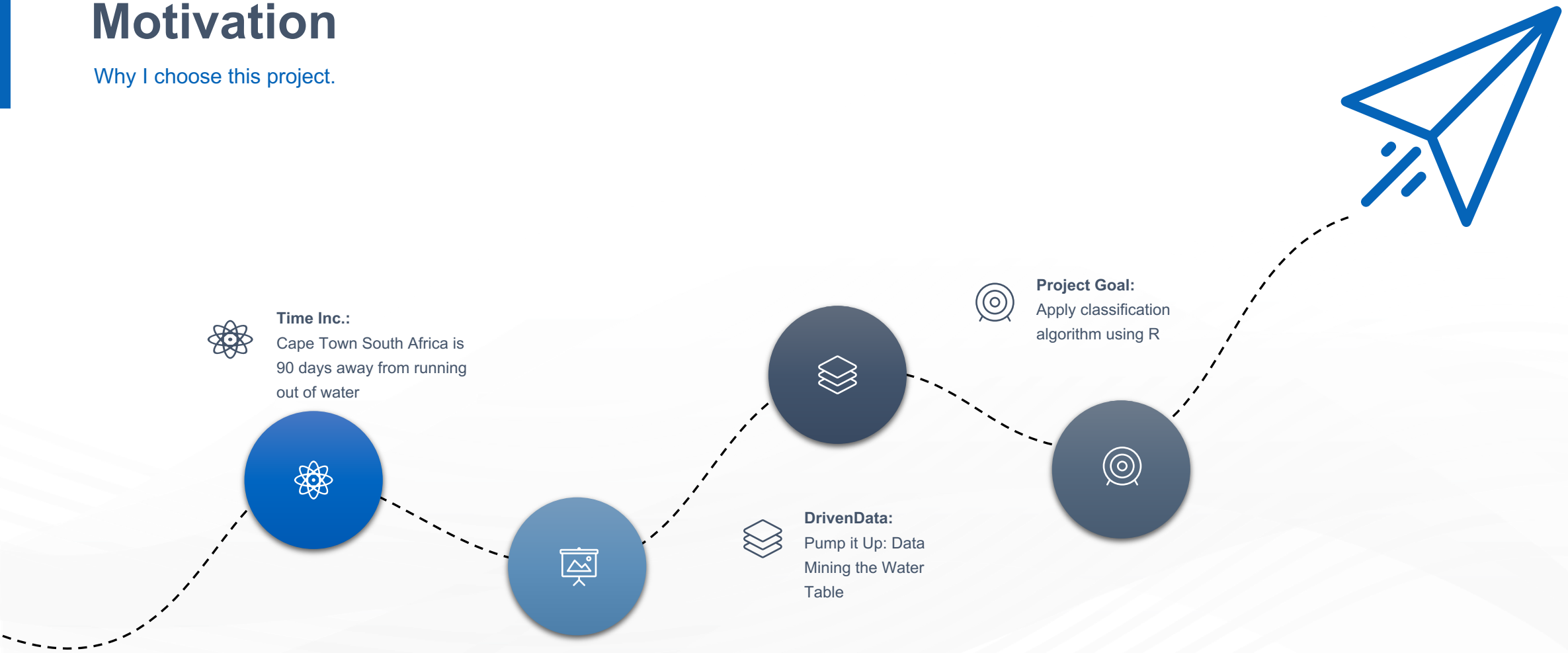
Tanzania.

Predicting the Operational Status of Water Pumps by Thomas Skowronek

Motivation

Why I choose this project.



Time Inc.:
Cape Town South Africa is 90 days away from running out of water

Home State of Michigan:
5 great lakes and 11K inland lakes > 5 acres

DrivenData:
Pump it Up: Data Mining the Water Table

Project Goal:
Apply classification algorithm using R

Tanzania

A brief overview.

Population

53,470,000

Land Area

945,087 km²

Poverty

47% of the population

Approximately 12 million in extreme poverty

Water

27 million people lack access to safe water

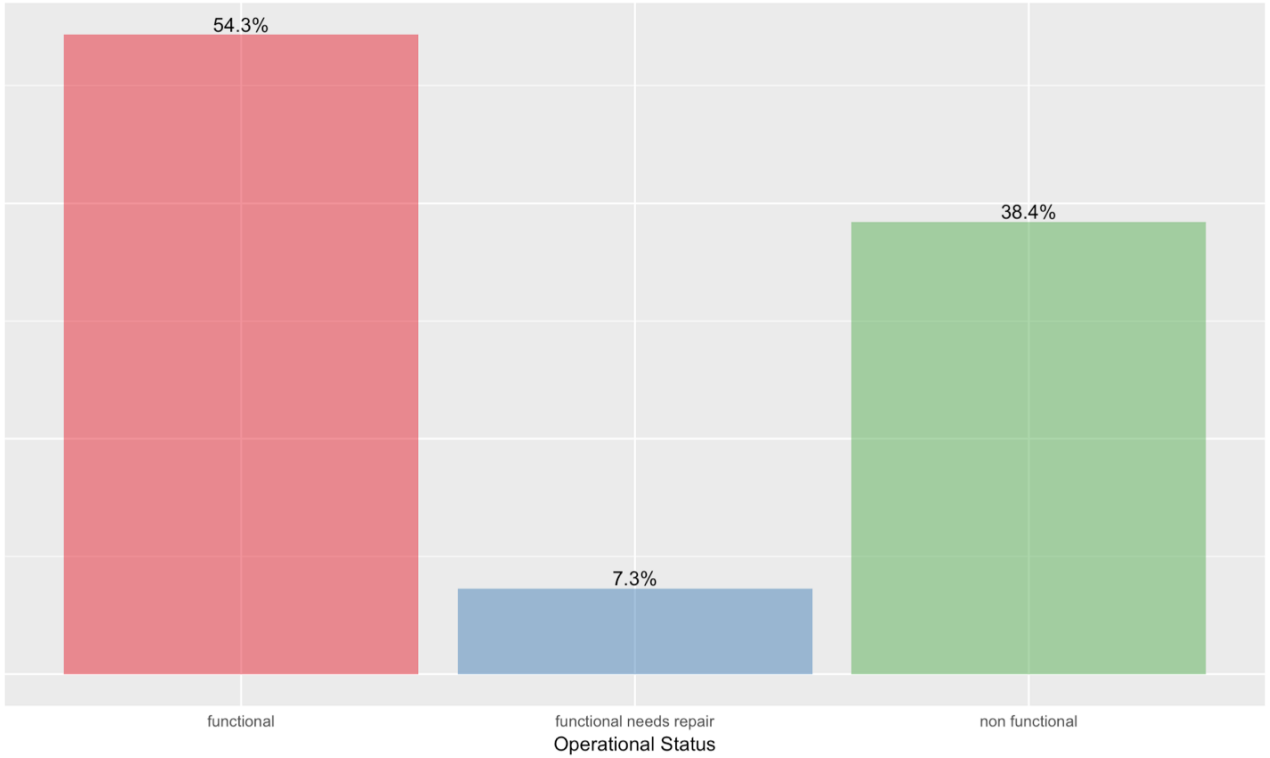
The Data

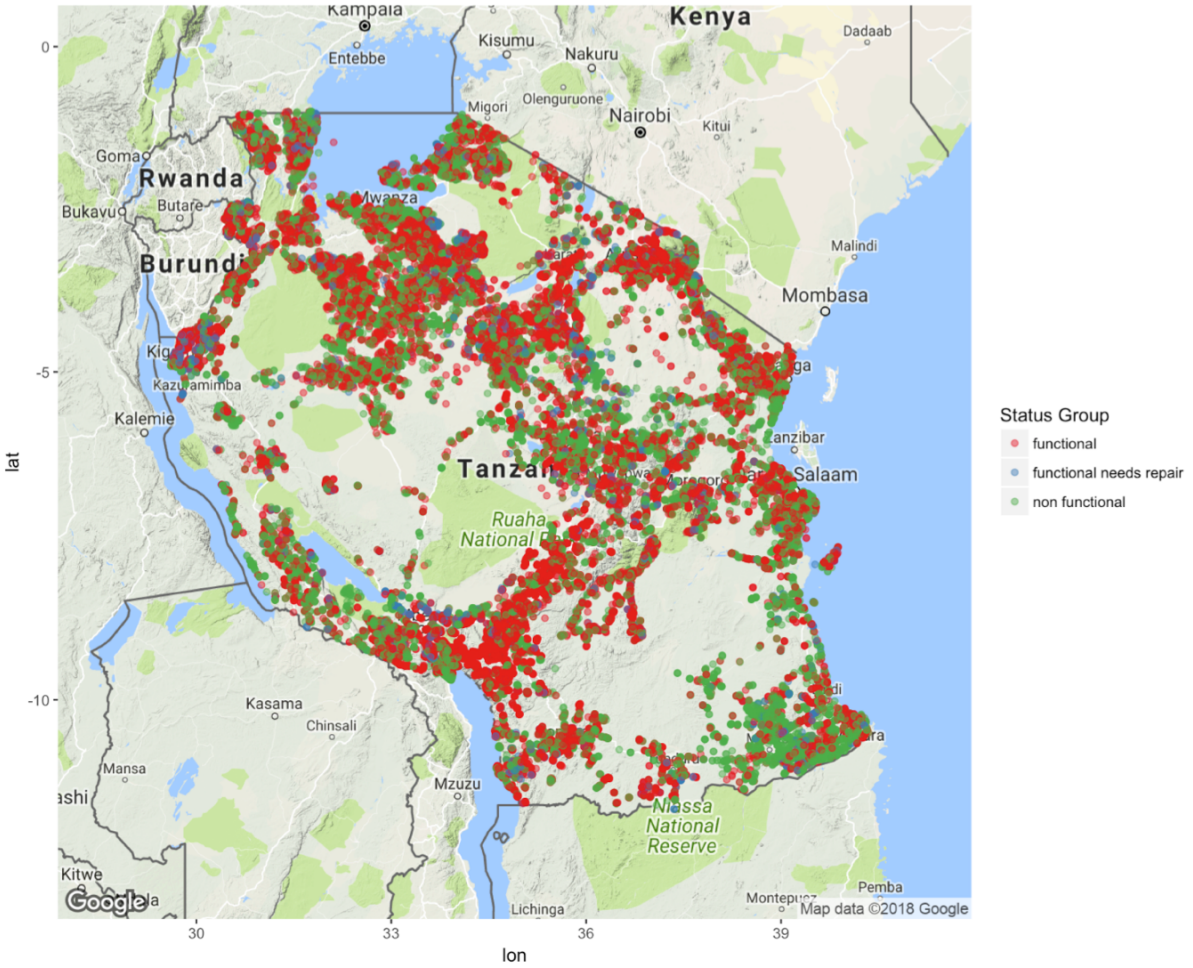
59,400 observations, 39 predictor variables & 1 response variable

`amount_tsh` - Total static head (amount water available to waterpoint)
`date_recorded` - The date the row was entered
`funder` - Who funded the well
`gps_height` - Altitude of the well
`installer` - Organization that installed the well
`longitude` - GPS coordinate
`latitude` - GPS coordinate
`wpt_name` - Name of the waterpoint if there is one
`num_private` -
`basin` - Geographic water basin
`subvillage` - Geographic location
`region` - Geographic location
`region_code` - Geographic location (coded)
`district_code` - Geographic location (coded)
`lga` - Geographic location
`ward` - Geographic location
`population` - Population around the well
`public_meeting` - True/False
`recorded_by` - Group entering this row of data
`scheme_management` - Who operates the waterpoint
`scheme_name` - Who operates the waterpoint
`permit` - If the waterpoint is permitted
`construction_year` - Year the waterpoint was constructed
`extraction_type` - The kind of extraction the waterpoint uses
`extraction_type_group` - The kind of extraction the waterpoint uses
`extraction_type_class` - The kind of extraction the waterpoint uses
`management` - How the waterpoint is managed
`management_group` - How the waterpoint is managed
`payment` - What the water costs
`payment_type` - What the water costs
`water_quality` - The quality of the water
`quality_group` - The quality of the water
`quantity` - The quantity of water
`quantity_group` - The quantity of water
`source` - The source of the water
`source_type` - The source of the water
`source_class` - The source of the water
`waterpoint_type` - The kind of waterpoint
`waterpoint_type_group` - The kind of waterpoint

Pump Status Group

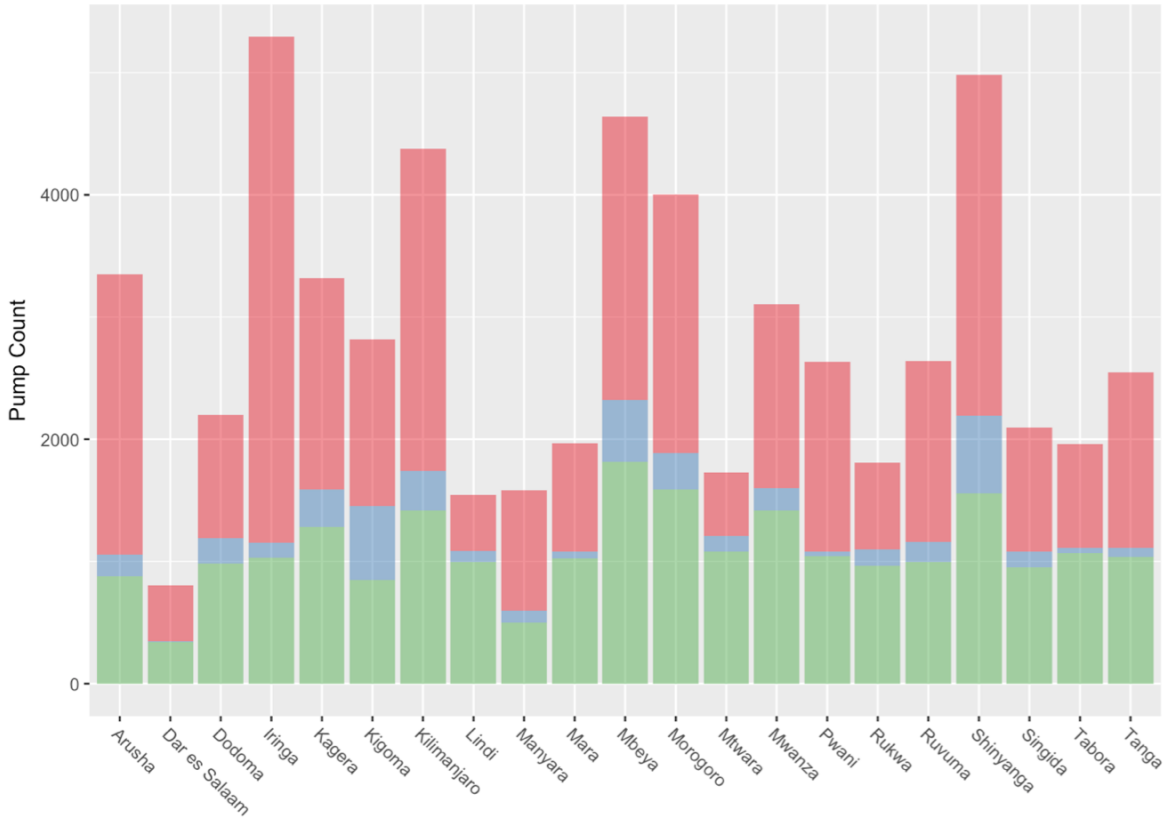
Distribution and Location

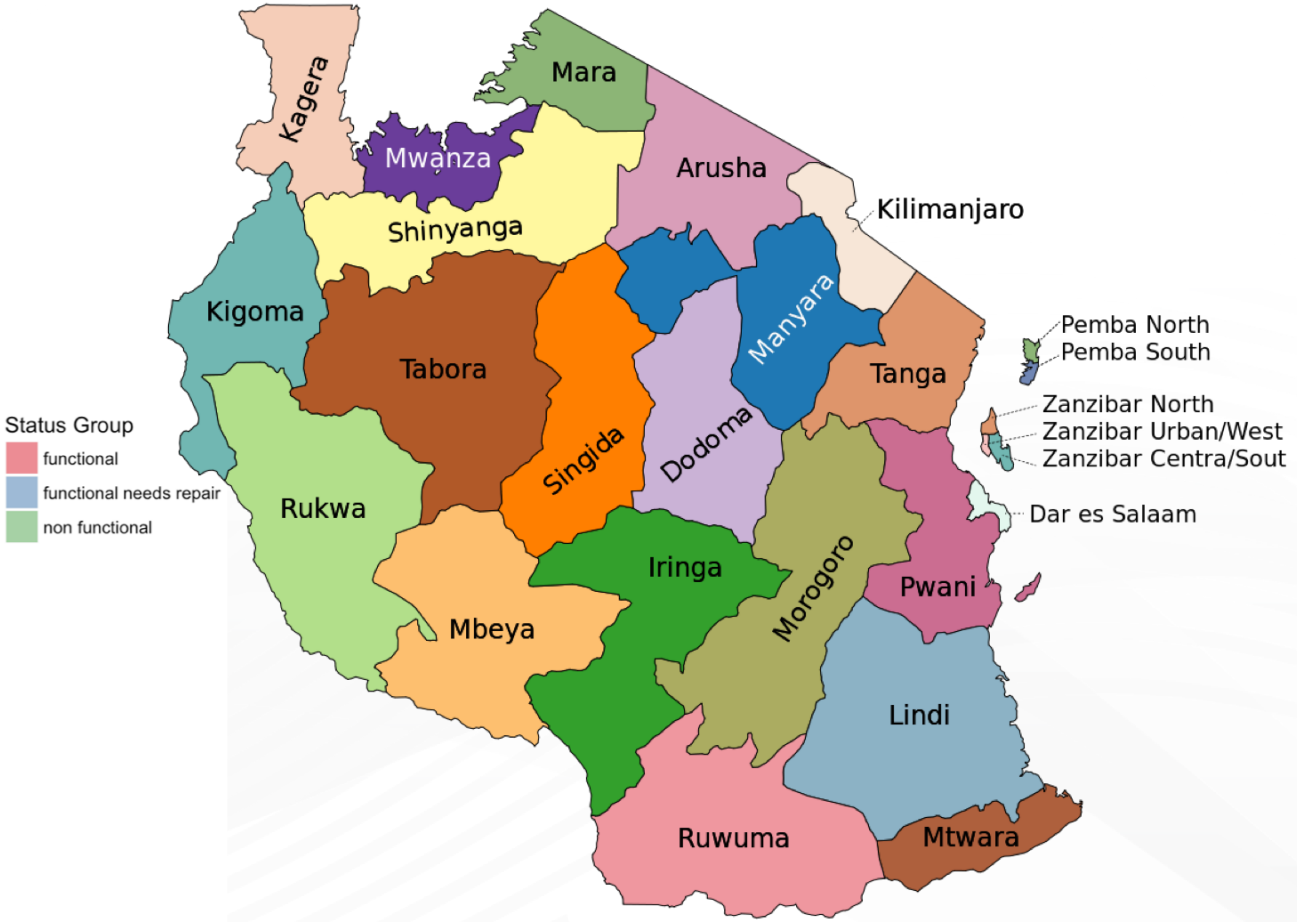




Regions

Geographic location

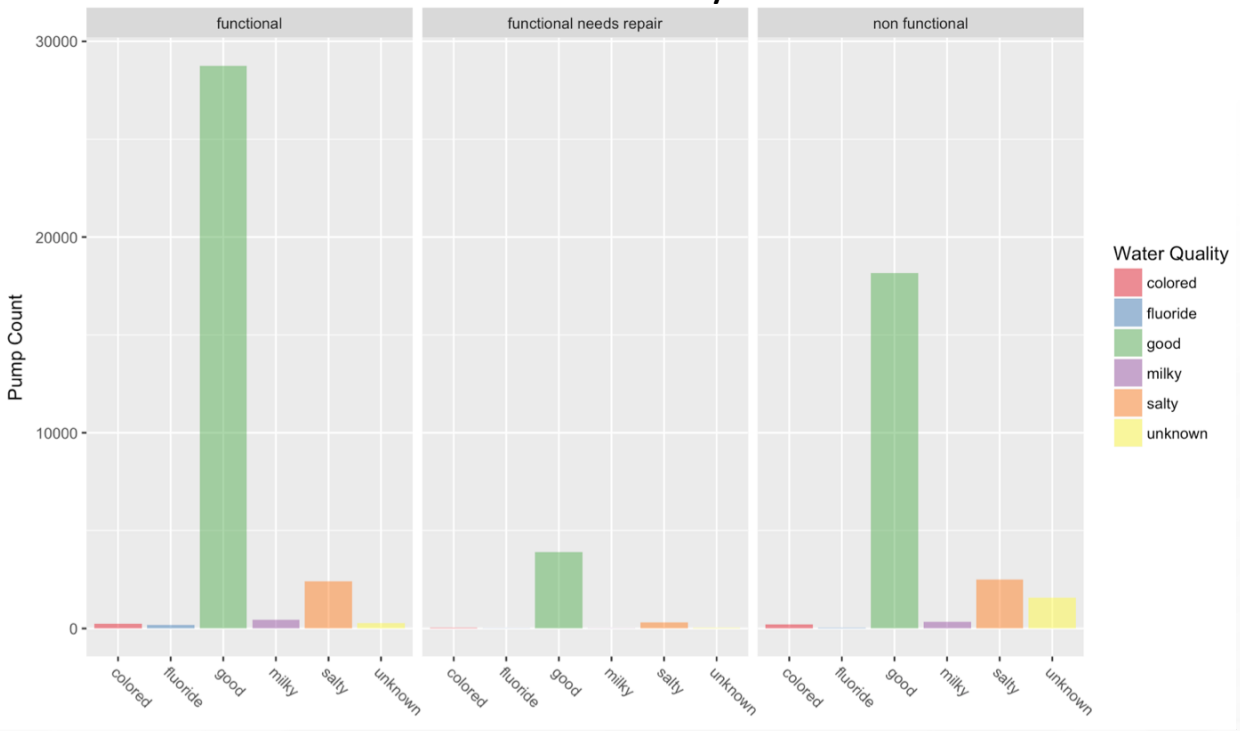




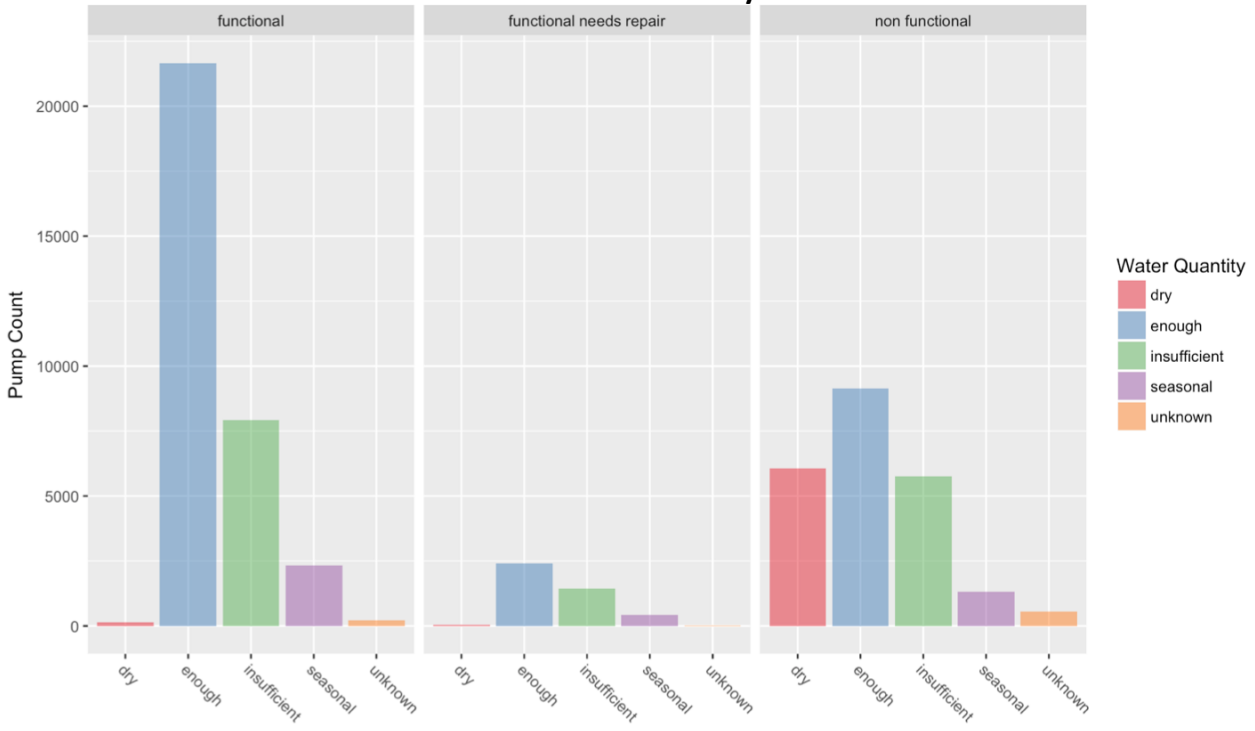
Water Quality & Quantity

The quality of the water and the quantity of water

Water Quality



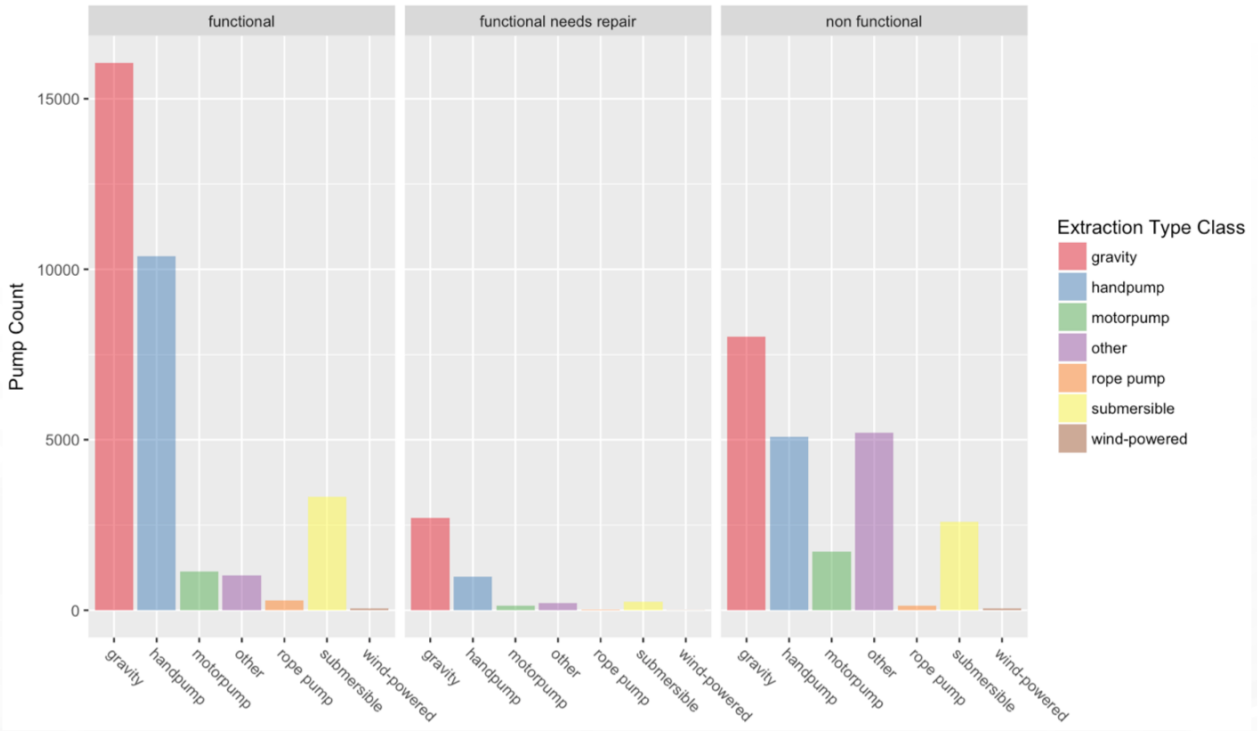
Water Quantity



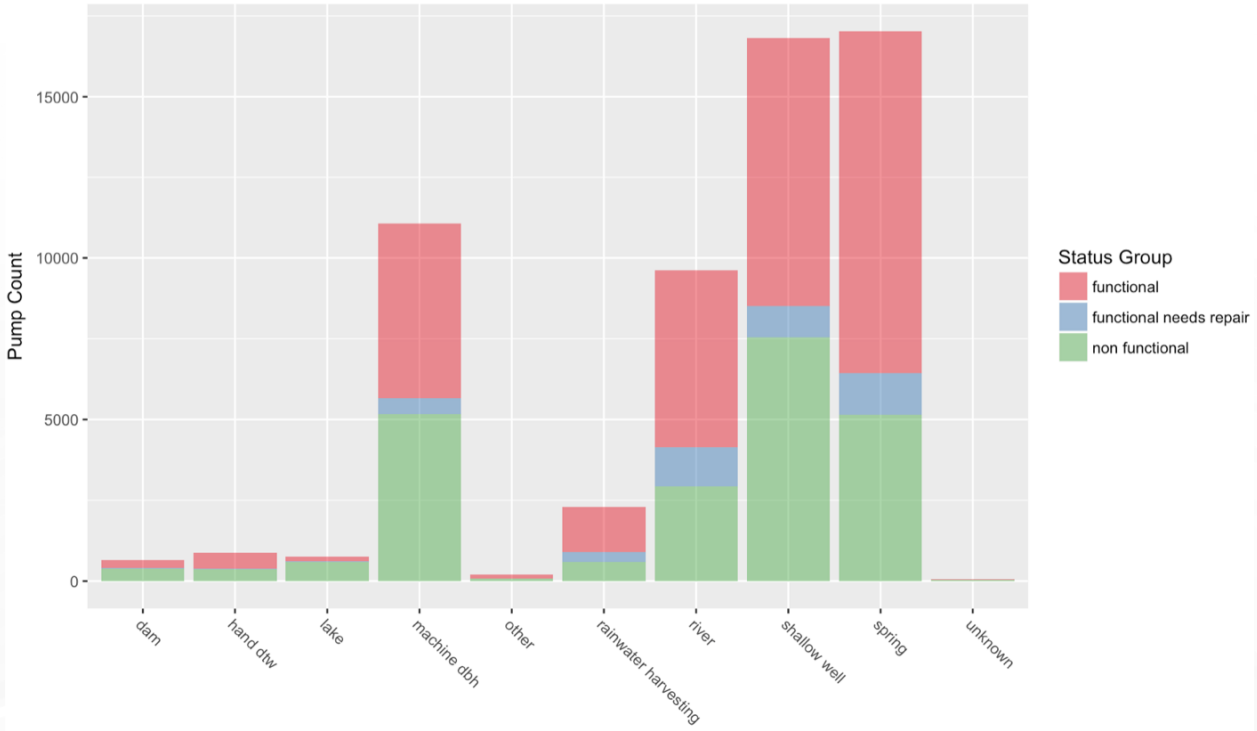
Extraction Type & Water Source

The kind of extraction the water point uses and the source of the water

Extraction Type

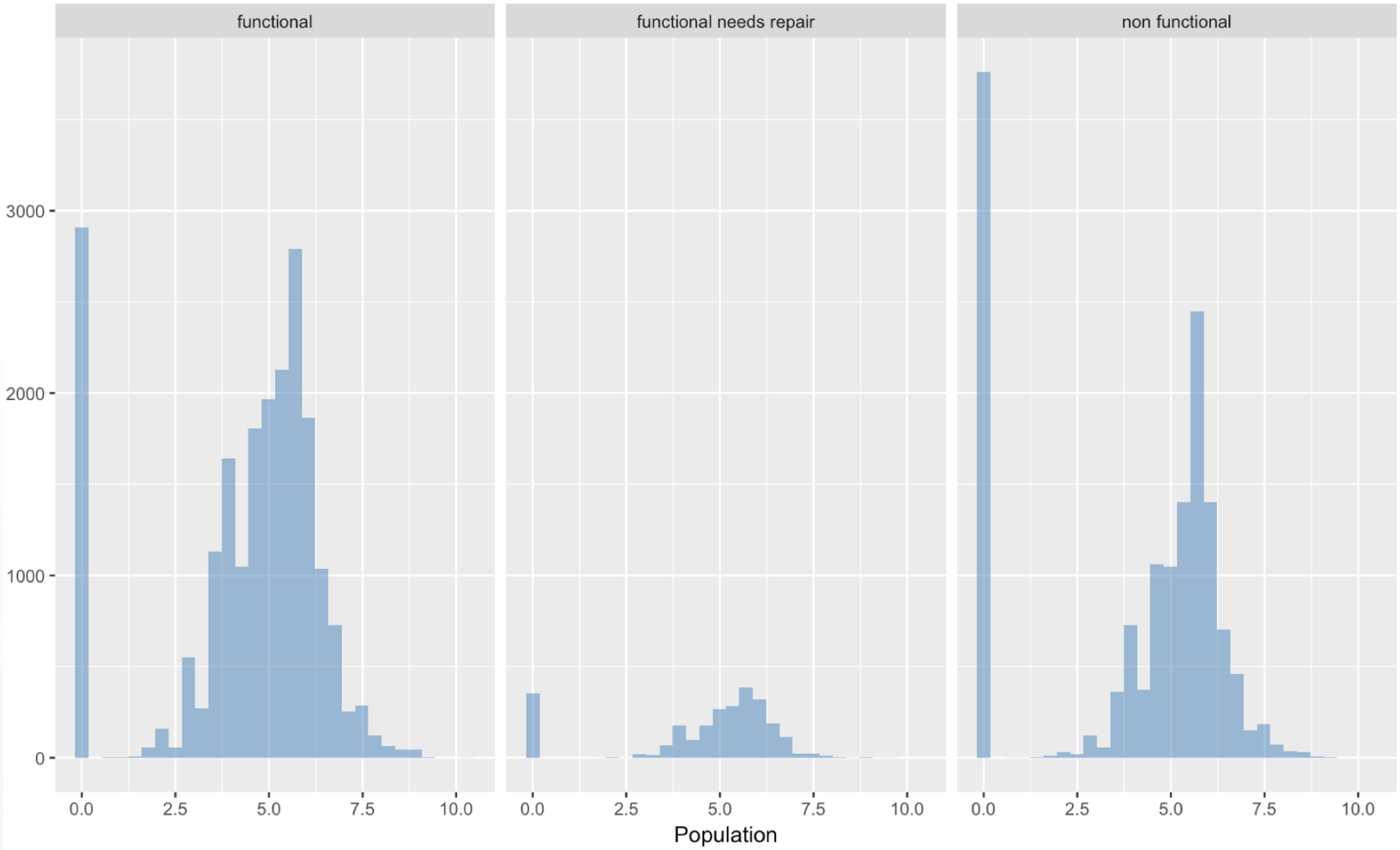


Water Source



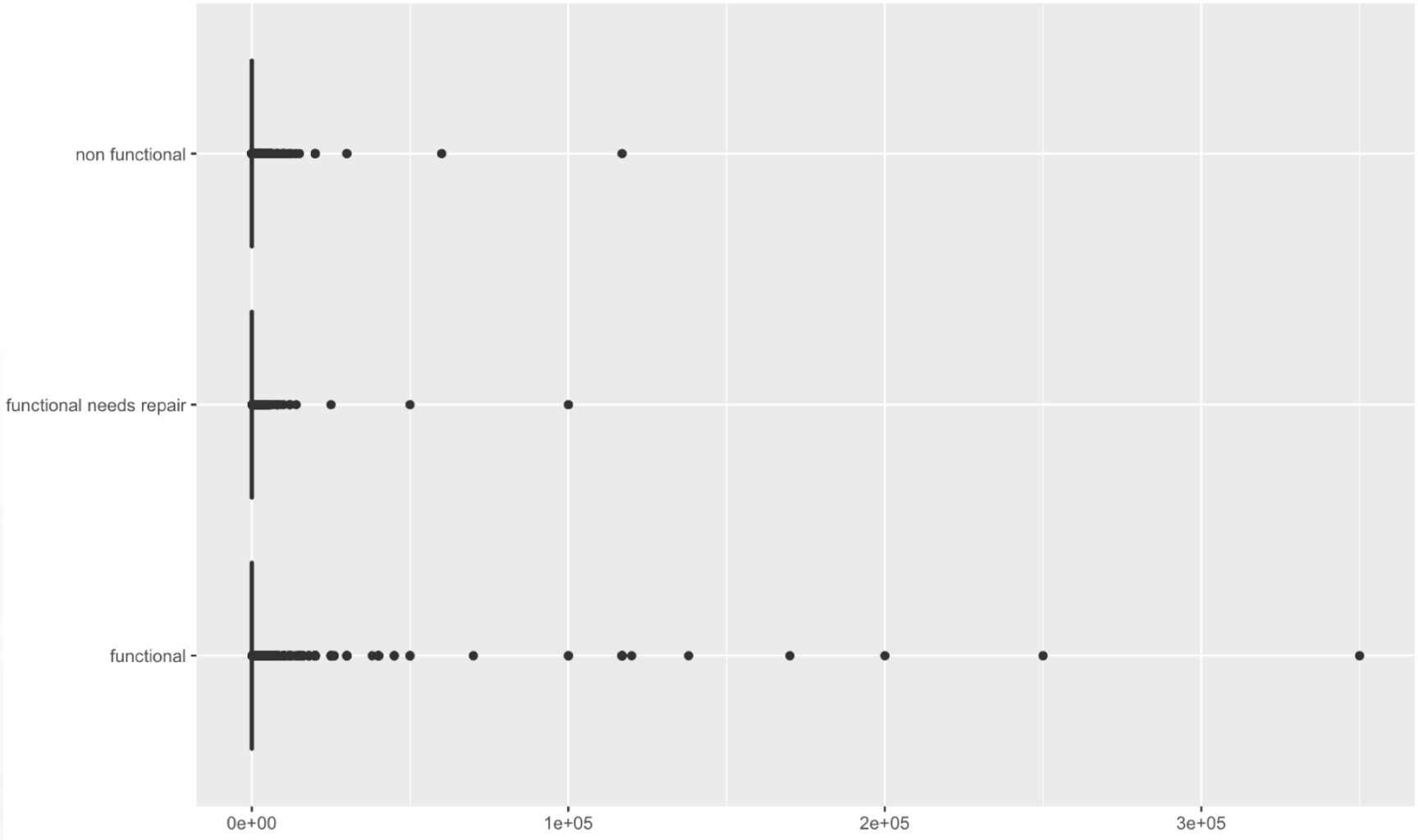
Population

Population around the well



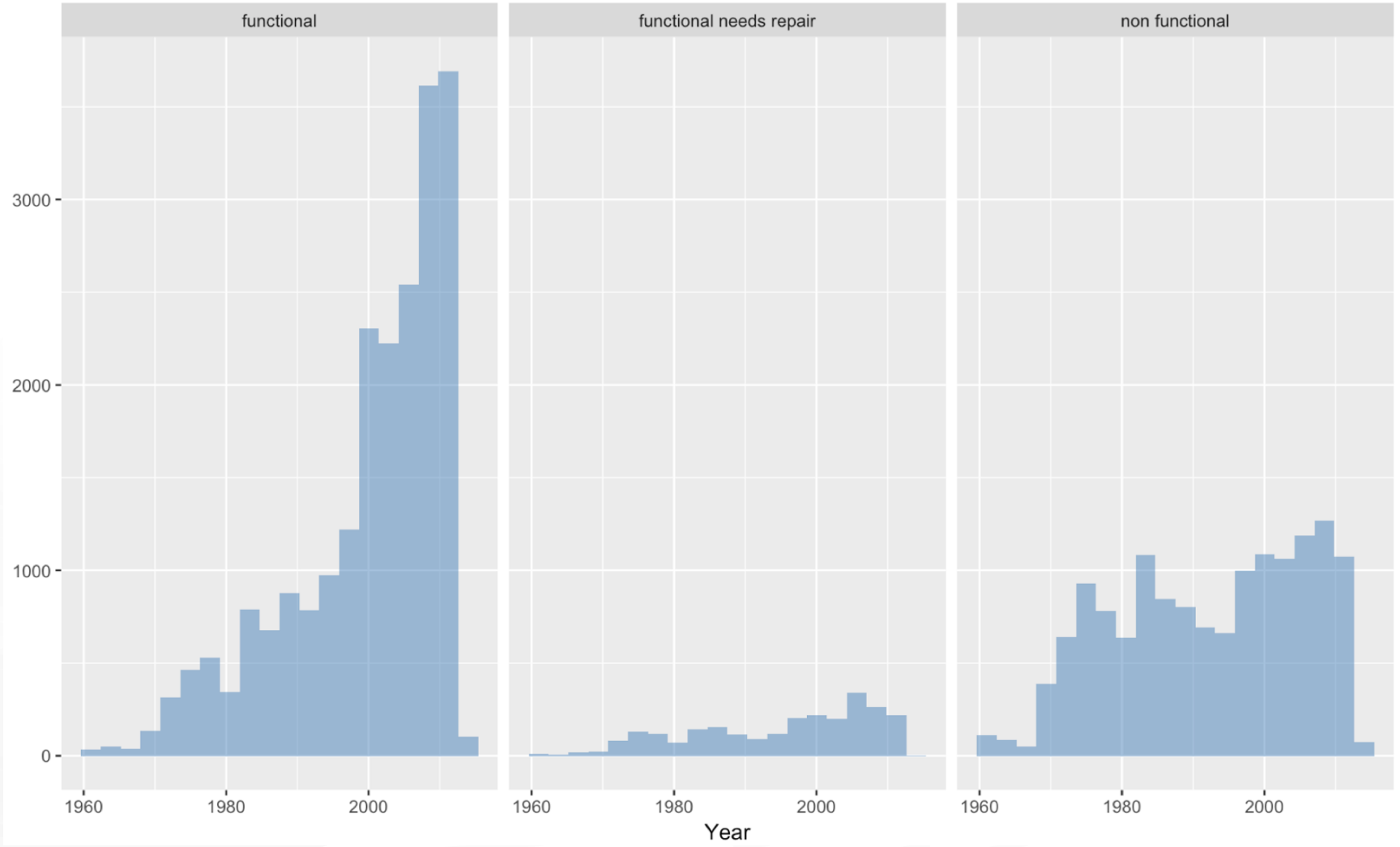
Total Static Head Amount

Amount of water available to water point



Construction Year

Year the water point was constructed



Supervised Learning

Classification Algorithms

Decision Tree
Package: C50

Random Forest
Package: randomForest

Extreme Gradient Boosting
Package: xgboost

Support Vector Machine
Package: e1071

Deep Neural Network
Package: h20

Iterative Approach

Start simple, then attempt to improve performance.

Step Number One

01

Create the initial models using a subset of the data.

Step Number Two

02

Increase the number of attributes used by the models.

Step Number Three

03

Manually applied different parameters to tune the models.

Step Number Four

04

Automate the tuning process to increase the quantity of model variation.

Extreme Gradient Boosting

Package xgboost

- 80/20 train/test
- sparse.model.matrix {Matrix}
- Select subset of attributes
- Round: 25, Max Depth: 15, ETA: 1
- Full set of predictors
- Round: 100, Max Depth: 15, ETA: 0.3

Classification Error: 19.01%

5th Place Submission – DrivenData Score: 0.3787

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction    0    1    2
##          0 5755  884  456
##          1  547 3601  143
##          2  149   79  264
##
## Overall Statistics
##
##                Accuracy : 0.8099
##                  95% CI : (0.8027, 0.8169)
##     No Information Rate : 0.5431
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.6439
##  Mcnemar's Test P-Value : < 2.2e-16
##
## Statistics by Class:
##
##                      Class: 0 Class: 1 Class: 2
## Sensitivity            0.8921   0.7890  0.30591
## Specificity            0.7531   0.9057  0.97930
## Pos Pred Value         0.8111   0.8392  0.53659
## Neg Pred Value         0.8545   0.8731  0.94739
## Precision              0.8111   0.8392  0.53659
## Recall                 0.8921   0.7890  0.30591
## F1                     0.8497   0.8133  0.38967
## Prevalence             0.5431   0.3842  0.07266
## Detection Rate         0.4845   0.3032  0.02223
## Detection Prevalence   0.5973   0.3613  0.04142
## Balanced Accuracy      0.8226   0.8473  0.64261
```

Class 0: functional, Class 1: non functional, Class 2: functional needs repair

Support Vector Machine

Package e1071

- 80/20 train/test
- Select subset of attributes
- Full set of predictors
- Kernels: radial, polynomial, sigmoid
- Tuning via Caret with 10-fold cross validation

Classification Error: 32.12%

4th Place Submission – DrivenData Score: 0.6764

```
## Confusion Matrix and Statistics
##
##
## pump.predict.5            functional functional needs repair non functional
##   functional                    5823                     733           2328
##   functional needs repair         18                       9              5
##   non functional                 610                     121           2231
##
## Overall Statistics
##
##                Accuracy : 0.6788
##                  95% CI : (0.6703, 0.6872)
##     No Information Rate : 0.5431
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.3548
##  Mcnemar's Test P-Value : < 2.2e-16
##
## Statistics by Class:
##
##                      Class: functional Class: functional needs repair Class: non functional
## Sensitivity                     0.9027                       0.0104287               0.4888
## Specificity                     0.4360                       0.9979119               0.9001
## Pos Pred Value                  0.6554                       0.2812500               0.7532
## Neg Pred Value                  0.7902                       0.9279082               0.7383
## Precision                       0.6554                       0.2812500               0.7532
## Recall                          0.9027                       0.0104287               0.4888
## F1                              0.7594                       0.0201117               0.5929
## Prevalence                      0.5431                       0.0726553               0.3842
## Detection Rate                  0.4902                       0.0007577               0.1878
## Detection Prevalence            0.7479                       0.0026941               0.2494
## Balanced Accuracy               0.6693                       0.5041703               0.6944
```

Deep Neural Network

Package h2o

- 80/20 train/test
- Full set of predictors
- Three hidden layers with 200 nodes each
- Disabled early stopping
- Early stopping enabled with defined stopping criteria
- Grid search

Classification Error: 22.17%

3rd Place Submission – DrivenData Score: 0.7745

```
## Confusion Matrix and Statistics
##
##                          Reference
## Prediction                functional functional needs repair non functional
##   functional                    5595                     493            1067
##   functional needs repair         72                     208              46
##   non functional                 764                     189            3434
##
## Overall Statistics
##
##                Accuracy : 0.7783
##                  95% CI : (0.7707, 0.7858)
##     No Information Rate : 0.5419
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.5814
##  Mcnemar's Test P-Value : < 2.2e-16
##
## Statistics by Class:
##
##                      Class: functional Class: functional needs repair Class: non functional
## Sensitivity                     0.8700                         0.23371                0.7552
## Specificity                     0.7131                         0.98925                0.8698
## Pos Pred Value                  0.7820                         0.63804                0.7828
## Neg Pred Value                  0.8226                         0.94091                0.8512
## Precision                       0.7820                         0.63804                0.7828
## Recall                          0.8700                         0.23371                0.7552
## F1                              0.8236                         0.34211                0.7687
## Prevalence                      0.5419                         0.07499                0.3831
## Detection Rate                  0.4714                         0.01753                0.2893
## Detection Prevalence            0.6029                         0.02747                0.3696
## Balanced Accuracy               0.7915                         0.61148                0.8125
```

Decision Tree

Package C50

- 80/20 train/test
- Select subset of attributes
- Rules-based model
- Boosted ruleset
- Full set of predictors
- Winnowing for feature selection
- Tuning via Caret: tuneLength, trainControl[method, repeats]

Classification Error: 19.23%

2nd Place Submission – DrivenData Score: 0.8123

```
## Confusion Matrix and Statistics
##
##                          Reference
## Prediction                functional functional needs repair non functional
##   functional                    5769                     448            928
##   functional needs repair        145                     271             82
##   non functional                 537                     144           3554
##
## Overall Statistics
##
##                Accuracy : 0.8077
##                  95% CI : (0.8005, 0.8148)
##     No Information Rate : 0.5431
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.6394
##  Mcnemar's Test P-Value : < 2.2e-16
##
## Statistics by Class:
##
##                      Class: functional Class: functional needs repair Class: non functional
## Sensitivity                     0.8943                         0.31402                0.7787
## Specificity                     0.7465                         0.97939                0.9069
## Pos Pred Value                  0.8074                         0.54418                0.8392
## Neg Pred Value                  0.8559                         0.94798                0.8679
## Precision                       0.8074                         0.54418                0.8392
## Recall                          0.8943                         0.31402                0.7787
## F1                              0.8486                         0.39824                0.8078
## Prevalence                      0.5431                         0.07266                0.3842
## Detection Rate                  0.4857                         0.02282                0.2992
## Detection Prevalence            0.6015                         0.04193                0.3565
## Balanced Accuracy               0.8204                         0.64671                0.8428
```

Random Forest

Package randomForest

- 80/20 train/test
- Select subset of attributes
- Full set of predictors
- 10-fold cross validation using Caret
- Tuning via Caret: tuneLength, trainControl[method, repeats]

Classification Error: 3.56%

1st Place Submission – DrivenData Score: 0.8170

```
## Confusion Matrix and Statistics
##
##                          Reference
## Prediction                functional functional needs repair non functional
##   functional                    6386                     141            170
##   functional needs repair         25                     690             15
##   non functional                  40                      32           4379
##
## Overall Statistics
##
##                Accuracy : 0.9644
##                  95% CI : (0.9609, 0.9676)
##     No Information Rate : 0.5431
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 0.9347
##  Mcnemar's Test P-Value : < 2.2e-16
##
## Statistics by Class:
##
##                      Class: functional Class: functional needs repair Class: non functional
## Sensitivity                     0.9899                         0.79954                0.9595
## Specificity                     0.9427                         0.99637                0.9902
## Pos Pred Value                  0.9536                         0.94521                0.9838
## Neg Pred Value                  0.9875                         0.98448                0.9751
## Precision                       0.9536                         0.94521                0.9838
## Recall                          0.9899                         0.79954                0.9595
## F1                              0.9714                         0.86629                0.9715
## Prevalence                      0.5431                         0.07266                0.3842
## Detection Rate                  0.5376                         0.05809                0.3687
## Detection Prevalence            0.5638                         0.06146                0.3747
## Balanced Accuracy               0.9663                         0.89795                0.9748
```

DrivenData Confirmation

Best Submission

Pump it Up: Data Mining the Water Table

HOSTED BY DRIVENDATA

Submissions

BEST SCORE	CURRENT RANK	# COMPETITORS	SUBS. TODAY
0.8170	375	4409	1 / 3

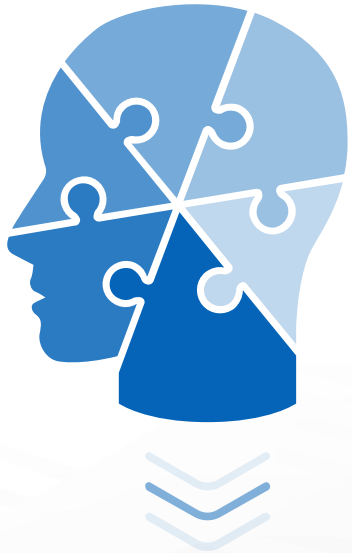
EVALUATION METRIC

Classification Rate $= \frac{1}{N} \sum_{i=0}^{N} I(y_i = \hat{y}_i)$

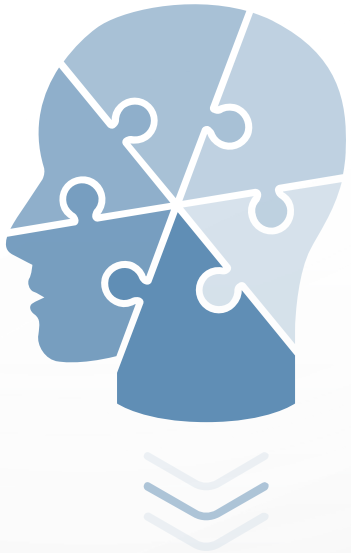
The metric used for this competition is the classification rate, which calculates the percentage of rows where the predicted class $\hat{y}$ in the submission matches the actual class, y in the test set. The maximum is 1 and the minimum is 0. The goal is to maximize the classification rate.

Conclusion

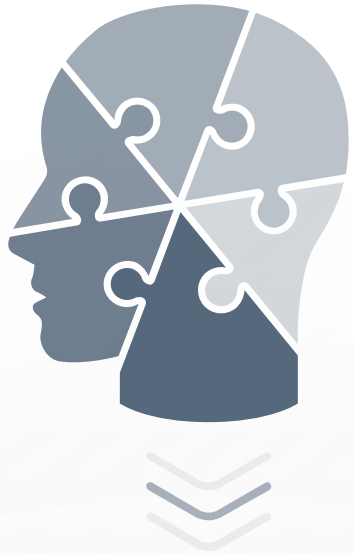
Project Takeaways.



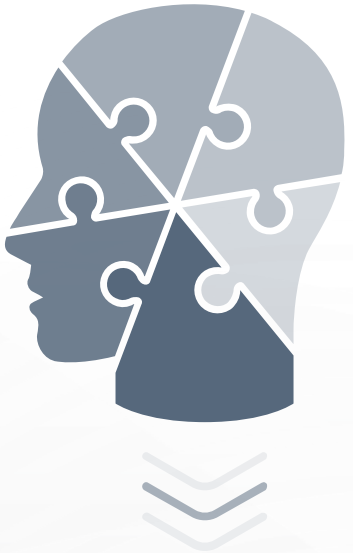
Data
Cleansing



Feature
Engineering



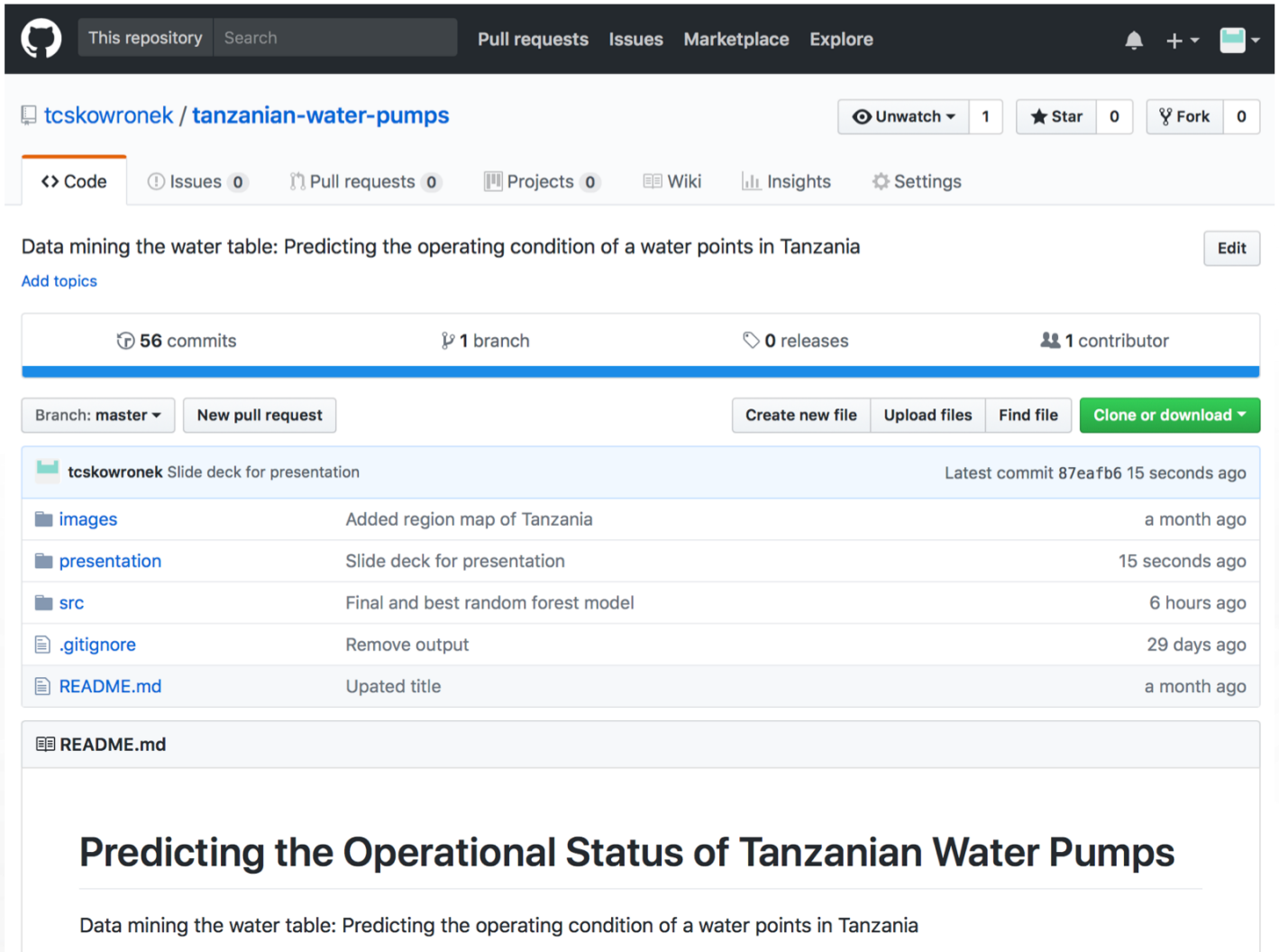
Model
Tuning



Data
Augmentation

Project Repository

GitHub



GitHub Repository: https://github.com/tcskowronek/tanzanian-water-pumps

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Thank You For Watching.

Have a nice day ☺