A Geostatistical Approach for an Optimal Planning of a Regional RWIS Network

By

Tae J. Kwon, PhD

Assistant Professor,

Department of Civil and Environmental Engineering,

University of Alberta

Authors: Simita Bisawas[1], Tae J. Kwon[1], and Liping Fu[2]

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WINTER WEATHER CAN BE HARSH AS IT AFFECTS…

MOBILITY

SAFETY

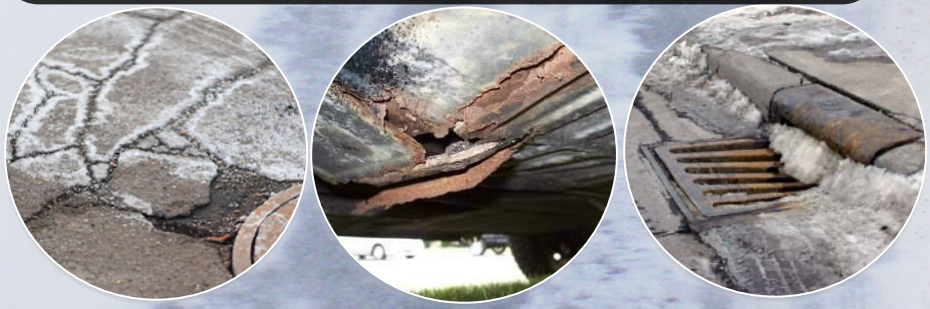
Weather-related Collision Costs

$1 billion annually

SNOW AND ICE CONTROL IN ACTION

Winter Road Maintenance Costs
$1.1 billion annually

Salt Applications
5 million tonnes annually



ONE POSSIBLE SOLUTION…

Road Weather Information System (RWIS)

RWIS stations are costly and many gaps still exist...

Improve Safety & Mobility

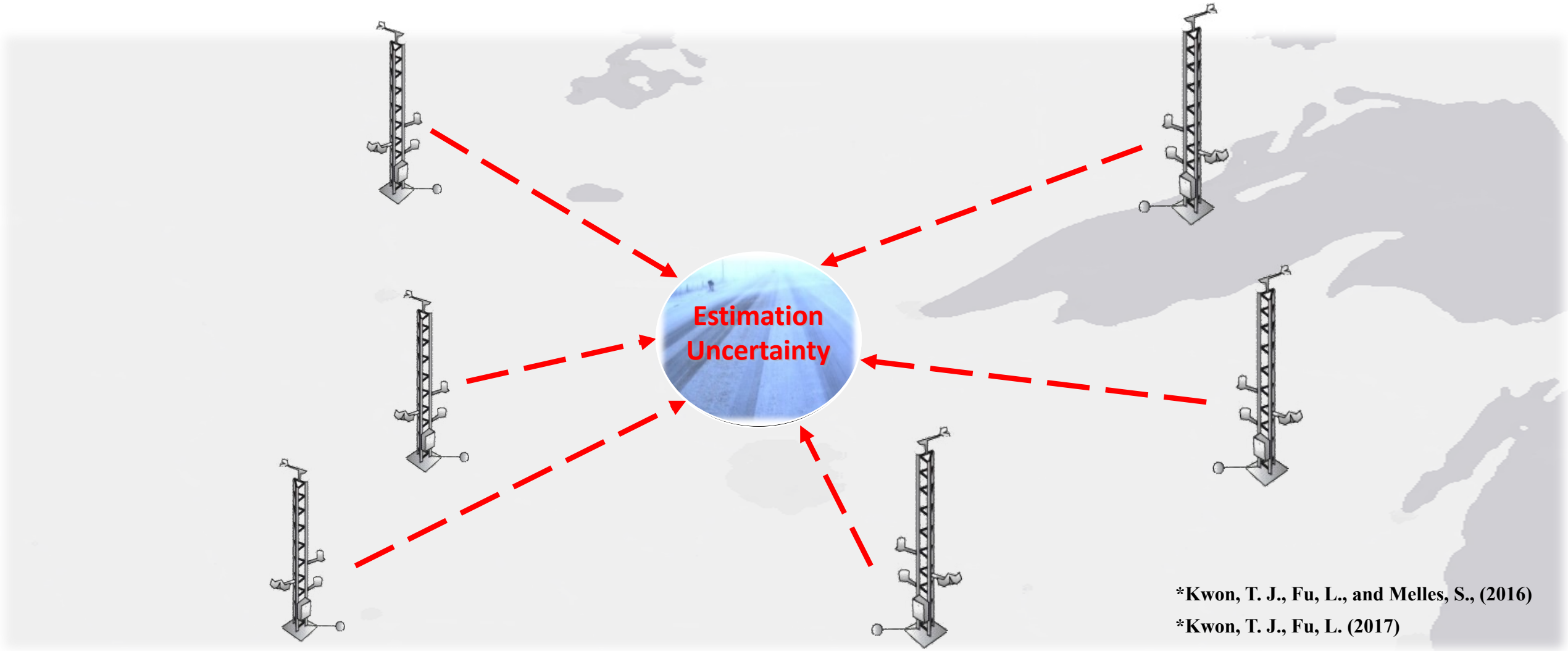
Reduce WRM Cost

AN IMPORTANT QUESTION

Where should we locate RWIS stations?

THE CORE IDEA - OPTIMAL LOCATION

*SPATIAL INFERENCE BASED APPROACH USING KRIGING**



*Kwon, T. J., Fu, L., and Melles, S., (2016)

*Kwon, T. J., Fu, L. (2017)

Application: Alternate Planning Scenarios

Scenario 1: All-new optimal RWIS network

For evaluating the location quality of the current RWIS network

Scenario 2: Expansion of current RWIS network

For determining the location for additional RWIS stations

OPTIMIZATION IN ACTION – AN EXAMPLE

Ontario_density.R* | optimizeON_RWIS_Dual_UK (1).R

```
hist(PtsAvg$AvgHRSC, breaks=15, xlab = "Road conditions", main = paste("Histogram of avg. road conditions"))

smplvarAvg.OK = variogram(AvgTemp ~ 1, PtsAvg)
plot(smplvarAvg.OK, pch = 19)

vfitOK = fit.variogram(variogram(AvgTemp ~ 1, PtsAvg), vgm(0.5, "Gau", 79618, nugget = 0.2))
plot(smplvarAvg.OK, vfitOK, pch = 19)

### Empty RWIS  ###
PtsEmpty <- readShapePoints('Empty_ON_RWIS.shp')
names(PtsEmpty@data)
names(PtsEmpty@data)<-c("y", "x", "AvgSurfEmpty")

### Current RWIS Network ###
PtsCurrent <- readShapePoints('140_RWIS.shp')
names(PtsCurrent@data)
names(PtsCurrent@data)<-c("ID", "y", "x","AvgValCurrent")


######        Functions       ############s
```

Console C:/Users/Tae/Dropbox/Spatiotemporal_variability/GIS_Layers/

```
Error in hist.default(PtsAvg$AvgHRSC, breaks = 15, xlab = "Road conditions",  :
  'x' must be numeric
>
> smplvarAvg.OK = variogram(AvgTemp ~ 1, PtsAvg)
> plot(smplvarAvg.OK, pch = 19)
>
> vfitOK = fit.variogram(variogram(AvgTemp ~ 1, PtsAvg), vgm(0.5, "Gau", 79618, nugget = 0.2))
> plot(smplvarAvg.OK, vfitOK, pch = 19)
>
> ### Empty RWIS  ###
> PtsEmpty <- readShapePoints('Empty_ON_RWIS.shp')
> names(PtsEmpty@data)
[1] "Lat"      "Long"     "NovHRSC"
> names(PtsEmpty@data)<-c("y", "x", "AvgSurfEmpty")
>
> ### Current RWIS Network ###
> PtsCurrent <- readShapePoints('140_RWIS.shp')
> names(PtsCurrent@data)
[1] "ID"     "Lat"    "Long"   "AvgVal"
> names(PtsCurrent@data)<-c("ID", "y", "x","AvgValCurrent")
> ON_State_density_stn1 <- optimizeNetwork(PtsEmpty, Preds, candidates=SA,
+                                          method="ssa", action="add", nDiff=100, model=vfitOK, criterion="MUKV",
+                                          nr_iterations=10000, formulaString = AvgSurfEmpty  ~ x+y)
[using universal kriging]
[using universal kriging]
Searching for an improved fitness value for 1
[Terminating SSA 200 iterations with no improvement]
[using universal kriging]
Searching for an improved fitness value for 2
[Terminating SSA 200 iterations with no improvement]
[using universal kriging]
Searching for an improved fitness value for 3 p =  0.1942423 lim =  0.1994009[Terminating SSA 200 iterations with no
 improvement]
```

Environment | History

```
names(PtsAvg@data)
proj4string(SA) <- CRS("+init=epsg:26917")
proj4string(PtsAvg) <- CRS("+init=epsg:26917")
proj4string(Preds) <- CRS("+init=epsg:26917")
hist(PtsAvg$AvgHRSC, breaks=15, xlab = "Road conditions", main = paste("Histogram of avg. road conditions"))
smplvarAvg.OK = variogram(AvgTemp ~ 1, PtsAvg)
plot(smplvarAvg.OK, pch = 19)
vfitOK = fit.variogram(variogram(AvgTemp ~ 1, PtsAvg), vgm(0.5, "Gau", 79618, nugget = 0.2))
plot(smplvarAvg.OK, vfitOK, pch = 19)
### Empty RWIS ###
PtsEmpty <- readShapePoints('Empty_ON_RWIS.shp')
names(PtsEmpty@data)
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### Current RWIS Network ###
PtsCurrent <- readShapePoints('140_RWIS.shp')
names(PtsCurrent@data)
names(PtsCurrent@data)<-c("ID", "y", "x","AvgValCurrent")
ON_State_density_stn1 <- optimizeNetwork(PtsEmpty, Preds, candidates=SA,
method="ssa", action="add", nDiff=100, model=vfitOK, criterion="MUKV",
nr_iterations=10000, formulaString = AvgSurfEmpty ~ x+y)
```
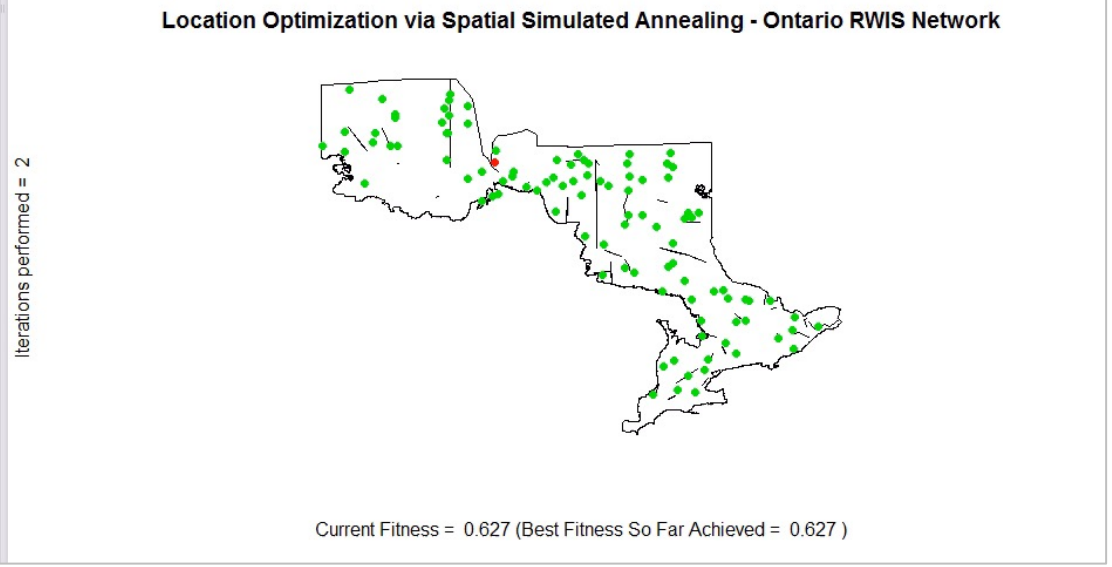

Files | Plots | Packages | Help | Viewer

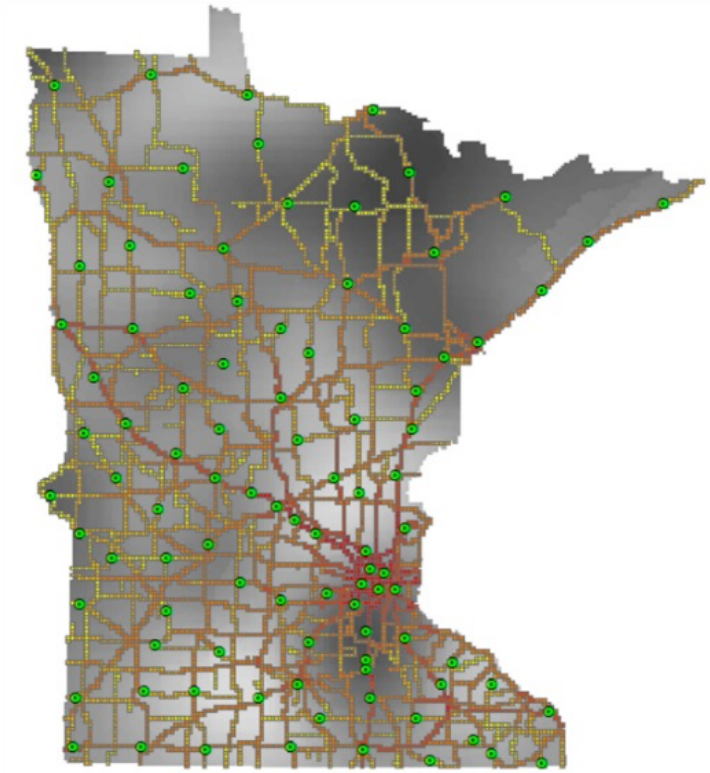


SOLUTIONS GENERATED*

Scenario 1:

All-new RWIS network

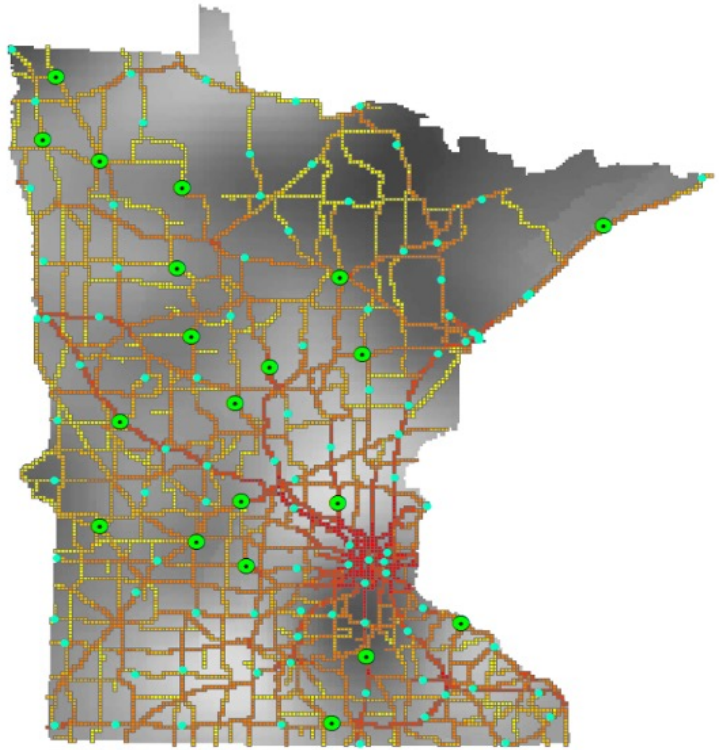
Minnesota Case



Scenario 2:

Expansion of RWIS network

Minnesota Case



***Kwon, T. J., Fu, L. (2017)** ***Kwon, T. J., Fu, L., and Melles, S., (2016)**

TESTIMONY FROM MINNESOTA DOT

Jakin Koll, Mn/DOT Director of MDSS & Road/Weather Forecasting Coordinator

ANOTHER IMPORTANT QUESTION

How many RWIS stations should we deploy?

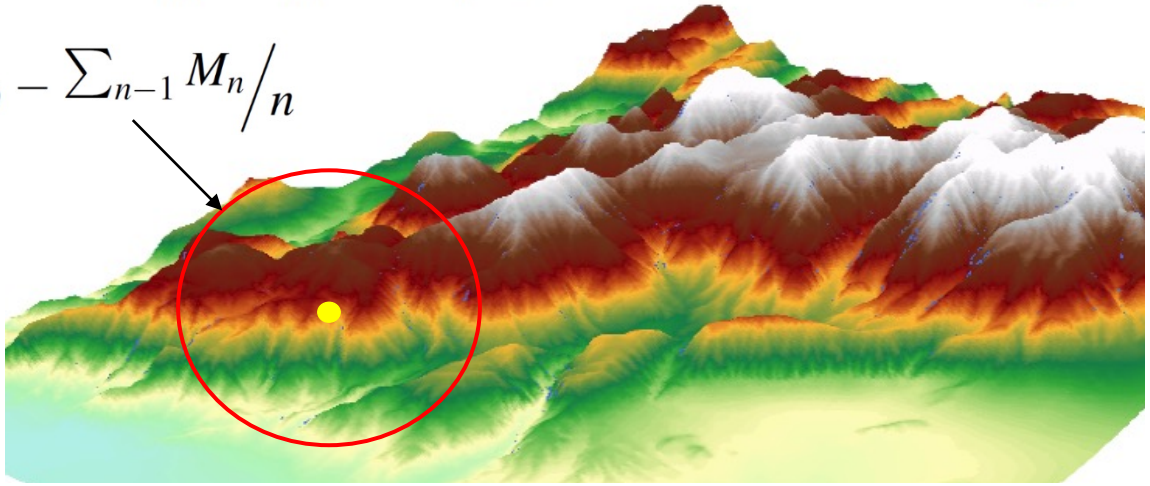
Hypothesis

Number of RWIS required may depend on topographic characteristics of regions

TOPOGRAPHY BASED ANALYSIS

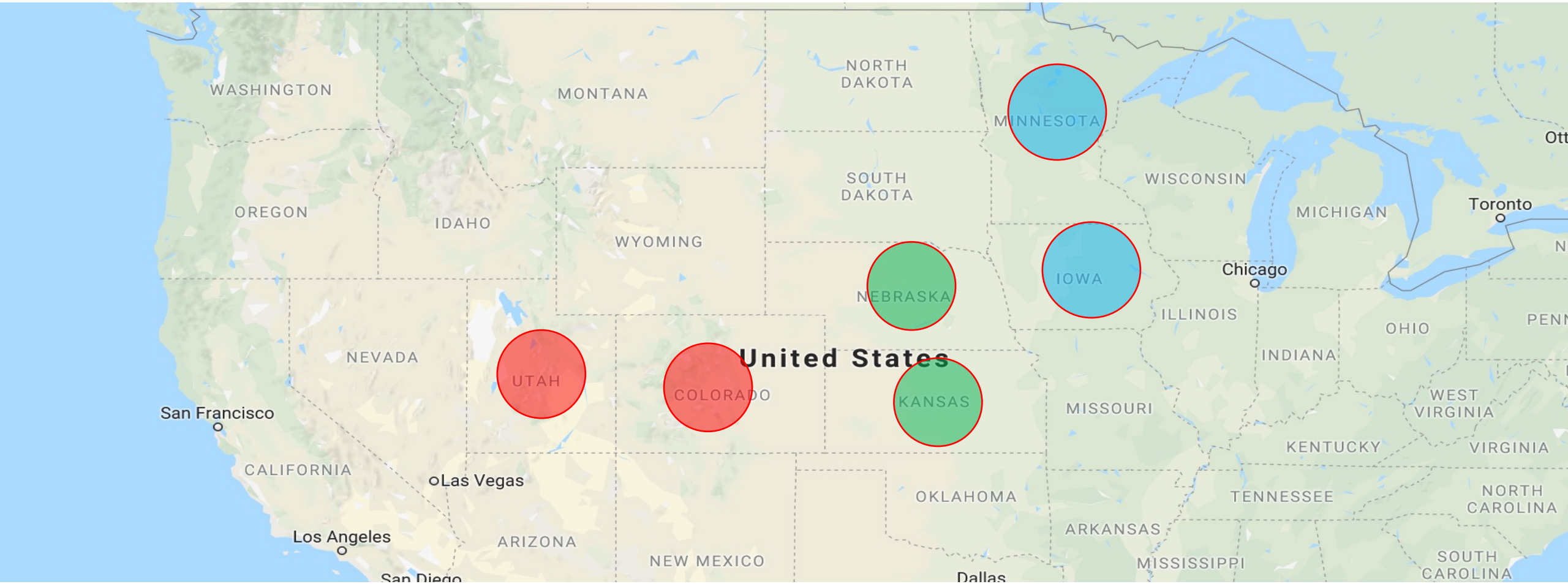
- Topographic Position Index (TPI)
- Difference between a cell elevation value and the average elevation of the neighborhood around that cell

$$TPI_i = M_0 - \sum_{n-1} M_n / n$$

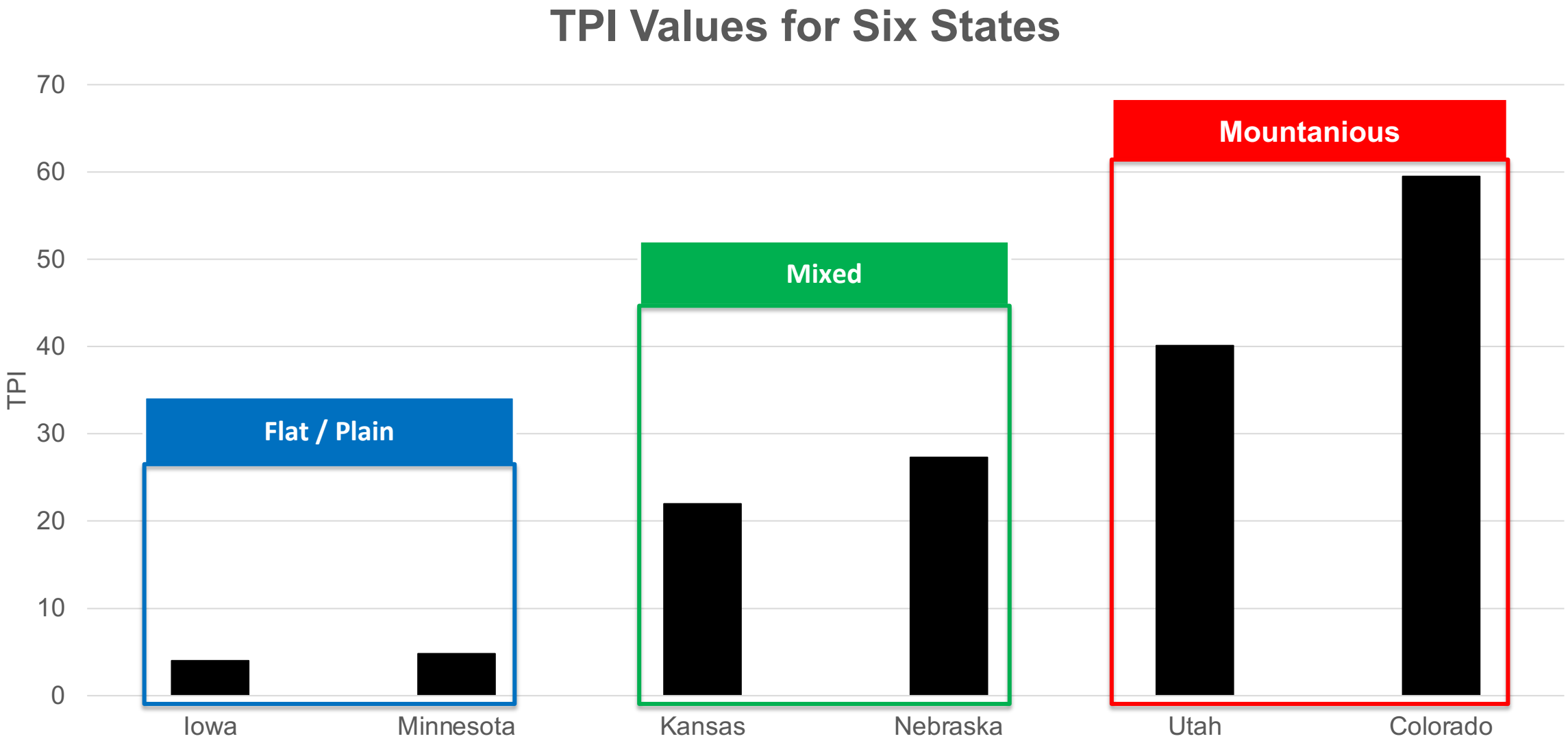


Category
Flat/Plain (TPI < 10)
Hilly (10 < TPI < 30)
Mountainous (TPI > 30)

Case Studies

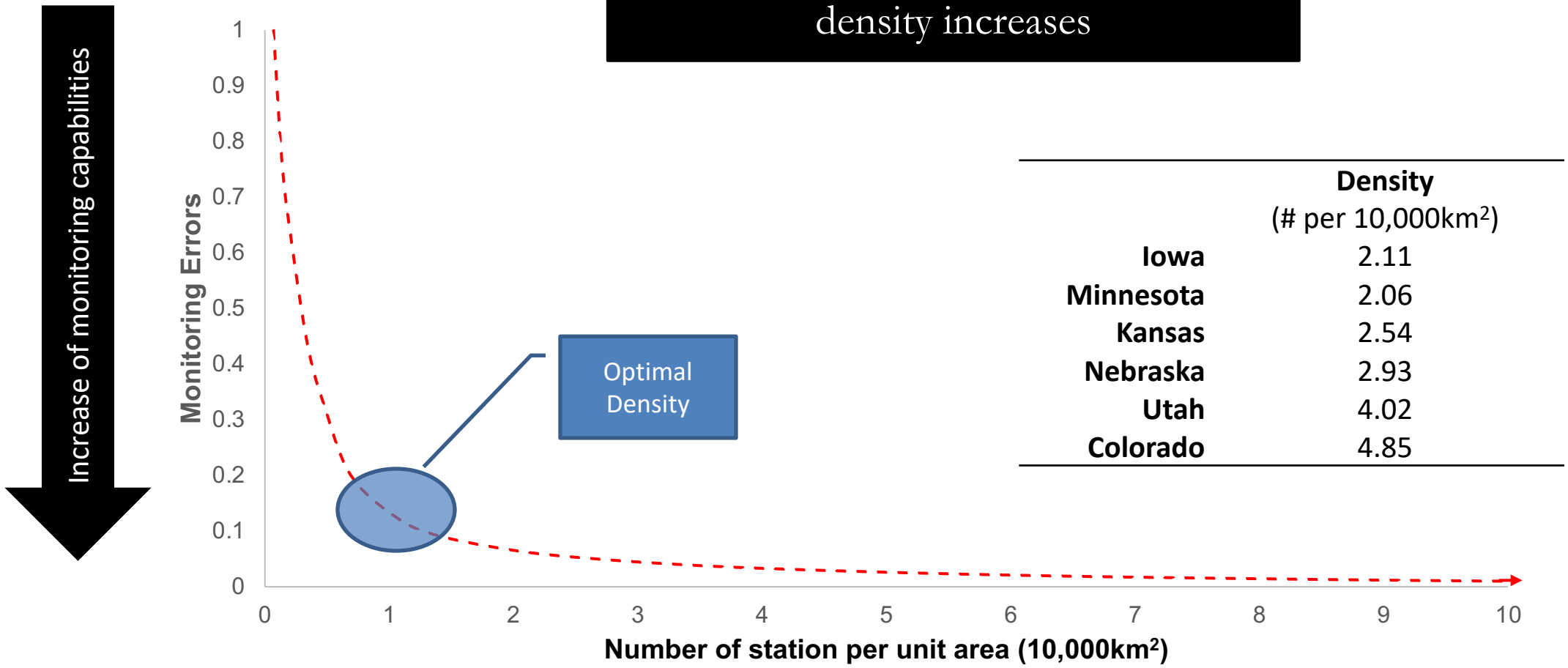


TPI BASED CLASSIFICATION



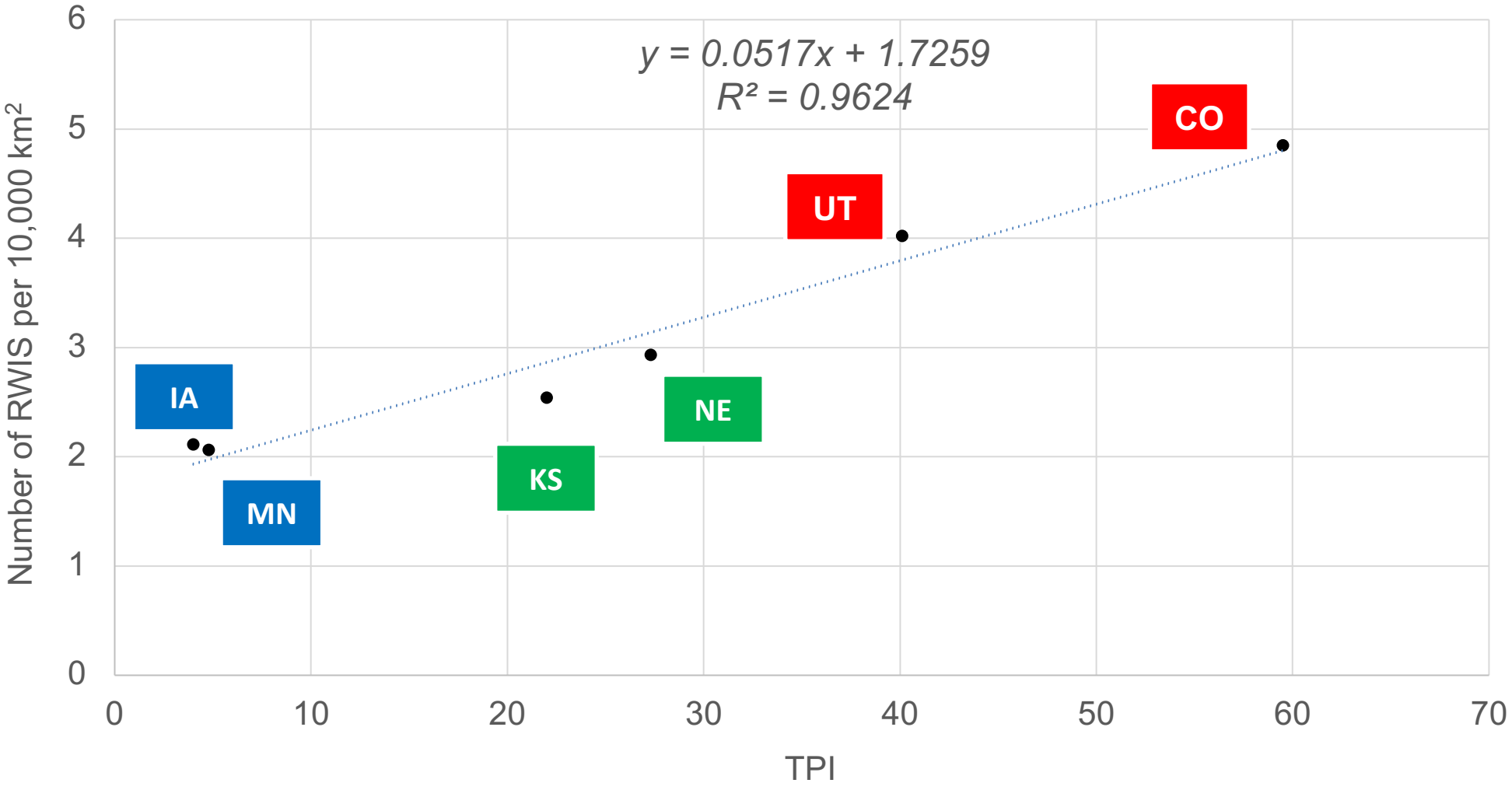
RWIS DENSITY ANALYSIS CHART

Marginal benefits decrease as the density increases



	Density (# per 10,000km²)
Iowa	2.11
Minnesota	2.06
Kansas	2.54
Nebraska	2.93
Utah	4.02
Colorado	4.85

TPI vs. DENSITY (per 10,000km^2)

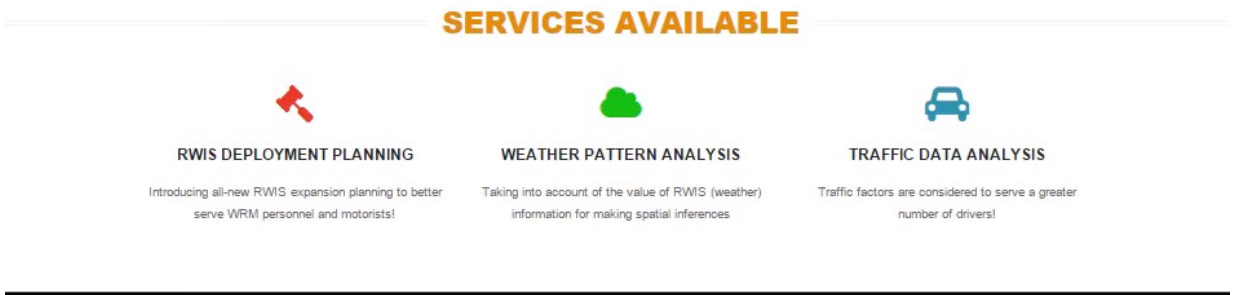


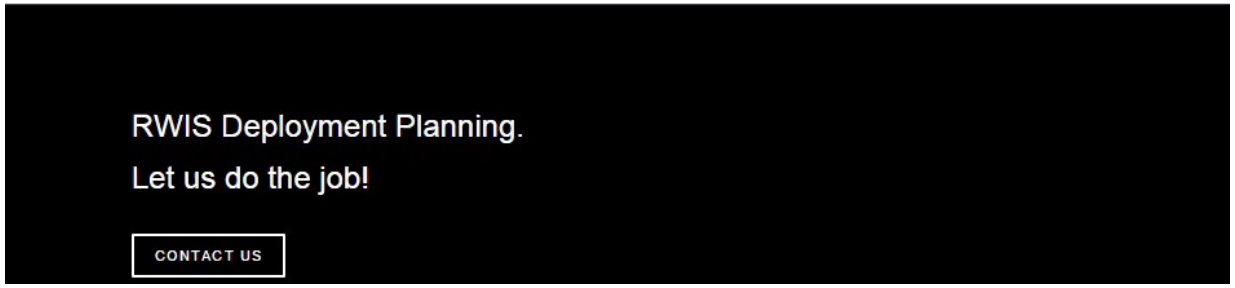
NEXT STEP

More case studies are currently underway…

DEMO

https//www.LoRWIS.com





ACKNOWLEDGMENTS

For more information:
http://www.taejnkwon.com

Thank you!