2_full)
tunedModel_rf_m1_to_raster_gaspard <- predict(covs_m1_gaspard, tunedModel_rf_m1_full)
tunedModel_rf_m2_to_raster_quesnel <- predict(covs_m2_quesnel, tunedModel_rf_m2_full)
tunedModel_rf_m1_to_raster_quesnel <- predict(covs_m1_quesnel, tunedModel_rf_m1_full)
writeRaster(tunedModel_rf_m2_to_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/wsvha/wsv
writeRaster(tunedModel_rf_m1_to_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/wsvha/wsv
writeRaster(tunedModel_rf_m2_to_raster_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/ws
writeRaster(tunedModel_rf_m1_to_raster_gaspard, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/ws
writeRaster(tunedModel_rf_m2_to_raster_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/ws
writeRaster(tunedModel_rf_m1_to_raster_quesnel, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/ws
```










```
tuneResult_svm_m2_full <- tune(
  svm, X_m2, y_m2,
  ranges = list(cost = c(1,5,7,15,20), gamma = 2^(-1:1)),
  tunecontrol = tune.control(cross = 10),
  preProcess = c("BoxCox","center","scale"))

tuneResult_svm_m1_full <- tune(
  svm, X_m1, y_m1,
  ranges = list(cost = c(1,5,7,15,20), gamma = 2^(-1:1)),
  tunecontrol = tune.control(cross = 10),
  preProcess = c("BoxCox","center","scale"))
```

```
tunedModel_svm_m2_full <- tuneResult_svm_m2_full$best.model
tunedModel_svm_m1_full <- tuneResult_svm_m1_full$best.model
print(summary(tunedModel_svm_m2_full))
print(summary(tunedModel_svm_m1_full))
save(tunedModel_svm_m2_full, file = "/media/seamus/128GB_WORKD/data/models/tcc-wsvha/wsvha_model2_svmRa
save(tunedModel_svm_m1_full, file = "/media/seamus/128GB_WORKD/data/models/tcc-wsvha/wsvha_model1_svmRa
tunedModel_svm_m2 = predict(tunedModel_svm_m2_full, data=faib_vri_true_m2_df)
tunedModel_svm_m1 = predict(tunedModel_svm_m1_full, data=faib_vri_true_m1_df)


tunedModel_rf_m2_full <- tuneResult_rf_m2_full$best.model
tunedModel_rf_m1_full <- tuneResult_rf_m1_full$best.model
print(summary(tunedModel_rf_m2_full))
print(summary(tunedModel_rf_m1_full))
tunedModel_rf_m2_full
tunedModel_rf_m1_full
save(tunedModel_rf_m2_full, file = "/media/seamus/128GB_WORKD/data/models/tcc-wsvha/wsvha_model2_rndmFo
save(tunedModel_rf_m1_full, file = "/media/seamus/128GB_WORKD/data/models/tcc-wsvha/wsvha_model1_rndmFo
tunedModel_rf_m2 = predict(tunedModel_rf_m2_full, X_m2, y_m2, type = "response")
tunedModel_rf_m1 = predict(tunedModel_rf_m1_full, X_m1, y_m1,type = "response")
tuneResult_rf_m2_train <- tune.randomForest(X_train_m2, y_train_m2, mtry = c(2:10), ntree = 50,
  tunecontrol = tune.control(sampling = "cross", cross = 10), preProcess = c("BoxCox","center","scale"))
tuneResult_rf_m1_train <- tune.randomForest(X_train_m1, y_train_m1, mtry = c(2:10), ntree = 50,
  tunecontrol = tune.control(sampling = "cross", cross = 10), preProcess = c("BoxCox","center","scale"))
tunedModel_rf_m2_train <- tuneResult_rf_m2_train$best.model
tunedModel_rf_m1_train <- tuneResult_rf_m1_train$best.model
tunedModel_rf_m2_test = predict(tunedModel_rf_m2_train, X_test_m2, y_test_m2, type="response")
tunedModel_rf_m1_test = predict(tunedModel_rf_m1_train, X_test_m1, y_test_m1, type="response")
tunedModel_rf_m2_full_MAE = MAE(tunedModel_rf_m2, y_m2)
tunedModel_rf_m2_full_RMSE = RMSE(tunedModel_rf_m2, y_m2)
tunedModel_rf_m1_full_MAE = MAE(tunedModel_rf_m1, y_m2)
tunedModel_rf_m1_full_RMSE = RMSE(tunedModel_rf_m1, y_m2)
tunedModel_rf_m2_test_MAE = MAE(tunedModel_rf_m2_test, y_test_m2)
tunedModel_rf_m2_test_RMSE = RMSE(tunedModel_rf_m2_test, y_test_m2)
tunedModel_rf_m1_test_MAE = MAE(tunedModel_rf_m1_test, y_test_m2)
tunedModel_rf_m1_test_RMSE = RMSE(tunedModel_rf_m1_test, y_test_m2)

R2(tunedModel_rf_m2, y_m2)
MAE(tunedModel_rf_m2, y_m2)
RMSE(tunedModel_rf_m2, y_m2)
MAE(tunedModel_rf_m2_test, y_test_m2)
RMSE(tunedModel_rf_m2_test, y_test_m2)
tunedModel_rf_m2_full_RMSE/tunedModel_rf_m2_test_RMSE
R2(tunedModel_rf_m1, y_m1)
MAE(tunedModel_rf_m1, y_m1)
RMSE(tunedModel_rf_m1, y_m1)
MAE(tunedModel_rf_m1_test, y_test_m1)
RMSE(tunedModel_rf_m1_test, y_test_m1)
tunedModel_rf_m1_full_RMSE/tunedModel_rf_m1_test_RMSE

tuneResult_rf_m2_full$performances
tuneResult_rf_m1_full$performances
tunedModel_rf_m2_to_raster <- predict(covs_m2, tunedModel_rf_m2_full)
```

```
tunedModel_rf_m1_to_raster <- predict(covs_m1, tunedModel_rf_m1_full)
writeRaster(tunedModel_rf_m2_to_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/wsvha/wsv
writeRaster(tunedModel_rf_m1_to_raster, filename = "/media/seamus/128GB_WORKD/data/raster/tcc/wsvha/wsv
```