# Analyzing Roads' Length As A Proxy For Impervious Areas In The Watersheds Of Puerto Rico Using Spatial Analysis And Statistical Programs

PRYSIG 2016

Ashley G. Benítez Ou and Javier A. Arce Nazario, Ph.D.
University of Puerto Rico at Cayey

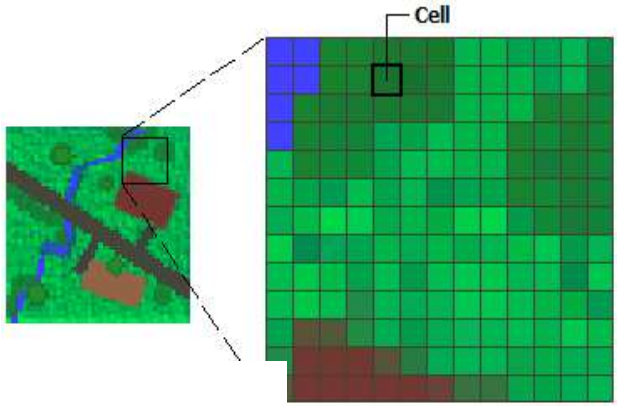
October 7th, 2016

# Overview

- Introduction
  - Concepts
  - Background
    - Importance
- Roads instead of impervious areas
- Data
- Methodology
- Results
- Conclusion

# Concepts

- Raster
- Shapefile
- Watersheds
- Proxy
- Imperviousness





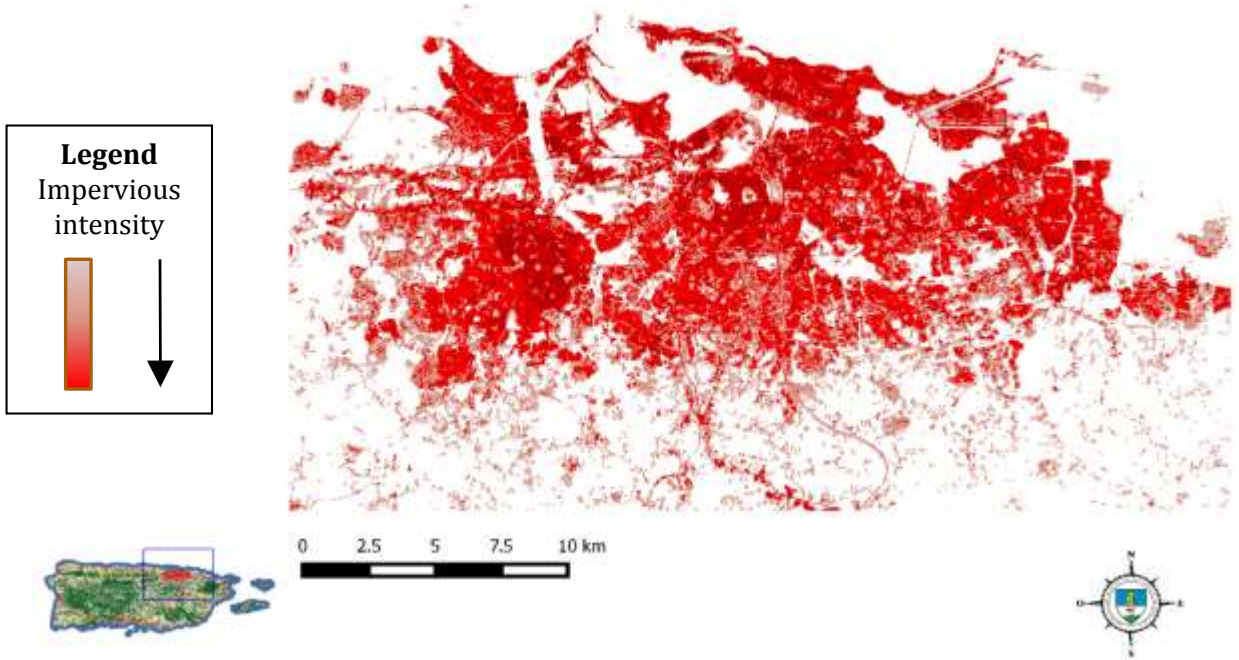
- http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/what-is-raster-data.htm

# Impervious areas

Urban pavements, such as rooftops, roads, sidewalks, parking lots, driveways; and other manmade concrete surfaces.

- Zhou Y., Wang Y.Q., (ONLINE) *Photogrammetric Engineering & Remote Sensing,* 2008. 48, 7, 857-868

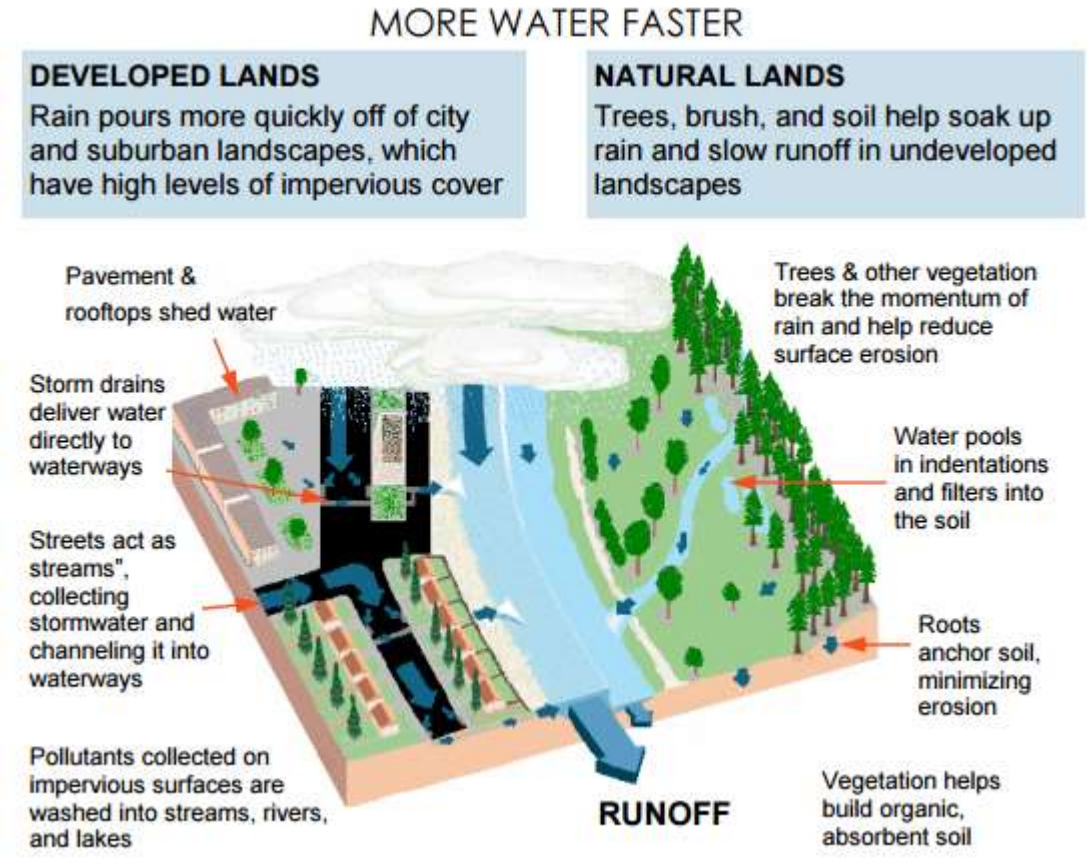
# Impervious areas



# Analyzing and determining imperviousness

- Water quality
- Stream flow
- Habitat degradation, loss, and fragmentation
- Alteration of local and regional hydrological cycles

# Analyzing and determining imperviousness




- http://www.coastal.ca.gov/nps/watercyclefacts.pdf

# Analyzing and determining imperviousness

- Water quality
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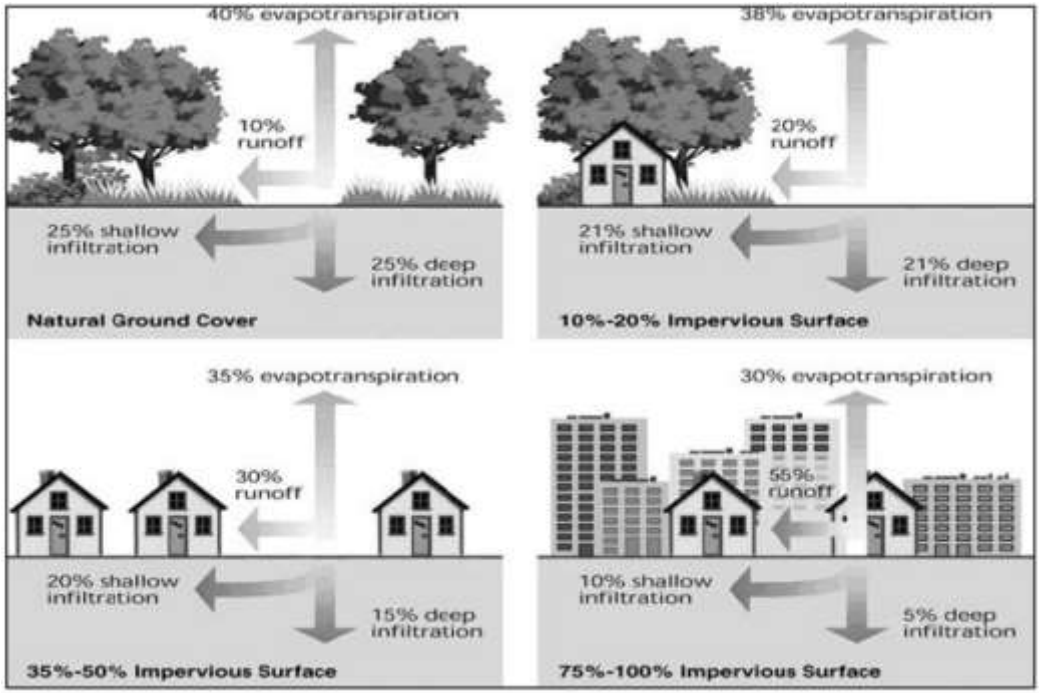
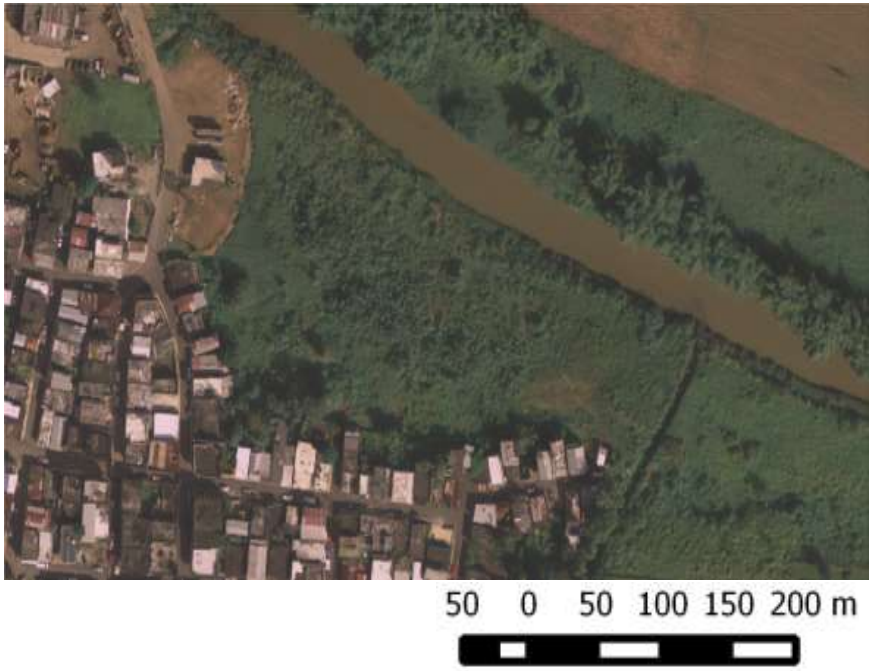
- Alteration of local and regional hydrological cycles




- http://cals.arizona.edu/extension/riparian/chapt7/p5a.html

# Why roads instead of impervious areas?

- Our objective is to optimize the determination of imperviousness of any region.




Aerial photography.
San Lorenzo, Puerto Rico (2001)

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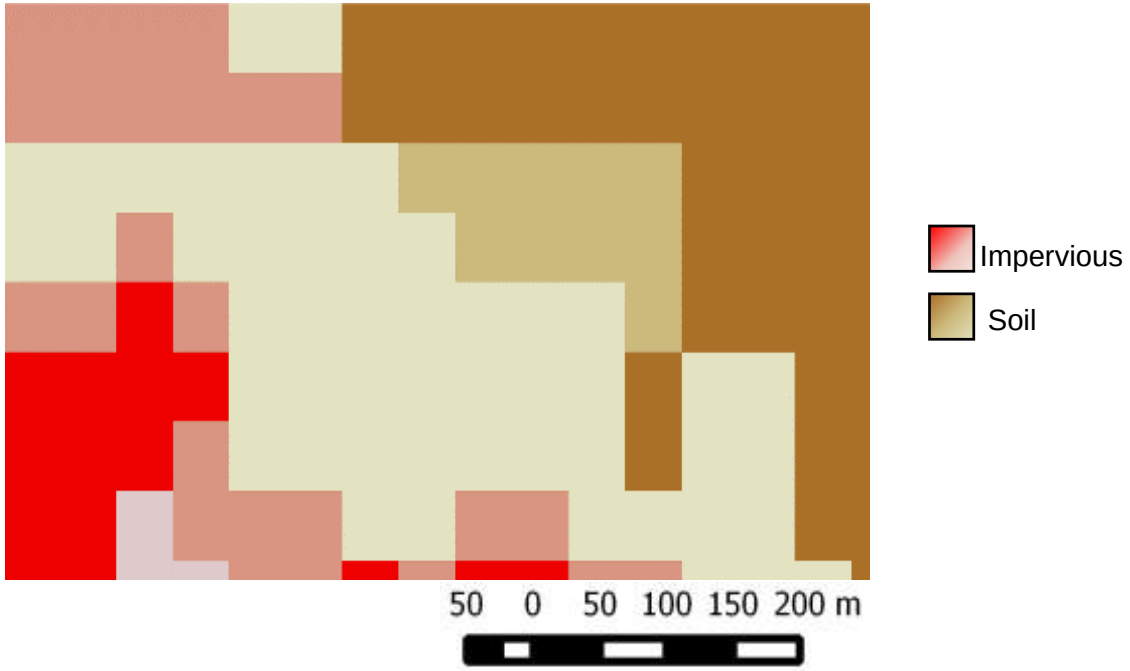


MRLC National Land Cover at 30 m resolution.
San Lorenzo, Puerto Rico (2001)

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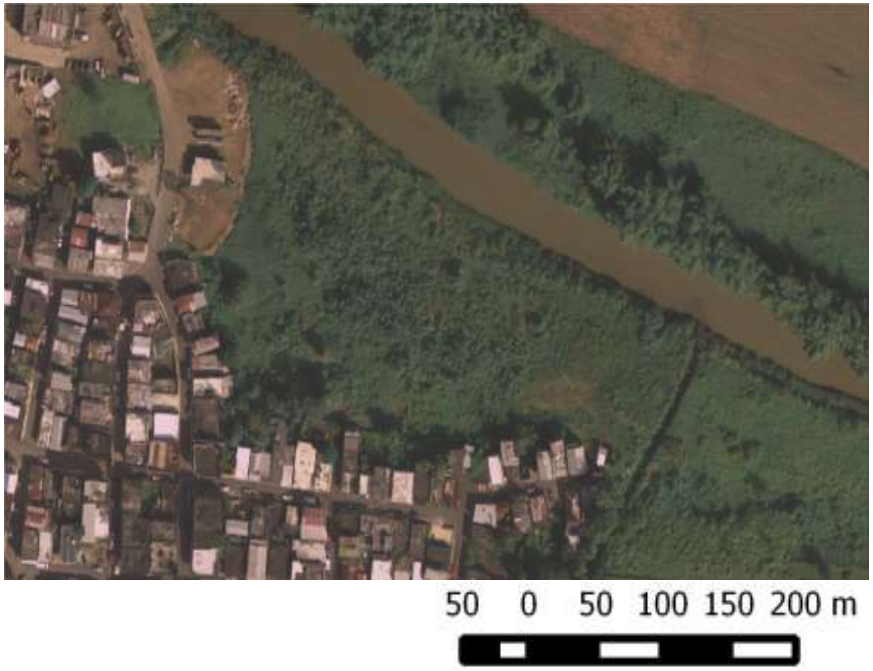


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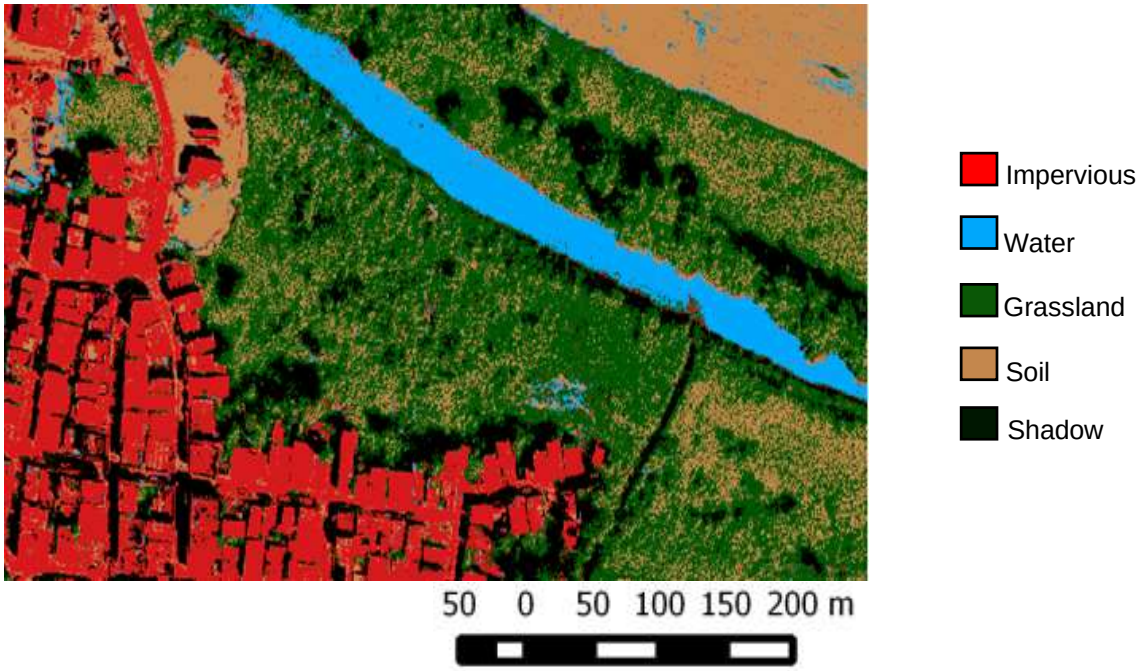
# Why roads instead of impervious areas?

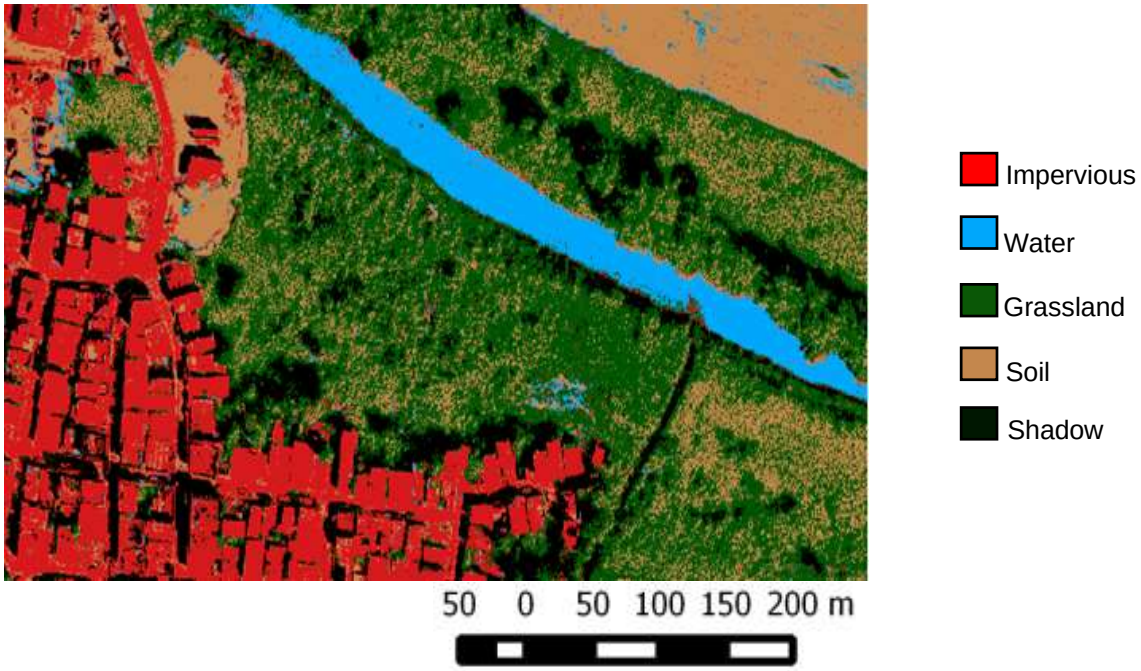
Classifying fine scale imagery is _____.




Reclassified aerial photography.
San Lorenzo, Puerto Rico (2001)

# Why roads instead of impervious areas?

Classifying fine scale imagery is **time consuming.**

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# Why roads instead of impervious areas?

- **Roads**
  - Accessible databases
    - Census
    - State agencies

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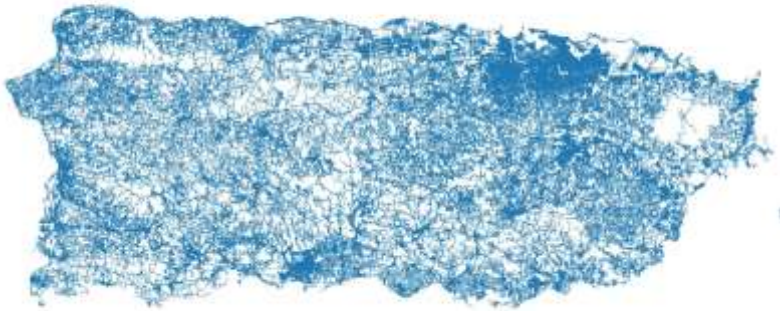
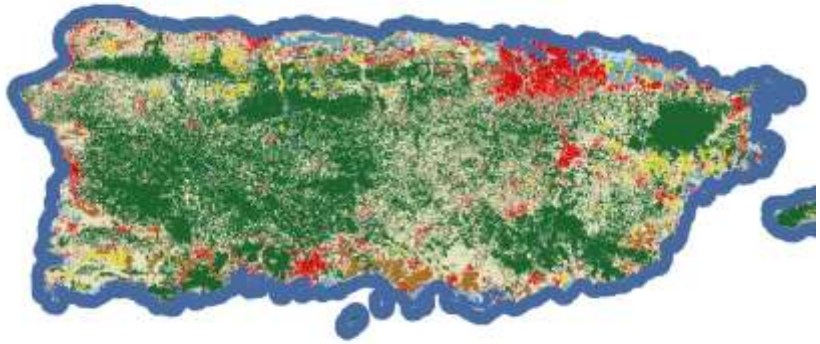
# Data

Watersheds boundaries



TIGER/lines (2006)



30 m land cover (2001)

# Methodology


Determination of impervious areas by watersheds

30 m land cover | Watershed boundaries

Impervious frequency by watershed

# Methodology


Determination of road length by watershed

| Roads layer | Watershed boundaries |
|---|---|

Road length by watershed

# Methodology

- Determining impervious areas by watershed.

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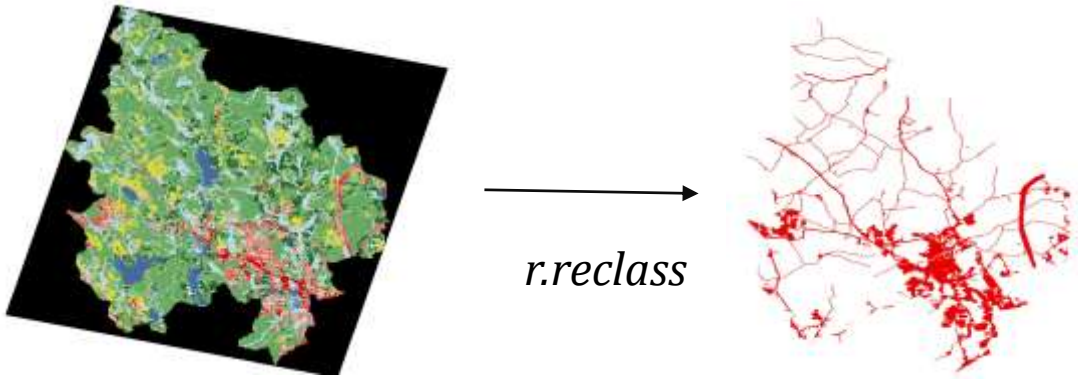

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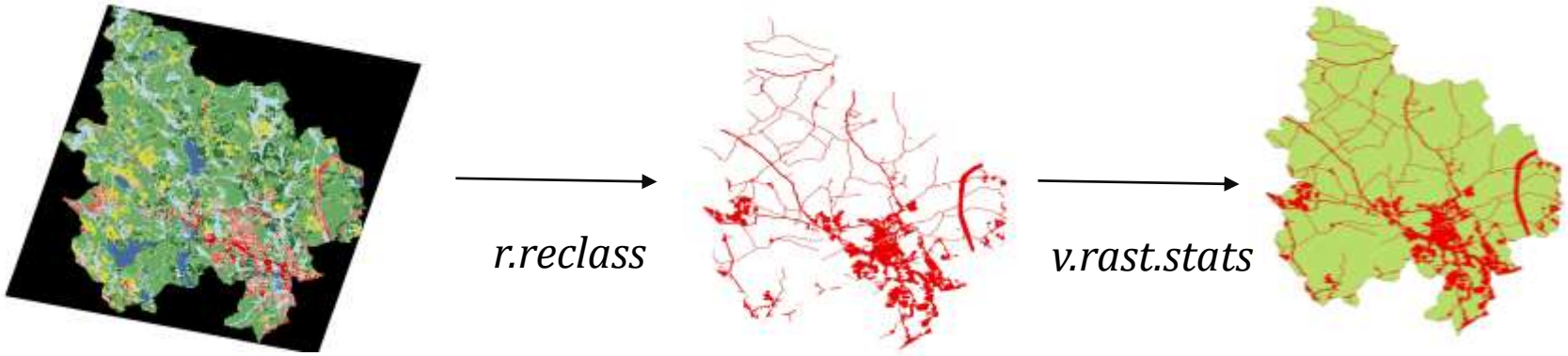

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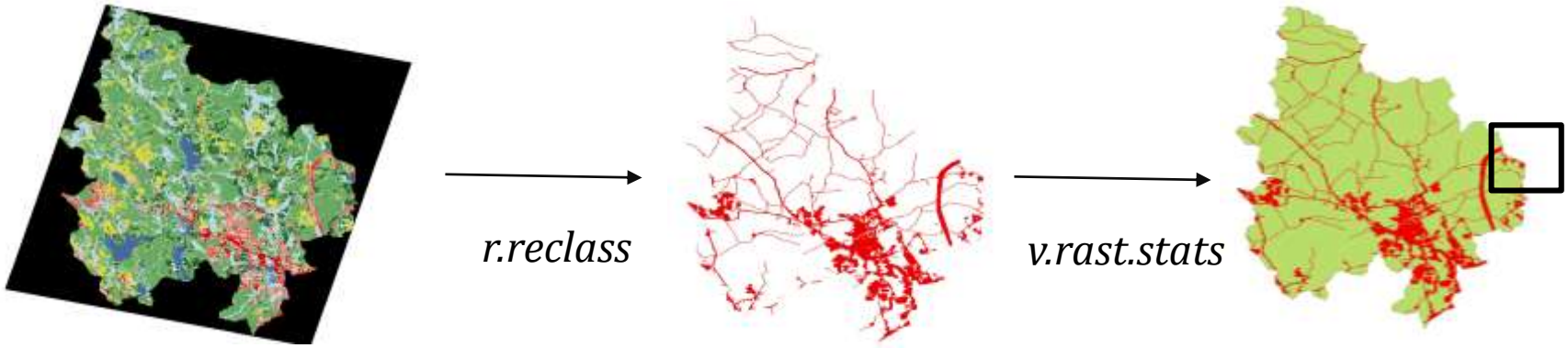

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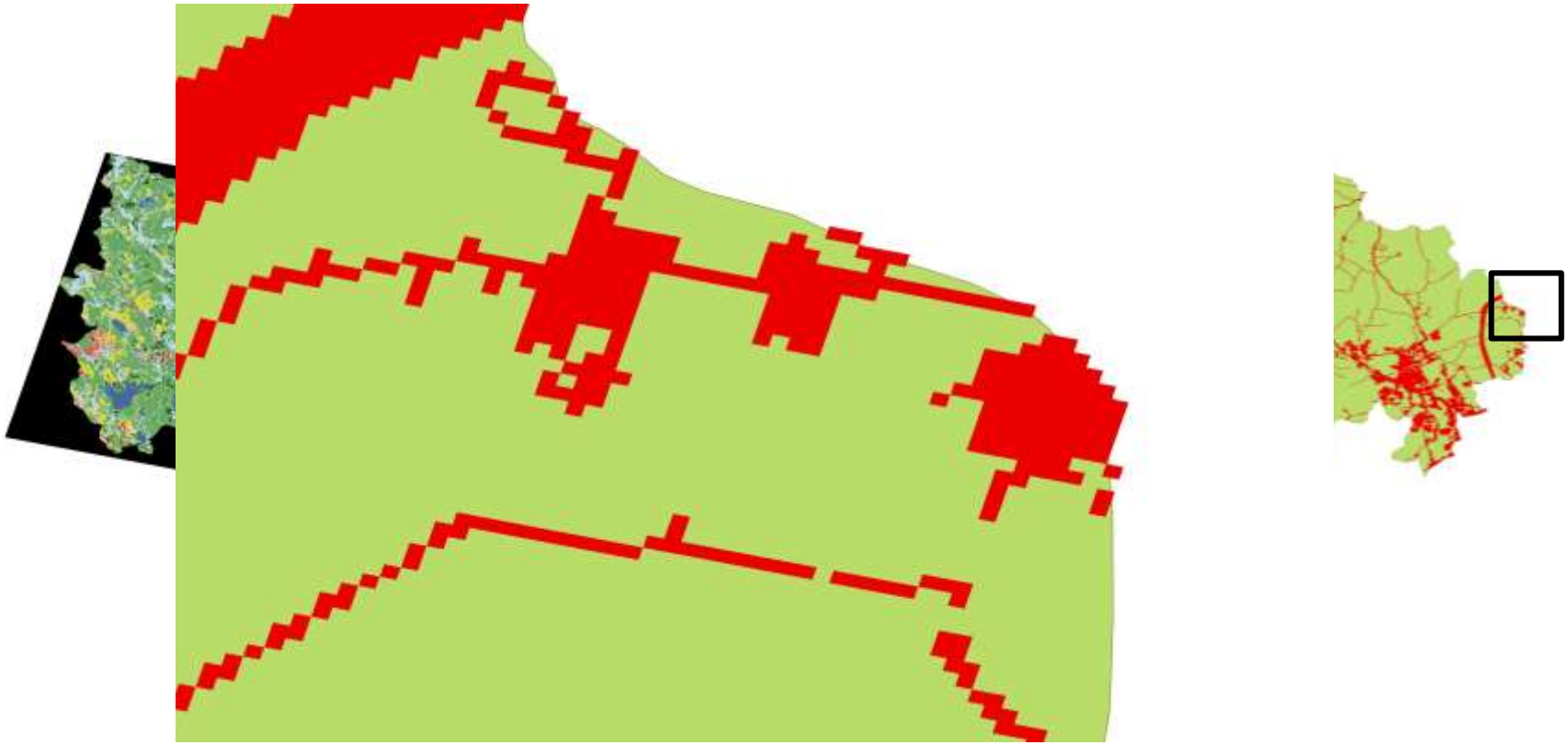

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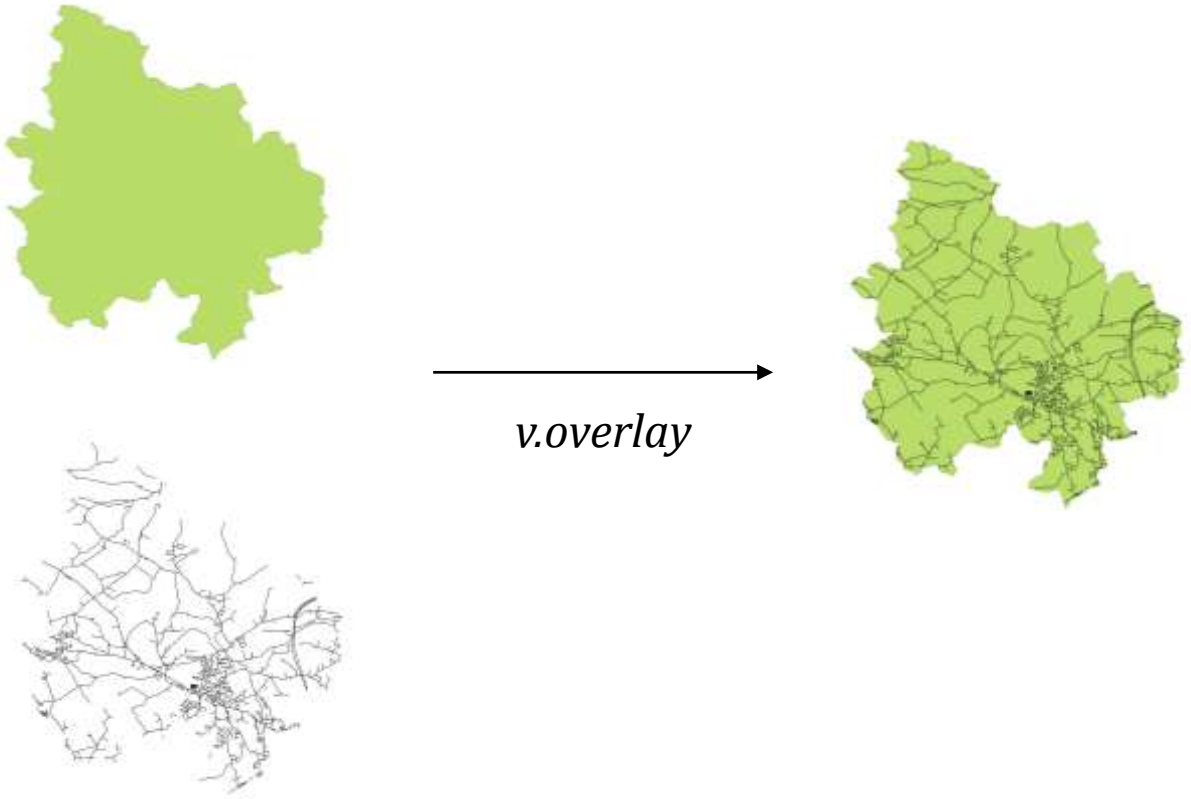
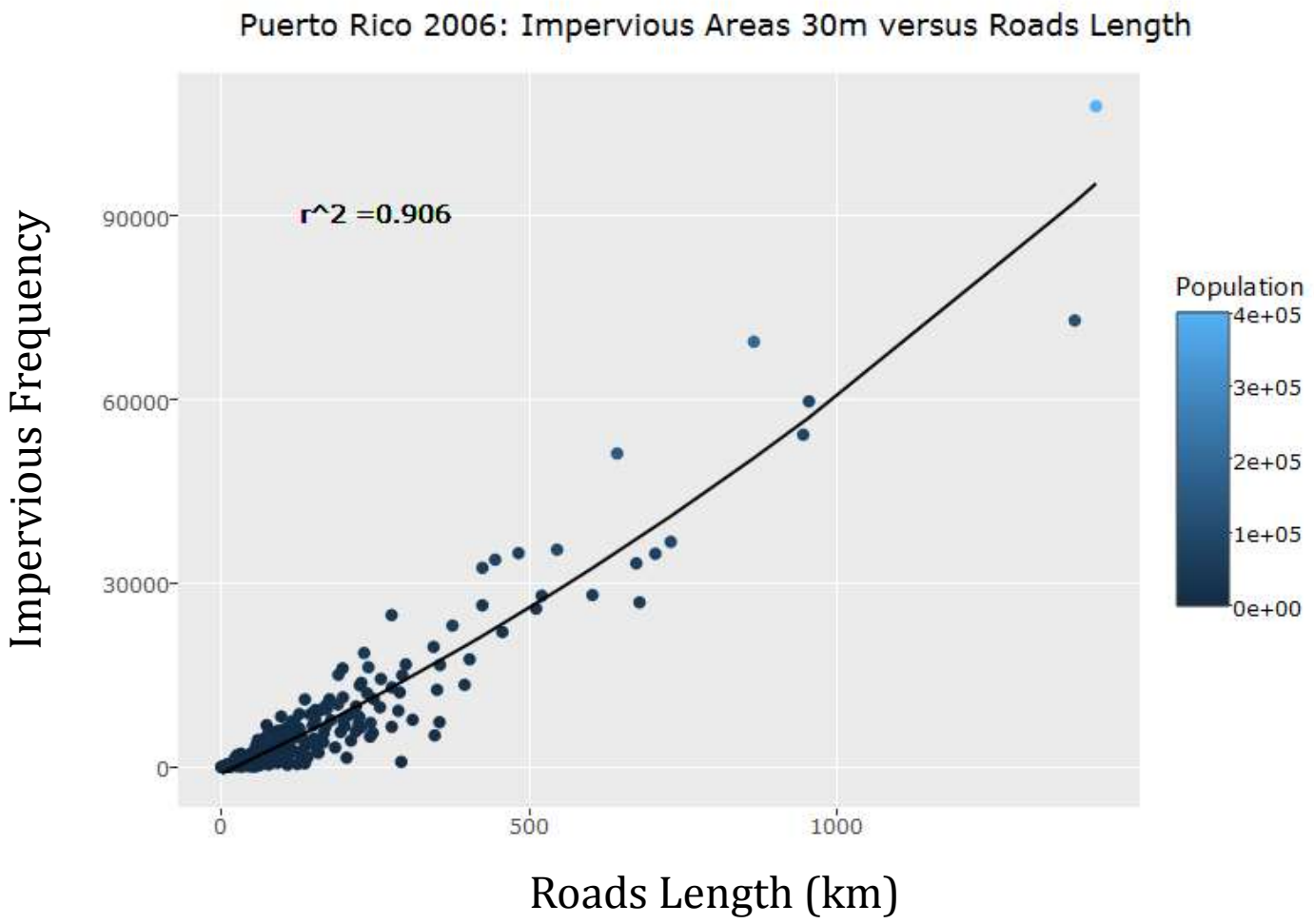


```
#PR impervious areas at 30m, Rlength and watersheds

library(dplyr)
library(sp)
library(raster)
library(rgdal)
library(rgeos)
library(rgrass7)

setwd("C:/AshleyR/Agosto2016/PR_GRASS")

#Out-of-GRASS working environment
loc <-initGRASS( gisBase = "C:/Program Files/GRASS GIS 7.0.4",
home = getwd(),gisDbase = "PR_GRASS_Imp30m", location = "PR_Imp30m",
override = TRUE)

#Change or establish working location
execGRASS("g.mapset", parameters = list(mapset = "PERMANENT",
location = "PR_Imp30m"))

#Modify location projection based on a georeferenced data file
execGRASS( "g.proj", flags = "c", parameters = list(georef = "C:/AshleyR/Agosto2016/PR_GRASS/PR_landcover_2001.tif"))

#Import raster of NLCD 2011
execGRASS("r.in.gdal", flags = "overwrite", parameters = list(input = "C:/AshleyR/Agosto2016/PR_GRASS/PR_landcover_2001.tif",
output = "PR_land_2001"))

#Retrieve raster information
execGRASS("r.info", parameters = list(map = "PR_land_2001"))

#Re-class raster values
execGRASS( "r.reclass", flags = c("overwrite"), parameters = list(input = "PR_land_2001", output = "PR_land_2001_reclass",
rules = "C:/AshleyR/Reclass_txt/pr_reclass.txt"))

#Retrieve reclassified raster information
execGRASS("r.info", parameters = list(map = "PR_land_2001_reclass"))

#Watersheds huc12 vector to GRASS
execGRASS( "v.in.ogr", flags = c("o", "overwrite"), parameters =
list(input = "C:/AshleyR/Agosto2016/PR_GRASS/Datasets/hydrologic_units/wbdhu12_a_pr.shp",
output = "PR_wds",snap = 1e-005, location = "PR_huc12_loc"))

#Roads 2006 vector to GRASS
execGRASS("v.in.ogr", flags = c("o", "overwrite"), parameters = list(input =
"C:/AshleyR/Agosto2016/PR_GRASS/Datasets/PR_Roads_2006_reclass/tiger_rds2006_reclass.shp", output = "PR_roads06", location = "PR_r06_loc"))
#Population 2000 census vector to GRASS
execGRASS("v.in.ogr", flags = c("o", "overwrite"),
parameters = list(input =
"//NSFGIS/Documents/Impervious-Ashley/Census_blocks/PR/Blocks_PR_2010.shp",
output = "PR_pop", location = "PR_pop_loc"))

#Establish working location
execGRASS("g.mapset", parameters = list(mapset = "PERMANENT",
location = "PR_Imp30m"))

#Reproject vectors to working location
execGRASS("v.proj", flags = "overwrite", parameters = list(
location = "PR_huc12_loc", mapset = "PERMANENT", input = "PR_wds",
output = "PR_wds_reproj"))

execGRASS( "v.proj", flags = "overwrite", parameters = list(
location = "PR_r06_loc", mapset = "PERMANENT", input = "PR_roads06",
output = "PR_roads06_reproj"))

execGRASS( "v.proj", flags = "overwrite", parameters = list(
location = "PR_pop00_loc", mapset = "PERMANENT", input = "PR_pop00",
output = "PR_pop00_reproj"))

#Get vectors and raster info
execGRASS("v.info", parameters = list(map = "PR_wds_reproj"))
execGRASS("v.info", parameters = list(map = "PR_roads06_reproj"))
execGRASS("r.info", parameters = list(map = "PR_land_2001_reclass"))

#Determine frequency of impervious areas
system.time(execGRASS("v.rast.stats", flags = c("verbose", "c"),
parameters = list(map = "PR_wds_reproj", raster = "PR_land_2001_reclass", column_prefix = "ImpFreq", method = "sum")))

#See vector header
execGRASS("v.db.select", parameters = list(map = "PR_wds_reproj",
where = "cat =1"))

#Vector from GRASS to R
PRImpWds <- readVECT("PR_wds_reproj")

#GRASS roads-wds intersection function
system.time(execGRASS( "v.overlay", flags = "overwrite", parameters = list(
ainput = "PR_roads06_reproj", atype = "line", binput = "PR_wds_reproj",
btype = "area",operator = "and", output = "PRwds_roads_int_06")))

#Add Rlength column to new intersection vector
execGRASS( "v.db.addcolumn", parameters = list(map = "PRwds_roads_int_06",
columns = "Rlength double precision"))


#Update vector database with line length by id
execGRASS("v.to.db", parameters = list( map = "PRwds_roads_int_06",
type = "line", option = "length", columns = "Rlength", units = "meters"))

#Vector from GRASS to R
PRRoads06Int <- readVECT("PRwds_roads_int_06")

#Aggregate of line length by TNMID
road06sag <- aggregate(Rlength ~ b_TNMID, PRRoads06Int@data, sum)

#Merge roads length shapefile with impervious data shapefile
PRImpRoads <- merge(PRImpWds, road06sag, by.x = "TNMID", by.y = "b_TNMID")

PRdata <- PRImpRoads@data
PRdata <- subset.data.frame(PRdata,
select = c(TNMID, AREAACRES, AREASQKM, NAME, ImpFreq_sum, Rlength), drop = T)

PRdata$Rlength[is.na(PRdata$Rlength)] <- 0
PRdata$ImpFreq_sum[is.na(PRdata$ImpFreq_sum)] <- 0


#GRASS Population-hexagons intersection function
system.time(execGRASS("v.overlay", flags = "overwrite",
parameters = list(ainput = "PRHexReproj", atype = "area",
binput = "PRPopReproj", btype = "area", operator = "and",
output ="PRhex_pop_int_2010")))

#Add column to new vector
execGRASS("v.db.addcolumn", parameters = list(map = "PRhex_pop_int_2010",
columns ="NewArea double precision"))

#See vector header
execGRASS("v.db.select", parameters = list(map = "PRhex_pop_int_2010",
where = "cat = 1"))

#Calculate new area from intersection
execGRASS("v.to.db", parameters = list( map = "PRhex_pop_int_2010",
type = "boundary", option = "area", columns = "NewArea", units = "meters"))

#Add PropArea column
execGRASS("v.db.addcolumn", parameters = list(map = "PRhex_pop_int_2010",
columns = "PropArea double precision"))

#Calculate PropArea
execGRASS("v.db.update", parameters = list( map = "PRhex_pop_int_2010", column = "PropArea", query_column = "NewArea/b_BlockArea"))

#Add PropPop column
execGRASS("v.db.addcolumn", parameters = list(map = "PRhex_pop_int_2010",
columns = "PropPop double precision"))

#Calculate PropPop
execGRASS( "v.db.update", parameters = list( map = "PRhex_pop_int_2010", column = "PropPop", query_column = "PropArea*b_POP2010"))

#Save OGRs
writeOGR(PRImpwds,"C:/AshleyR/Agosto2016/PR_GRASS", "PR_Wds_Imp30m", "ESRI Shapefile")
writeOGR(PRRoads06, "C:/AshleyR/Agosto2016/PR_GRASS", "PR_Roads_06_GRASS", "ESRI Shapefile")
```

# Results

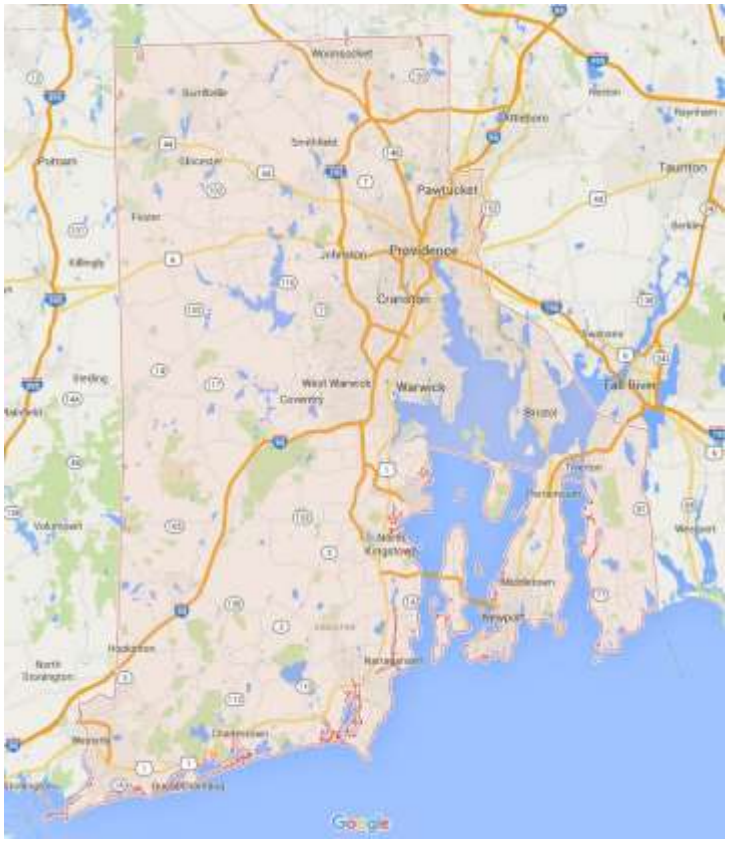

Puerto Rico 2006: Impervious Areas 30m versus Roads Length
r^2 =0.906
Impervious Frequency
90000
60000
30000
0
0
500
1000
Roads Length (km)
Population
4e+05
3e+05
2e+05
1e+05
0e+00

# Further analysis

- What happens when a land cover with better resolution is used?

- **Rhode Island**
  - North-east of United States
  - Area = 3,140 $km^2$

- **Why Rhode Island?**
  - Impervious data resolution (30m and 0.6 m)
  - Comparable area



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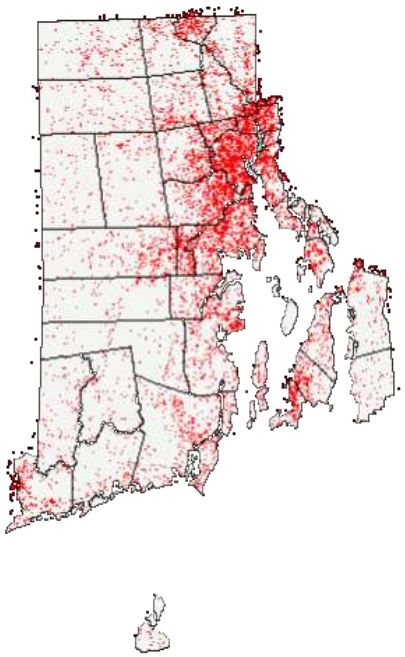
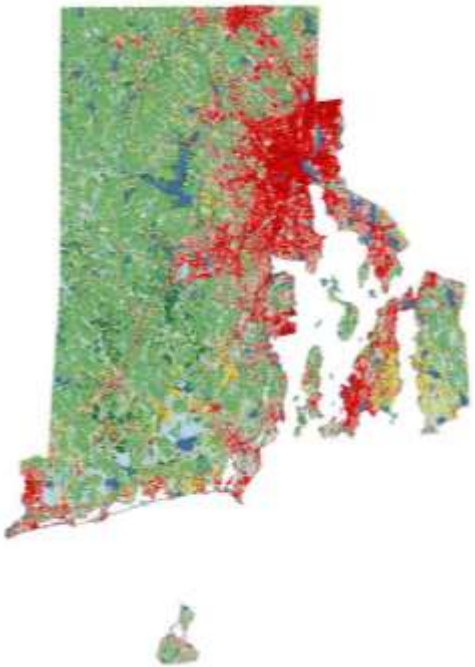
- **Rhode Island**



0.6 m – Resolution Raster
(2011)



30 m – Resolution Raster
(2011)

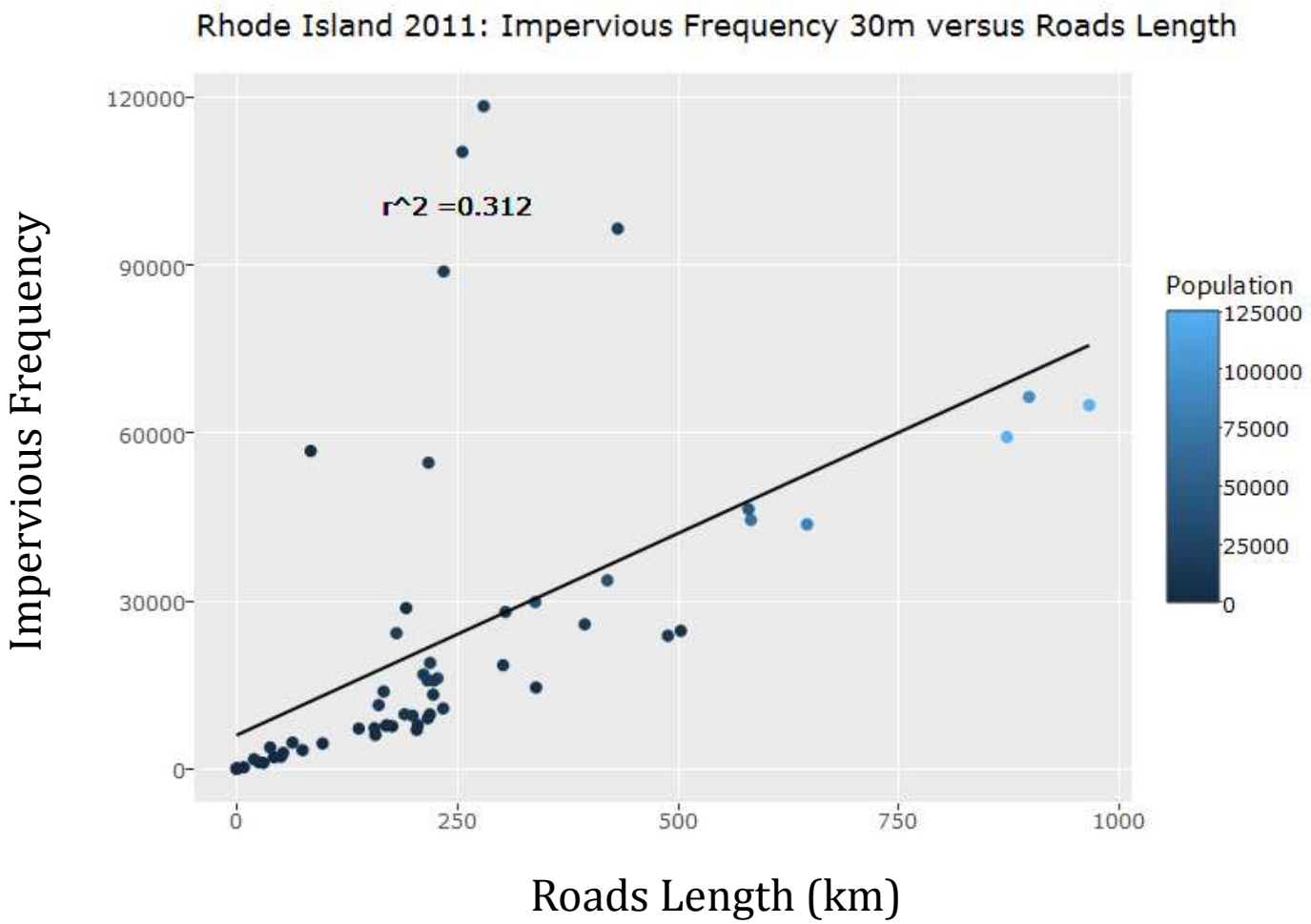
# Further analysis

- **Rhode Island**

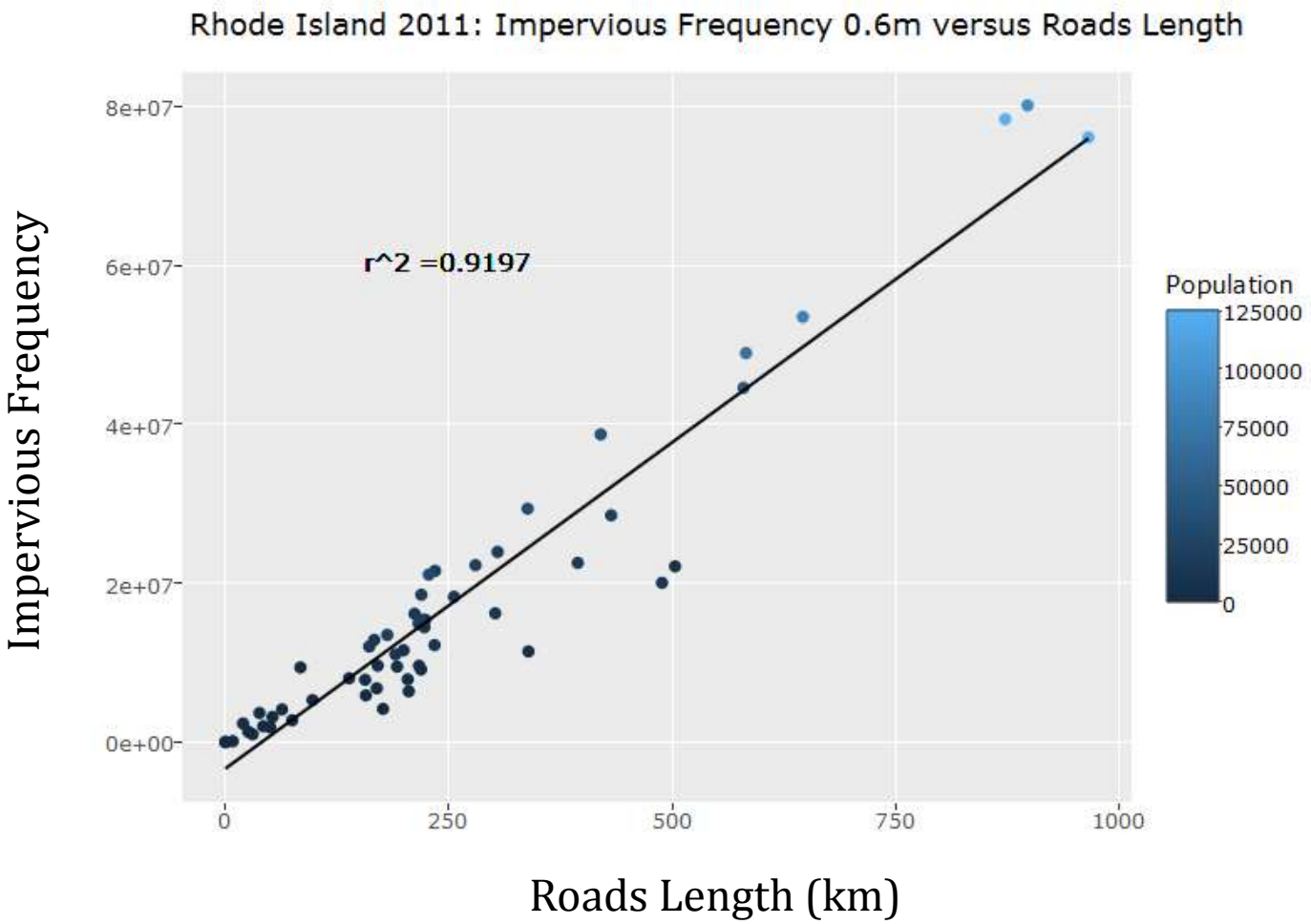
TIGER/lines
(2011)

Watershed boundaries

# Further analysis - Results



# Further analysis - Results



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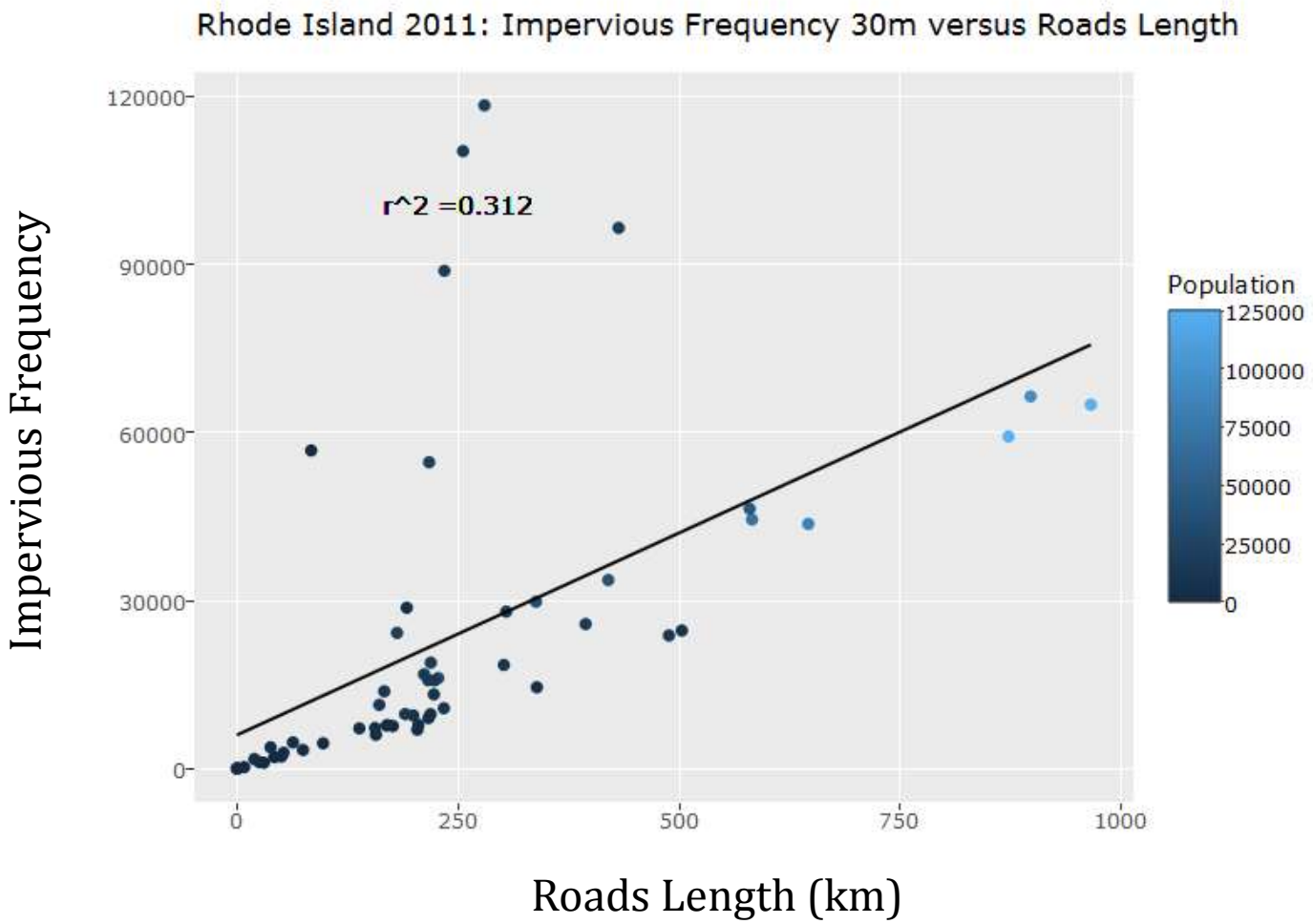
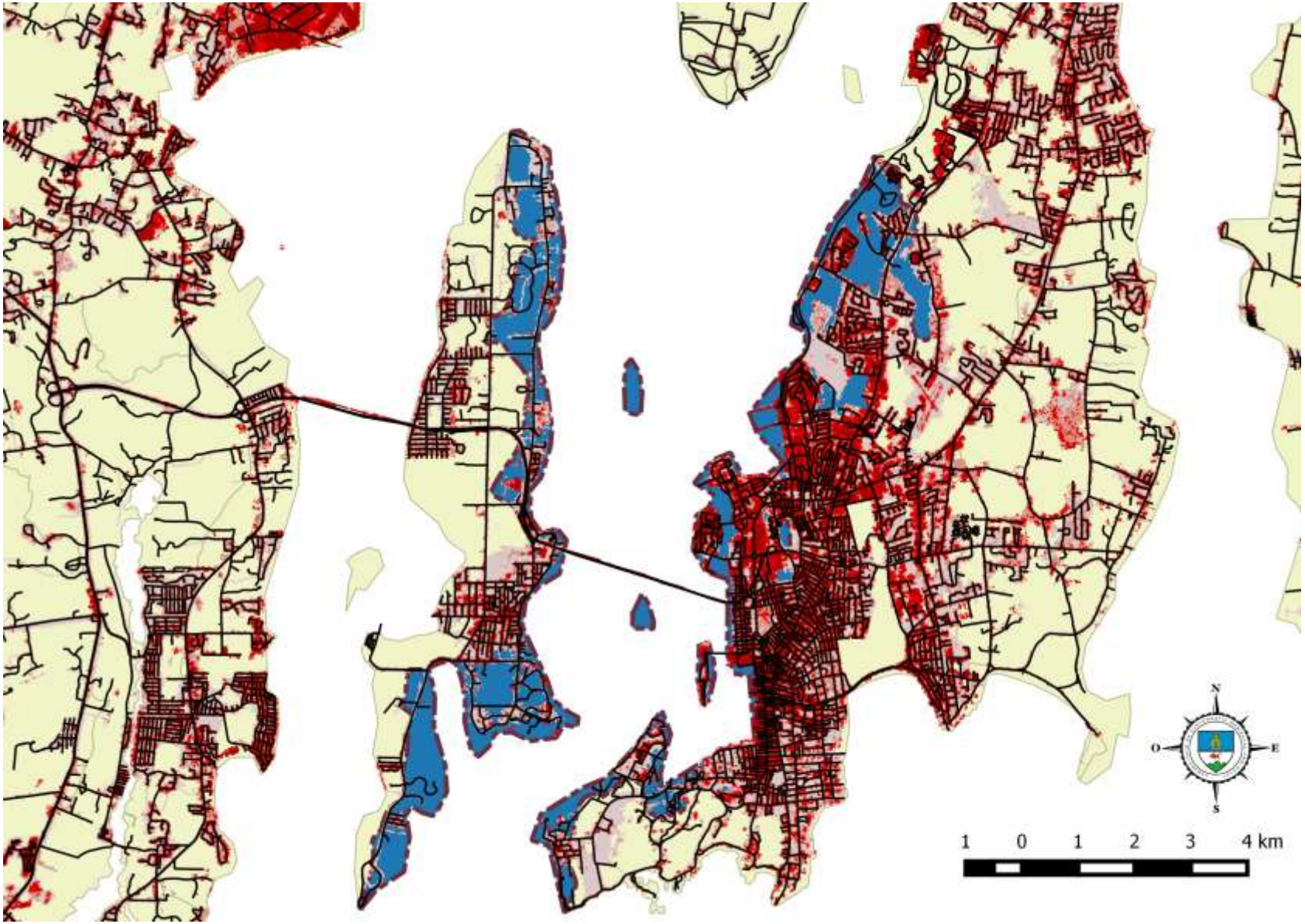
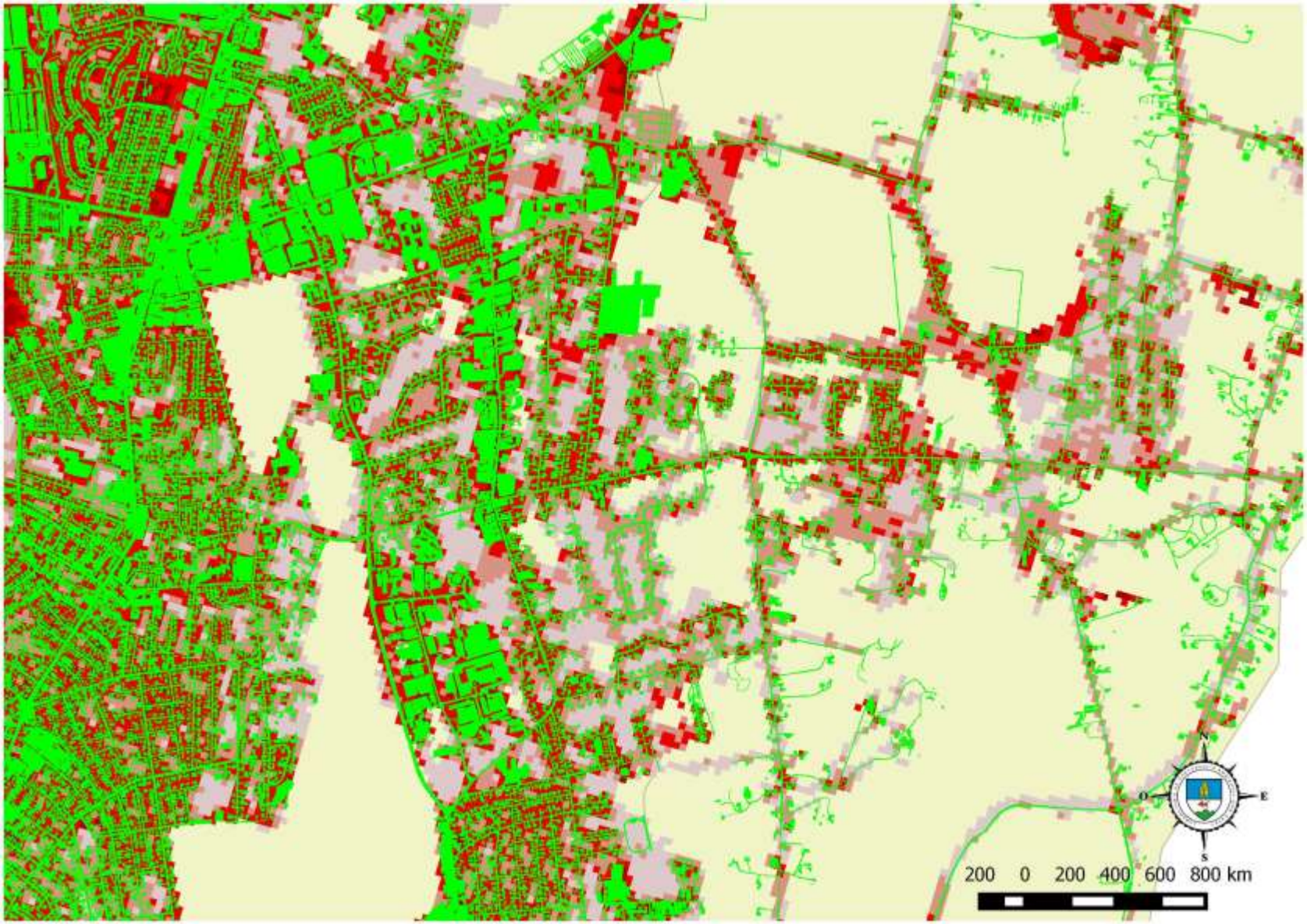





Jamestown and Newport, RI




Newport, RI

# Conclusions

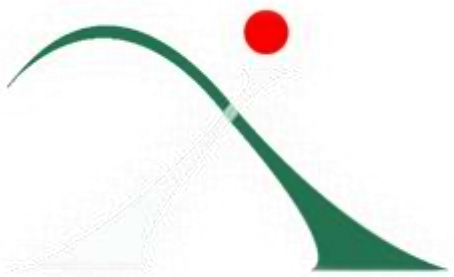
The available impervious data layers are not useful for detailed analysis.

A better resolution raster dataset help us accomplish an accurate assessment of the correlation of impervious areas and roads' length in the watersheds of Rhode Island.

It is demonstrated that roads can be used as a predictor of imperviousness of an area notwithstanding the area of study.

# Acknowledgements

Dr. Javier A. Arce, Ph.D.
Arce's Laboratory Group





NSF Career BCS 1151458
NIH NIMHD 1P20MD006144-01

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