

Predicting the Functionality of Tanzanian Water Wells

By Group 12:

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Overview

According to a report by World Bank, 39% of Tanzanians do not have access to basic water supply. Consequently, sanitation is also very poor with more than half of the population lacking access to basic sanitation. Installation of wells has been a frontline measure in trying to resolve the water crisis in Tanzania. The Tanzanian government, foreign donor organizations, churches and faith-based organizations, and even the villagers have all been involved in funding and installation of wells. Some of the installed wells however cease to function over time while others remain in dilapidated conditions needing repair. A high number of dilapidated and non-functional wells can hamper the benefits being achieved by the well installations and compound the crisis further. It is therefore important to monitor the wells being built to ensure they remain functional. As representatives of an NGO contracted by the government to ensure the installed wells are maintained and repaired to remain functional, we were tasked to come up with machine learning model that

can predict the functional status wells in Tanzania. This should help direct stakeholders and policy makers attention to where wells need attention to ensure the gains in solving the

Business Problem

39% of Tanzanians lack access to basic water supply. While wells have been installed as a solution to the water crisis, there is lack of reliable infrastructure for monitoring and maintaining water wells. This leads to inefficiencies in resource allocation and delays in addressing non functional wells and functional wells that need repair. The traditional approaches in management of wells are ineffective as a high proportion of installed water wells cease to function over time while others remain in dilapidated conditions needing repair for a long time. There is need for stakeholders and policy makers to be able to know which wells are likely to be non functional or to need repairs, so they can focus their attention and resources there.

Data Understanding

The data was accessed from DrivenData Labs. It consists over 70,000 records split into training set labels, training set values, test set values and test set labels(also named submission format on the website). For the purposes of this project, we accessed the training set values and training set labels data with over 59,000 records, which we merged together for our analysis. each record contains various features describing aspects of the wells such as geographical location, year of construction, funders and installers, water quality, quantity and source type, and management of the wells amongst other features.

Features of the data

- **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)
- **Iga** - 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

Research Questions

1. Which features are related to the functional status of wells in Tanzania
2. Which model best predicts the the functional status of the wells
3. Which areas can the government and stakeholders focus on to ensure that wells remain in a functioning state.

Data Preparation

In [1]: ► #Importing the required libraries

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns

import warnings
warnings.filterwarnings("ignore")

from sklearn.model_selection import train_test_split, GridSearchCV, cross_val_score
from sklearn.preprocessing import StandardScaler
from sklearn.dummy import DummyClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import confusion_matrix
from sklearn.metrics import ConfusionMatrixDisplay
from sklearn.metrics import plot_confusion_matrix, accuracy_score, recall_score
from sklearn.metrics import classification_report
from sklearn.metrics import roc_curve, auc, roc_auc_score
from sklearn.tree import DecisionTreeClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.ensemble import BaggingClassifier, RandomForestClassifier
from imblearn.over_sampling import SMOTE
```

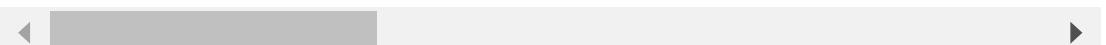
In [2]: ► #Loading the training-set-values dataset as downloaded

```
training = pd.read_csv('data/Training-set-values.csv')
#Previewing the first 5 lines
training.head()
```

Out[2]:

	id	amount_tsh	date_recorded	funder	gps_height	installer	longitude	latitude
0	69572	6000.0	2011-03-14	Roman	1390	Roman	34.938093	-9.85
1	8776	0.0	2013-03-06	Grumeti	1399	GRUMETI	34.698766	-2.14
2	34310	25.0	2013-02-25	Lottery Club	686	World vision	37.460664	-3.82
3	67743	0.0	2013-01-28	Unicef	263	UNICEF	38.486161	-11.15
4	19728	0.0	2011-07-13	Action In A	0	Artisan	31.130847	-1.82

5 rows × 40 columns



In [3]: ┌ #Setting pandas to display all the rows in the output
#and the best fit for columns
#pd.options.display.max_columns = 0
#pd.options.display.max_rows = None

In [4]: ┌ #Checking training data shape
training.shape

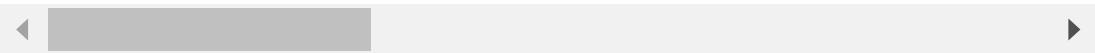
Out[4]: (59400, 40)

In [5]: ┌ #Loading the test-set-values dataset as downloaded
test = pd.read_csv('data/Test-set-values.csv')
#Previewing the first 5 lines
test.head()

Out[5]:

	id	amount_tsh	date_recorded	funder	gps_height	installer	longitude
0	50785	0.0	2013-02-04	Dmdd	1996	DMDD	35.290799
1	51630	0.0	2013-02-04	Government Of Tanzania	1569	DWE	36.656709
2	17168	0.0	2013-02-01	NaN	1567	NaN	34.767863
3	45559	0.0	2013-01-22	Finn Water	267	FINN WATER	38.058046
4	49871	500.0	2013-03-27	Bruder	1260	BRUDER	35.006123

5 rows × 40 columns



In [6]: ┌ #Checking the shape of the test dataset
test.shape

Out[6]: (14850, 40)

We'll start by concatenating the training set values and the test set values datasets downloaded so as to perform initial data cleaning and scrubbing together.

In [7]: ┌ #Concatenating the training and testing data sets
X = pd.concat([training, test])
X.shape

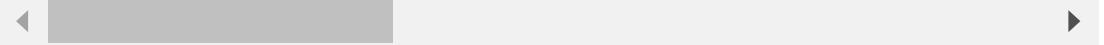
Out[7]: (74250, 40)

In [8]: ┌ #Checking for duplicated rows in the concatenated data set
duplicateRows = X[X.duplicated()]
duplicateRows

Out[8]:

	id	amount_tsh	date_recorded	funder	gps_height	installer	longitude	latitude	wpt_
0 rows × 40 columns									

0 rows × 40 columns



The resulting dataset has a shape of 74,250 rows and 40 columns and no duplicated rows.

In [9]: ┌ #Loading the outcome dataset
outcome = pd.read_csv('data/Training-set-labels.csv')
#Previewing the first 5 Lines
outcome.head()

Out[9]:

	id	status_group
0	69572	functional
1	8776	functional
2	34310	functional
3	67743	non functional
4	19728	functional

In [10]: ┌ #Checking the outcome dataset shape
outcome.shape

Out[10]: (59400, 2)

We'll proceed to merge the concatenated data set with the outcomes data set before starting the data cleaning process.

In [11]: ┌ #Merging the datasets
 df = pd.merge(outcome, X, how = 'inner', on='id')
 #Checking the first 5 lines of the merged dataset
 df.head()

Out[11]:

	id	status_group	amount_tsh	date_recorded	funder	gps_height	installer	longitude
0	69572	functional	6000.0	2011-03-14	Roman	1390	Roman	34
1	8776	functional	0.0	2013-03-06	Grumeti	1399	GRUMETI	34
2	34310	functional	25.0	2013-02-25	Lottery Club	686	World vision	37
3	67743	non functional	0.0	2013-01-28	Unicef	263	UNICEF	38
4	19728	functional	0.0	2011-07-13	Action In A	0	Artisan	31

5 rows × 41 columns



In [12]: ┌ #Checking the shape of the merged dataset
 df.shape

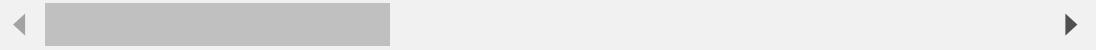
Out[12]: (59400, 41)

In [13]: ┌ #Checking for duplicated Rows in the merged Dataset
 df_duplicates = df[df.duplicated()]
 df_duplicates

Out[13]:

	id	status_group	amount_tsh	date_recorded	funder	gps_height	installer	longitude
0								

0 rows × 41 columns



The resulting dataset has 59,400 rows and 41 columns.

This means that only 59,400 rows in the concatenated data set had matching IDs with the outcome dataset.

The dataset does not have any duplicated rows.

We'll proceed with this dataset

In [14]: #Checking data types of the dataset
df.info()

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 59400 entries, 0 to 59399
Data columns (total 41 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   id               59400 non-null   int64  
 1   status_group     59400 non-null   object  
 2   amount_tsh       59400 non-null   float64 
 3   date_recorded   59400 non-null   object  
 4   funder           55765 non-null   object  
 5   gps_height      59400 non-null   int64  
 6   installer        55745 non-null   object  
 7   longitude        59400 non-null   float64 
 8   latitude         59400 non-null   float64 
 9   wpt_name         59400 non-null   object  
 10  num_private     59400 non-null   int64  
 11  basin            59400 non-null   object  
 12  subvillage       59029 non-null   object  
 13  region           59400 non-null   object  
 14  region_code      59400 non-null   int64  
 15  district_code    59400 non-null   int64  
 16  lga               59400 non-null   object  
 17  ward              59400 non-null   object  
 18  population       59400 non-null   int64  
 19  public_meeting   56066 non-null   object  
 20  recorded_by      59400 non-null   object  
 21  scheme_management 55523 non-null   object  
 22  scheme_name      31234 non-null   object  
 23  permit            56344 non-null   object  
 24  construction_year 59400 non-null   int64  
 25  extraction_type  59400 non-null   object  
 26  extraction_type_group 59400 non-null   object  
 27  extraction_type_class 59400 non-null   object  
 28  management        59400 non-null   object  
 29  management_group  59400 non-null   object  
 30  payment           59400 non-null   object  
 31  payment_type      59400 non-null   object  
 32  water_quality     59400 non-null   object  
 33  quality_group     59400 non-null   object  
 34  quantity          59400 non-null   object  
 35  quantity_group    59400 non-null   object  
 36  source            59400 non-null   object  
 37  source_type        59400 non-null   object  
 38  source_class       59400 non-null   object  
 39  waterpoint_type   59400 non-null   object  
 40  waterpoint_type_group 59400 non-null   object  
dtypes: float64(3), int64(7), object(31)
memory usage: 19.0+ MB
```

In [15]: #Checking the numerical columns
df.describe()

Out[15]:

	id	amount_tsh	gps_height	longitude	latitude	num_
count	59400.000000	59400.000000	59400.000000	59400.000000	5.940000e+04	59400.000000
mean	37115.131768	317.650385	668.297239	34.077427	-5.706033e+00	0.4
std	21453.128371	2997.574558	693.116350	6.567432	2.946019e+00	12.2
min	0.000000	0.000000	-90.000000	0.000000	-1.164944e+01	0.0
25%	18519.750000	0.000000	0.000000	33.090347	-8.540621e+00	0.0
50%	37061.500000	0.000000	369.000000	34.908743	-5.021597e+00	0.0
75%	55656.500000	20.000000	1319.250000	37.178387	-3.326156e+00	0.0
max	74247.000000	350000.000000	2770.000000	40.345193	-2.000000e-08	1776.0



In [16]: #Checking the number and percentage of missing values in the dataset
no_missing = df.isna().sum()
percent_missing = (df.isna().sum() * 100 / len(df)).round(2)
missing_value_df = pd.DataFrame({'no_missing_values': no_missing,
 'percent_missing': percent_missing})
missing_value_df

Out[16]:

	no_missing_values	percent_missing
id	0	0.00
status_group	0	0.00
amount_tsh	0	0.00
date_recorded	0	0.00
funder	3635	6.12
gps_height	0	0.00
installer	3655	6.15
longitude	0	0.00
latitude	0	0.00
wpt_name	0	0.00
num_private	0	0.00
basin	0	0.00
subvillage	371	0.62
region	0	0.00
region_code	0	0.00
district_code	0	0.00
Iga	0	0.00
ward	0	0.00
population	0	0.00
public_meeting	3334	5.61
recorded_by	0	0.00
scheme_management	3877	6.53
scheme_name	28166	47.42
permit	3056	5.14
construction_year	0	0.00
extraction_type	0	0.00
extraction_type_group	0	0.00
extraction_type_class	0	0.00
management	0	0.00
management_group	0	0.00
payment	0	0.00
payment_type	0	0.00
water_quality	0	0.00
quality_group	0	0.00
quantity	0	0.00
quantity_group	0	0.00
source	0	0.00
source_type	0	0.00

	no_missing_values	percent_missing
source_class	0	0.00
waterpoint_type	0	0.00
waterpoint_type_group	0	0.00

In [17]: ┆ #Checking for the number of unique values in the columns

```
data_type = df.dtypes
no_unique_values = df.nunique()
unique_values_df = pd.DataFrame({'data_type': data_type,
                                  'unique_values': no_unique_values})
unique_values_df
```

Out[17]:

	data_type	unique_values
id	int64	59400
status_group	object	3
amount_tsh	float64	98
date_recorded	object	356
funder	object	1897
gps_height	int64	2428
installer	object	2145
longitude	float64	57516
latitude	float64	57517
wpt_name	object	37400
num_private	int64	65
basin	object	9
subvillage	object	19287
region	object	21
region_code	int64	27
district_code	int64	20
Iga	object	125
ward	object	2092
population	int64	1049
public_meeting	object	2
recorded_by	object	1
scheme_management	object	12
scheme_name	object	2696
permit	object	2
construction_year	int64	55
extraction_type	object	18
extraction_type_group	object	13
extraction_type_class	object	7
management	object	12
management_group	object	5
payment	object	7
payment_type	object	7
water_quality	object	8
quality_group	object	6
quantity	object	5
quantity_group	object	5
source	object	10
source_type	object	7

	data_type	unique_values
source_class	object	3
waterpoint_type	object	7
waterpoint_type_group	object	6

Observations

The columns contain integer, float and object data types

7 columns have missing values. The columns, funder, installer and scheme_management have an average of 6% of values missing; public_meeting and permit an average of 5% of values missing and subvillage 0.6% of values missing. The column scheme_name has the highest percentage of values missing at 47%.

The categorical columns date_recorded, funder, installer, wpt_name, subvillage, ward and scheme_name have a very high number of unique values in the columns ranging from 356 to 37400. This will prove tricky during one-hot-encoding so we'll have to find a way of reducing the number of unique values.

Data Cleaning

In this section, we'll investigate the data column by column to clean it

```
In [18]: ┆ #Investigating the target
df['status_group'].value_counts(normalize=True)
```

```
Out[18]: functional           0.543081
non functional          0.384242
functional needs repair  0.072677
Name: status_group, dtype: float64
```

Our target variable is a ternary variable(3 classes). It has class imbalance as the first class(functional) accounts for approximately 54% of the values, the second class (non functional) approximately 38% and the third class (functional needs repair) approximately 7%.

```
In [19]: ┆ df['amount_tsh'].value_counts(dropna=False, normalize=True)
```

```
Out[19]: 0.0        0.700993
500.0      0.052222
50.0       0.041616
1000.0     0.025051
20.0       0.024630
...
8500.0     0.000017
6300.0     0.000017
220.0      0.000017
138000.0   0.000017
12.0       0.000017
Name: amount_tsh, Length: 98, dtype: float64
```

The 'amount_tsh' column represents the total amount of water available to a well in terms of the total static head. 70% of the values in this column are 0. However, we will leave it as it is for now as 0 in terms of total static head is a viable figure meaning the well is at the surface and there is no need for pumping.

In [20]: ┏ df['gps_height'].value_counts(dropna=False, normalize=True)

Out[20]:

0	0.344074
-15	0.001010
-16	0.000926
-13	0.000926
-20	0.000875
	...
2285	0.000017
2424	0.000017
2552	0.000017
2413	0.000017
2385	0.000017

Name: gps_height, Length: 2428, dtype: float64

'gps_height' is a numerical column with a high number of 0s, representing 34% of the values. However, since the column indicates the altitude of the well, zero is a valid figure as it represents the altitude at sea level. We'll leave this column out for now.

In [21]: ┏ df['num_private'].value_counts(dropna=False, normalize=True)

Out[21]:

0	0.987256
6	0.001364
1	0.001229
5	0.000774
8	0.000774
	...
180	0.000017
213	0.000017
23	0.000017
55	0.000017
94	0.000017

Name: num_private, Length: 65, dtype: float64

It is not clear from the data sets what this column represents as it does not have a label. Moreover, 98% of the values are a 0. We will therefore drop this column from our dataframe.

In [22]: ┆ df['population'].value_counts(dropna=False, normalize=True)

```
Out[22]: 0      0.359949
1      0.118266
200    0.032660
150    0.031852
250    0.028300
...
3241   0.000017
1960   0.000017
1685   0.000017
2248   0.000017
1439   0.000017
Name: population, Length: 1049, dtype: float64
```

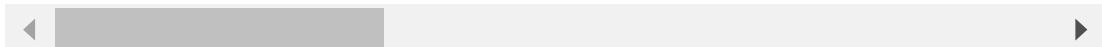
Population column represents the total population around the well. Approximately 35% of the population column values are 0. This could well mean that noone is living around these wells. We'll check the functionality of the wells around the areas where population is recorded as 0 to get a better glimpse of the situation.

In [23]: ┆ df_pop = df.loc[df['population']==0]
df_pop.head()

Out[23]:

	id	status_group	amount_tsh	date_recorded	funder	gps_height	installer	lon
4	19728	functional	0.0	2011-07-13	Action In A		0	Artisan
6	19816	non functional	0.0	2012-10-01	Dwsp		0	DWSP
7	54551	non functional	0.0	2012-10-09	Rwssp		0	DWE
8	53934	non functional	0.0	2012-11-03	Wateraid		0	Water Aid
9	46144	functional	0.0	2011-08-03	Isingiro Ho		0	Artisan

5 rows × 41 columns



In [24]: ┌ #Investigating the wells around the areas with a population of 0
df_pop.groupby('status_group').count()

Out[24]:

	id	amount_tsh	date_recorded	funder	gps_height	installer	longitude	latitude
status_group								
functional	11274		11274		11274	10048	11274	10033
functional needs repair	1775		1775		1775	1464	1775	1462
non functional	8332		8332		8332	7753	8332	7755

3 rows × 40 columns



There are functional wells around these areas where the population is zero. As such, the 0 might be more a case of missing data than an actual value. We will therefore fill the zeros with the population mean.

In [25]: ┌ #Extracting the data records without a population of 0 to compute the mean
df_mean = df.loc[df['population']!=0]
df_mean.describe()

Out[25]:

	id	amount_tsh	gps_height	longitude	latitude	num_p
count	38019.000000	38019.000000	38019.000000	38019.000000	38019.000000	38019.000000
mean	37107.559115	447.787681	969.889634	36.074387	-6.139781	0.7
std	21406.803661	3706.770967	612.544787	2.586779	2.737733	15.2
min	1.000000	0.000000	-90.000000	29.607122	-11.649440	0.0
25%	18514.500000	0.000000	347.000000	34.715340	-8.388839	0.0
50%	37128.000000	0.000000	1135.000000	36.706815	-5.750877	0.0
75%	55505.500000	100.000000	1465.000000	37.940149	-3.597016	0.0
max	74247.000000	350000.000000	2770.000000	40.345193	-1.042375	1776.0



In [26]: ┌ #Filling the 0 values with the population mean of 281
df['population'].replace(to_replace = 0, value = 281, inplace=True)

In [27]: #Checking the population column value counts again
df['population'].value_counts()

Out[27]:

281	21385
1	7025
200	1940
150	1892
250	1681
...	
406	1
1960	1
1685	1
2248	1
1439	1

Name: population, Length: 1048, dtype: int64

In [28]: df['construction_year'].value_counts(dropna=False, normalize=True)

Out[28]:

0	0.348636
2010	0.044529
2008	0.043990
2009	0.042643
2000	0.035202
2007	0.026717
2006	0.024764
2003	0.021650
2011	0.021145
2004	0.018906
2012	0.018249
2002	0.018098
1978	0.017458
1995	0.017071
2005	0.017020
1999	0.016481
1998	0.016263
1990	0.016061
1985	0.015909
1992	0.012652

Construction year has a value of 0 in approximately 34% of the values. A 0 year is not valid in this case. we'll replace this value with the year median

In [29]: #Getting the median year
median_val = int(df[df['construction_year'] != 0]['construction_year'].
#Replacing 0 values with the median
df['construction_year'].replace(to_replace = 0, value = median_val, inplace=True))

```
In [30]: df['construction_year'].value_counts(normalize=True)
```

```
Out[30]: 2000    0.383838
2010    0.044529
2008    0.043990
2009    0.042643
2007    0.026717
2006    0.024764
2003    0.021650
2011    0.021145
2004    0.018906
2012    0.018249
2002    0.018098
1978    0.017458
1995    0.017071
2005    0.017020
1999    0.016481
1998    0.016263
1990    0.016061
1985    0.015909
1996    0.013653
1980    0.012653
```

```
In [31]: df['date_recorded'].value_counts(dropna=False, normalize=True)
```

```
Out[31]: 2011-03-15    0.009630
2011-03-17    0.009394
2013-02-03    0.009192
2011-03-14    0.008754
2011-03-16    0.008636
...
2011-08-31    0.000017
2011-09-09    0.000017
2011-08-30    0.000017
2011-09-13    0.000017
2004-04-05    0.000017
Name: date_recorded, Length: 356, dtype: float64
```

Feature Engineering

We will convert the construction_year and date_recorded columns to date time format and use them to engineer a new feature, age of the well, by subtracting the construction year from the year the data was collected.

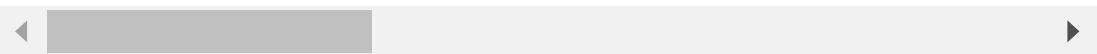
In [32]:

```
df["date_recorded"] = pd.to_datetime(df["date_recorded"])
df["date_of_record"] = df["date_recorded"].dt.year
df["construction_year"] = pd.to_datetime(df["construction_year"])
df.head()
```

Out[32]:

	id	status_group	amount_tsh	date_recorded	funder	gps_height	installer	lo
0	69572	functional	6000.0	2011-03-14	Roman	1390	Roman	34
1	8776	functional	0.0	2013-03-06	Grumeti	1399	GRUMETI	34
2	34310	functional	25.0	2013-02-25	Lottery Club	686	World vision	37
3	67743	non functional	0.0	2013-01-28	Unicef	263	UNICEF	38
4	19728	functional	0.0	2011-07-13	Action In A	0	Artisan	31

5 rows × 42 columns



In [33]:

```
#Converting the columns back into integer format for ease of subtraction
df[["construction_year", "date_of_record"]] = df[["construction_year",
```

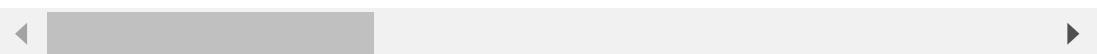
In [34]:

```
#Calculating the age_of_well column
df['age_of_well'] = df["date_of_record"] - df["construction_year"]
df.head()
```

Out[34]:

	id	status_group	amount_tsh	date_recorded	funder	gps_height	installer	lo
0	69572	functional	6000.0	2011-03-14	Roman	1390	Roman	34
1	8776	functional	0.0	2013-03-06	Grumeti	1399	GRUMETI	34
2	34310	functional	25.0	2013-02-25	Lottery Club	686	World vision	37
3	67743	non functional	0.0	2013-01-28	Unicef	263	UNICEF	38
4	19728	functional	0.0	2011-07-13	Action In A	0	Artisan	31

5 rows × 43 columns



```
In [35]: df['age_of_well'].value_counts()
```

```
Out[35]: 11    14695
12    5701
13    4079
3     2740
1     2303
2     2130
5     1980
4     1903
7     1404
6     1381
8     1160
14    1160
33    1120
15    993
23    905
10    868
16    826
9     814
19    766
--   --
```

There are a few wells whose values run into the negative. This is not a possibility since age of well was calculated at the point of data collection by subtracting the year of construction by the date of recording. We will therefore drop these values from our dataset.

```
In [36]: df = df[df['age_of_well'] > 0]
df['age_of_well'].value_counts()
```

```
Out[36]: 11    14695
12    5701
13    4079
3     2740
1     2303
2     2130
5     1980
4     1903
7     1404
6     1381
8     1160
14    1160
33    1120
15    993
23    905
10    868
16    826
9     814
19    766
--   --
```

In [37]: ┏ df['funder'].value_counts(dropna=False, normalize=True)

```
Out[37]: Government Of Tanzania    0.154108
NaN                      0.061817
Danida                  0.052956
Hesawa                   0.037447
Rwssp                     0.023366
...
Ramadhani M. Mvugalo    0.000017
Samsoni                  0.000017
Thomasi Busigaye        0.000017
Uniceg                   0.000017
African 2000 Network     0.000017
Name: funder, Length: 1873, dtype: float64
```

The column funder has a significant number of missing values as well as unknown values. The string values of the column also have a lot of misspellings leading to values being strewn across different categories. We'll clean up the names and replace the missing and 0 values with unkown to preserve data.

In [38]: ┏ df['funder'] = df['funder'].replace(to_replace = ('Tanzania Government',
'Tz', 'Tanzania', 'Gc'))

In [39]: ┏ df['funder'] = df['funder'].replace(to_replace = ('villigers', 'Village
'Village Government',
'Village', 'Village C
'Olgilai Village Comm
'Kijiji', 'Nduku Vill
'Serikali ya Kijiji'
'Village Office', 'V
'Buluga Subvillage Co
value ='Villagers'))

In [40]: ┏ df['funder'] = df['funder'].replace(to_replace = ('Nethalan', 'Netherla
'Uhoranzi', 'Mhoranzi
value = 'Netherlands'))

In [41]: ┏ df['funder'] = df['funder'].replace(to_replace = ('Jaica', 'Jika', 'Jic'))

In [42]: ┏ df['funder'] = df['funder'].replace(to_replace = ('FinW', 'Fini water',
'FINN WATER', 'Finw', 'FW', 'F
value ='Fini Water'))

```
In [43]: ┏━ df['funder'] = df['funder'].replace(to_replace = ('RC churc', 'Roman Ca
          'Roman Church', 'Rc Church',
          'Roman Catholic Rulenge Dioc
          'Roman Cathoric', 'Rc Church
          'Kanisa Katoliki Lollovoni',
          value ='R C Church')

df['funder'] = df['funder'].replace(to_replace = ('The People Of Japan'
          'Japan Food', 'Japan
          value ='Japan')

df['funder'] = df['funder'].replace(to_replace = ('Lottery Club', 'Rota
          value ='Rotary Club')

df['funder'] = df['funder'].replace(to_replace = ('China Government', 'C
          value ='Government')

df['funder'] = df['funder'].replace(to_replace = ('Mosque', 'Islam', 'Is
          'Islamic Community', 'I
          value ='Muslims')

df['funder'] = df['funder'].replace(to_replace = ('Qwickwin', 'Quik', 'Qu
          'Kwikwiz', 'Qukwwin', 'Qu

df['funder'] = df['funder'].replace(to_replace = ('Hesaw', 'Hesawa And
          'Hesawa And

df['funder'] = df['funder'].replace(to_replace = ('Swedish', 'People of
          'Sweden', 'Swedes',
          value ='Sweden')

df['funder'] = df['funder'].replace(to_replace = ('Germany Republi', 'A
          'Germany Republic', 'Germany

df['funder'] = df['funder'].replace(to_replace = ('Water', 'Idara Ya Ma
```

```
In [44]: ┏━ df['funder'] = df['funder'].replace(to_replace = '0', value ='Unknown')
          df['funder'] = df['funder'].fillna('Unknown')
```

```
In [45]: ┏━ df['funder'].value_counts(dropna=False, normalize=True)
```

```
Out[45]: Government Of Tanzania      0.157543
          Unknown                  0.075098
          Danida                   0.052956
          Hesawa                    0.037447
          Rwssp                     0.023366
          ...
          Hasnein Murij            0.000017
          Tanzaling                 0.000017
          Nasan                     0.000017
          Igolola Community         0.000017
          African Reflections Foundation 0.000017
          Name: funder, Length: 1787, dtype: float64
```

The column still has too many categories to carry out one-hot encoding. We will reduce dimensionality by picking the top 10 categories with the highest number of variables and then categorising all the rest to others.

```
In [46]: ┏ top_15 = df['funder'].value_counts(normalize=True).head(15).index.tolist()
          ┡ df['funder'] = [type_ if type_ in top_15 else "Other" for type_ in df['
```

```
In [47]: ┏ df['funder'].value_counts()
```

```
Out[47]: Other                27930
          Government Of Tanzania  9264
          Unknown                4416
          Danida                  3114
          Hesawa                  2202
          Rwssp                   1374
          World Bank               1299
          Kkkt                     1286
          World Vision             1245
          Ministry Of Water        1224
          Unicef                  1056
          R C Church               956
          Fini Water               919
          Tasaf                    854
          District Council          835
          Dhv                      829
          Name: funder, dtype: int64
```

```
In [48]: ┏ df['installer'].value_counts(dropna=False, normalize=True)
```

```
Out[48]: DWE                 0.294645
          NaN                 0.062157
          Government           0.030322
          RWE                 0.020509
          Commu                0.018026
          ...
          QUIK                0.000017
          Ramadhani M. Mvugalo 0.000017
          Samsoni               0.000017
          RWI                  0.000017
          WSSP                 0.000017
          Name: installer, Length: 2124, dtype: float64
```

The column `installer` has a lot of categories that are similar to the column `'funder'`. We will therefore drop this column to minimise multicollinearity issues.

In [49]: ┏ df['wpt_name'].value_counts(dropna=False)

```
Out[49]:   none           3526
Shuleni        1726
Zahanati        820
Msikitini        529
Kanisani         318
...
Kwa Fred Mwenda      1
Kwa Mzee Yotamu      1
Kwa Saduka          1
Kwa Salaita Massawe  1
Kwa Emil Rungu        1
Name: wpt_name, Length: 37057, dtype: int64
```

The column water point name has no impact on the functionality of the wells and with its high number of unique values at 37,400, it will prove bothersome in modeling. We will therefore drop it.

In [50]: ┏ df['basin'].value_counts(dropna=False)

```
Out[50]: Lake Victoria       10154
Pangani             8841
Rufiji              7825
Internal            7766
Lake Tanganyika     6407
Wami / Ruvu         5861
Lake Nyasa           5036
Ruvuma / Southern Coast 4475
Lake Rukwa            2438
Name: basin, dtype: int64
```

The column 'basin' has no missing values and no null or 0 values. We will therefore retain it as it is.

Public_meeting column

In [51]: ┏ df['public_meeting'].value_counts(dropna=False)

```
Out[51]:  True    50556
False    4987
NaN      3260
Name: public_meeting, dtype: int64
```

The column 'public_meeting' has 3260 missing values. We will create a third category called unknown to accomodate the null values.

```
In [52]: df['public_meeting'].fillna('unknown', inplace=True)
df['public_meeting'].value_counts()
```

```
Out[52]: True      50556
False     4987
unknown   3260
Name: public_meeting, dtype: int64
```

```
In [53]: df['recorded_by'].value_counts()
```

```
Out[53]: GeoData Consultants Ltd    58803
Name: recorded_by, dtype: int64
```

The column 'recorded_by' contains only one value for all the values. It is therefore not important in modeling and we'll drop it.

Permit column

```
In [54]: df['permit'].value_counts(dropna=False)
```

```
Out[54]: True      38406
False     17351
NaN       3046
Name: permit, dtype: int64
```

The column 'permit' which indicated whether a waterpoint is permitted or not has 3046 missing values. We'll create a third category of unknown to contain these records.

```
In [55]: df['permit'].fillna('unknown', inplace=True)
df['permit'].value_counts()
```

```
Out[55]: True      38406
False     17351
unknown   3046
Name: permit, dtype: int64
```

Scheme_name column

```
In [56]: df['scheme_name'].value_counts(dropna=False, normalize=True)
```

```
Out[56]: NaN              0.474993
K                0.011598
None             0.010952
Borehole         0.009234
M                0.006802
...
Zahanati pipeline  0.000017
Mand             0.000017
Shirimatunda water supply 0.000017
Kaseni water supply  0.000017
Windmili system    0.000017
Name: scheme_name, Length: 2677, dtype: float64
```

The column 'scheme_name' has the highest percentage of missing values at 47%. It also has 2696 unique values and the information contained therein has nothing to do with well function. We will therefore drop it.

Extraction_type, extraction_type_group and extraction_type_class columns

```
In [57]: ┌─ df['extraction_type'].value_counts(dropna=False)
```

```
Out[57]: gravity           26454
nira/tanira          8139
other                6358
submersible           4712
swn 80                3661
mono                 2849
india mark ii         2387
afridev               1753
ksb                  1373
other - rope pump    423
other - swn 81        229
windmill              117
india mark iii        97
cemo                  90
other - play pump    79
walimi                48
climax                32
other - mkulima/shinyanga  2
Name: extraction_type, dtype: int64
```

```
In [58]: ┌─ df['extraction_type_group'].value_counts(dropna=False)
```

```
Out[58]: gravity           26454
nira/tanira          8139
other                6358
submersible           6085
swn 80                3661
mono                 2849
india mark ii         2387
afridev               1753
rope pump             423
other handpump        358
other motorpump       122
wind-powered          117
india mark iii        97
Name: extraction_type_group, dtype: int64
```

In [59]: ┏ df['extraction_type_class'].value_counts(dropna=False)

```
Out[59]: gravity           26454
handpump          16395
other             6358
submersible       6085
motorpump         2971
rope pump         423
wind-powered      117
Name: extraction_type_class, dtype: int64
```

The three columns extraction_type, extraction_type_group and extraction_type class all contain similar information. We will retain the extraction_type_group column as it contains more categories and thus more data than extraction_type class and is cleaner than extraction_type

Scheme_management, management and management_group columns

In [60]: ┏ df['scheme_management'].value_counts(dropna=False)

```
Out[60]: VWC            36528
WUG            5158
NaN            3819
Water authority    3114
WUA            2825
Water Board      2725
Parastatal       1655
Private operator   1024
Company          1023
Other             764
SWC              97
Trust             70
None              1
Name: scheme_management, dtype: int64
```

In [61]: ┏ df['management'].value_counts(dropna=False)

```
Out[61]: vwc            40209
wug            6427
water board     2910
wua            2498
private operator  1883
parastatal      1743
water authority   898
other            832
company          681
unknown          547
other - school    99
trust             76
Name: management, dtype: int64
```

In [62]: ┆ df['management_group'].value_counts(dropna=False)

```
Out[62]: user-group    52044
          commercial   3538
          parastatal    1743
          other         931
          unknown       547
Name: management_group, dtype: int64
```

The columns scheme_management, management and management_group also contain similar information. We will retain the management column as it contains more information than management group and it does not have null values. We'll replace the other - school category in this column by school

In [63]: ┆ #Replacing other - school category in management with school
df['management'] = df['management'].replace(to_replace = ('other - schc
df['management'].value_counts()

```
Out[63]: vwc            40209
          wug            6427
          water board    2910
          wua            2498
          private operator 1883
          parastatal     1743
          water authority 898
          other           832
          company         681
          unknown          547
          school           99
          trust             76
Name: management, dtype: int64
```

Payment and payment_type columns

In [64]: ┆ df['payment'].value_counts(dropna=False)

```
Out[64]: never pay      25176
          pay per bucket  8886
          pay monthly      8202
          unknown          8018
          pay when scheme fails 3860
          pay annually     3612
          other             1049
Name: payment, dtype: int64
```

In [65]: ┏ df['payment_type'].value_counts(dropna=False)

```
Out[65]: never pay      25176
          per bucket     8886
          monthly        8202
          unknown        8018
          on failure     3860
          annually       3612
          other           1049
Name: payment_type, dtype: int64
```

The columns payment and payment_type also contain similar data. We will keep payment_type column and drop the payment column as it has cleaner categories.

Quantity and quantity_group columns

In [66]: ┏ df['quantity'].value_counts(dropna=False)

```
Out[66]: enough        32763
          insufficient  15046
          dry            6212
          seasonal       4029
          unknown         753
Name: quantity, dtype: int64
```

In [67]: ┏ df['quantity_group'].value_counts(dropna=False)

```
Out[67]: enough        32763
          insufficient  15046
          dry            6212
          seasonal       4029
          unknown         753
Name: quantity_group, dtype: int64
```

The two columns quantity and quantity_group also contain similar columns and identical categories. We will therefore retain quantity and drop quantity_group.

Water_quality and quality_group

In [68]: ┏ df['water_quality'].value_counts(dropna=False)

```
Out[68]: soft           50304
          salty          4823
          unknown         1836
          milky          802
          coloured        485
          salty abandoned 337
          fluoride         199
          fluoride abandoned 17
Name: water_quality, dtype: int64
```

```
In [69]: ┌ df['quality_group'].value_counts(dropna=False)
```

```
Out[69]: good      50304
          salty     5160
          unknown   1836
          milky     802
          colored    485
          fluoride   216
Name: quality_group, dtype: int64
```

The columns water_quality and quality_group have similar information. We will therefore keep water_quality column as it has more information and drop quality_group column

Source, source_type and source_class columns

```
In [70]: ┌ df['source'].value_counts(dropna=False)
```

```
Out[70]: spring           16834
          shallow well     16740
          machine dbh       10958
          river             9464
          rainwater harvesting 2249
          hand dtw           872
          lake               759
          dam                654
          other              207
          unknown             66
Name: source, dtype: int64
```

```
In [71]: ┌ df['source_type'].value_counts(dropna=False)
```

```
Out[71]: spring           16834
          shallow well     16740
          borehole          11830
          river/lake        10223
          rainwater harvesting 2249
          dam                654
          other              273
Name: source_type, dtype: int64
```

```
In [72]: ┌ df['source_class'].value_counts(dropna=False)
```

```
Out[72]: groundwater     45404
          surface          13126
          unknown           273
Name: source_class, dtype: int64
```

This is also another set of 3 columns(source, source_type and source_class) with similar information. We will keep the source column and drop the rest as it contains more information.

Waterpoint_type and waterpoint_type_group columns

In [73]: df['waterpoint_type'].value_counts(dropna=False)

```
Out[73]: communal standpipe      28166
hand pump                      17395
other                           6311
communal standpipe multiple    6033
improved spring                  775
cattle trough                     116
dam                             7
Name: waterpoint_type, dtype: int64
```

In [74]: df['waterpoint_type_group'].value_counts(dropna=False)

```
Out[74]: communal standpipe      34199
hand pump                      17395
other                           6311
improved spring                  775
cattle trough                     116
dam                             7
Name: waterpoint_type_group, dtype: int64
```

These two columns, waterpoint_type and waterpoint_type_group also contain similar information. We will retain the waterpoint_type_group column and drop the waterpoint_type column.

In [75]: #Dropping columns

```
to_be_dropped = ['id', 'installer', 'date_recorded', 'wpt_name', 'num_p
                 'management_group', 'scheme_name', 'extraction_type',
                 'quantity_group', 'quality_group', 'source_type', 'so
                 'construction_year', 'date_of_record']

df = df.drop(to_be_dropped, axis=1)
df.head()
```

Out[75]:

	status_group	amount_tsh	funder	gps_height	longitude	latitude	basin	su
0	functional	6000.0	R C Church	1390	34.938093	-9.856322	Lake Nyasa	N
1	functional	0.0	Other	1399	34.698766	-2.147466	Lake Victoria	V
2	functional	25.0	Other	686	37.460664	-3.821329	Pangani	I
3	non functional	0.0	Unicef	263	38.486161	-11.155298	Ruvuma / Southern Coast	Mah
4	functional	0.0	Other	0	31.130847	-1.825359	Lake Victoria	Kya

5 rows × 24 columns

Subvillage, Iga and ward columns

In [76]: ┌ df['subvillage'].value_counts(dropna=False)

```
Out[76]: Madukani      504
Shuleni       503
Majengo       501
Kati          371
NaN           369
...
Ivugula Juu    1
Mwabung'Ando   1
Ibanga         1
Mtajuma        1
Damaygwa       1
Name: subvillage, Length: 19206, dtype: int64
```

In [77]: ┌ df['ward'].value_counts(dropna=False)

```
Out[77]: Igosi        307
Imalinyi      252
Mdandu         231
Siha Kati     224
Nduruma        217
...
Ukata          1
Kirongo        1
Rasbura        1
Linda          1
Kitete          1
Name: ward, Length: 2090, dtype: int64
```

In [78]: ┌ df['lga'].value_counts(dropna=False)

```
Out[78]: Njombe        2442
Arusha Rural   1252
Moshi Rural    1251
Bariadi        1175
Rungwe          1106
...
Moshi Urban    79
Kigoma Urban   71
Arusha Urban   63
Lindi Urban    21
Nyamagana       1
Name: lga, Length: 125, dtype: int64
```

The three columns subvillage, ward and lga contain geographical information. However, they have very many categories at 19287, 2092 and 125 respectively. Before we start selecting the topmost categories, we will explore other columns with geographical information to select the most relevant.

Region, region_code and district_code

In [79]: ┌ df['region'].value_counts(dropna=False)

```
Out[79]: Iringa      5213
Shinyanga    4980
Mbeya        4639
Kilimanjaro  4326
Morogoro     3910
Kagera       3316
Arusha       3311
Mwanza       3074
Kigoma       2792
Ruvuma       2597
Pwani        2527
Tanga        2523
Dodoma       2201
Singida      2093
Tabora       1959
Mara         1905
Rukwa        1791
Mtwara       1723
Manyara      1575
Lindi         1543
Dar es Salaam 805
Name: region, dtype: int64
```

In [80]: ┌ df['region_code'].value_counts(dropna=False)

```
Out[80]: 11      5219
17      5009
12      4639
3       4326
5       3944
18      3324
19      3019
2       2985
16      2792
10      2597
4       2489
1       2201
13      2093
14      1979
20      1905
15      1791
21      1575
6       1536
80      1236
--      --
```

In [81]: df['district_code'].value_counts(dropna=False)

```
Out[81]: 1    11993
2    11147
3    9886
4    8902
5    4344
6    4037
7    3287
8    1038
30   995
33   865
53   726
43   491
13   391
23   293
63   195
62   109
60   63
0    23
80   12
--   -
```

The above columns region, region_code and district_code have 21, 27 and 20 categories respectively. We'll select region from the above to represent geographical information as it has clear labels and drop the rest of the columns with geographical information.

In [82]: to_be_dropped = ['subvillage', 'lga', 'ward', 'region_code', 'district_code']
df = df.drop(to_be_dropped, axis=1)
df.head()

Out[82]:

	status_group	amount_tsh	funder	gps_height	longitude	latitude	basin	region
0	functional	6000.0	R C Church	1390	34.938093	-9.856322	Lake Nyasa	Iringa
1	functional	0.0	Other	1399	34.698766	-2.147466	Lake Victoria	Mwanza
2	functional	25.0	Other	686	37.460664	-3.821329	Pangani	Manyara
3	non functional	0.0	Unicef	263	38.486161	-11.155298	Ruvuma / Southern Coast	Mtvi
4	functional	0.0	Other	0	31.130847	-1.825359	Lake Victoria	Kagera

Longitude and latitude

In [83]: ┌ df['longitude'].value_counts(dropna=False, normalize=True)

```
Out[83]: 0.000000    0.030815
32.982698    0.000034
32.978062    0.000034
32.987670    0.000034
39.088875    0.000034
...
36.871976    0.000017
37.579803    0.000017
33.196490    0.000017
34.017119    0.000017
30.999792    0.000017
Name: longitude, Length: 56921, dtype: float64
```

In [84]: ┌ #Exploring the zero Longitude records further
df.loc[df['longitude'] == 0]

Out[84]:

	status_group	amount_tsh	funder	gps_height	longitude	latitude	bas
21	functional	0.0	Other	0	0.0	-2.000000e-08	Lal Victor
53	non functional	0.0	Government Of Tanzania	0	0.0	-2.000000e-08	Lal Victor
168	functional	0.0	Other	0	0.0	-2.000000e-08	Lal Victor
177	non functional	0.0	Other	0	0.0	-2.000000e-08	Lal Victor
253	functional needs repair	0.0	Hesawa	0	0.0	-2.000000e-08	Lal Victor
...
59189	functional needs repair	0.0	Other	0	0.0	-2.000000e-08	Lal Victor
59208	functional	0.0	Other	0	0.0	-2.000000e-08	Lal Victor
59295	functional needs repair	0.0	Rwssp	0	0.0	-2.000000e-08	Lal Victor
59324	functional	0.0	World Vision	0	0.0	-2.000000e-08	Lal Victor
59374	functional	0.0	Rwssp	0	0.0	-2.000000e-08	Lal Victor

1812 rows × 19 columns

The longitude column contains approximately 3% of zero values which are not possible based on Tanzania's location. Moreover, the records with zero value for longitude all have the same latitude value of -2e-08. Since all these values are the same and they only account for 3% of the data, we'll drop them so we can use the rest of the data for modeling.

```
In [85]: df = df.loc[df['longitude'] != 0]
df['longitude'].value_counts()
```

```
Out[85]: 33.005032    2
          32.982698    2
          32.978062    2
          32.987670    2
          32.926012    2
          ..
          37.579803    1
          33.196490    1
          34.017119    1
          33.788326    1
          35.005922    1
Name: longitude, Length: 56920, dtype: int64
```

```
In [86]: df['latitude'].value_counts(dropna=False)
```

```
Out[86]: -7.065373    2
          -2.515321    2
          -7.177203    2
          -6.963565    2
          -6.983115    2
          ..
          -1.971113    1
          -10.539785   1
          -9.162589    1
          -4.463114    1
          -2.598965    1
Name: latitude, Length: 56920, dtype: int64
```

Exploration of Features

In [87]: ► df.info()

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 56991 entries, 0 to 59399
Data columns (total 19 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   status_group     56991 non-null   object  
 1   amount_tsh       56991 non-null   float64 
 2   funder           56991 non-null   object  
 3   gps_height       56991 non-null   int64   
 4   longitude        56991 non-null   float64 
 5   latitude         56991 non-null   float64 
 6   basin            56991 non-null   object  
 7   region           56991 non-null   object  
 8   population       56991 non-null   int64   
 9   public_meeting    56991 non-null   object  
 10  permit            56991 non-null   object  
 11  extraction_type_group 56991 non-null   object  
 12  management        56991 non-null   object  
 13  payment_type      56991 non-null   object  
 14  water_quality     56991 non-null   object  
 15  quantity          56991 non-null   object  
 16  source            56991 non-null   object  
 17  waterpoint_type_group 56991 non-null   object  
 18  age_of_well       56991 non-null   int64  
dtypes: float64(3), int64(3), object(13)
memory usage: 8.7+ MB
```

Target: Status Group

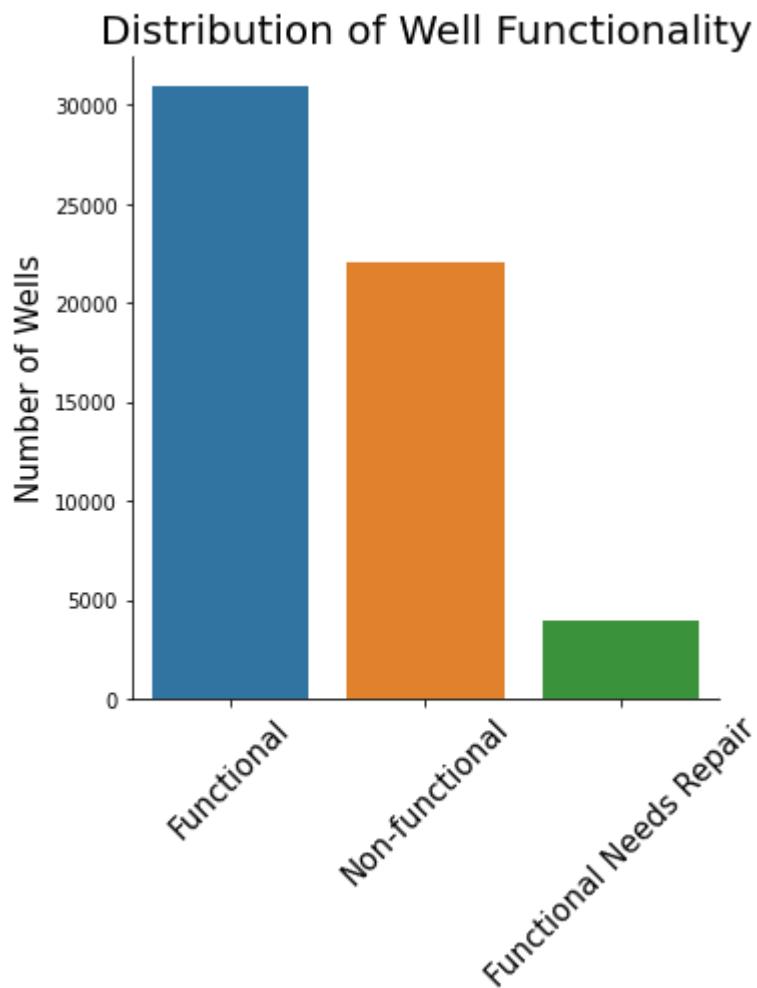
In [88]: ┌ #Visualizing the status group column

```
# plot
ax = sns.catplot(data=df, x='status_group', kind='count', palette='tab1

# Title and y-axis labels
plt.title('Distribution of Well Functionality', fontsize=20)
plt.ylabel('Number of Wells', fontsize=15)
plt.xlabel(' ', fontsize=15)

# X Labels
labels = ['Functional', 'Non-functional', 'Functional Needs Repair']
plt.xticks(ticks=(0,1,2), labels=labels, rotation=45, fontsize=15)

plt.show();
```



Slightly more than half of the wells are functional and the minority are functional but need repair. However, there is a significant proportion of wells that aren't functioning.

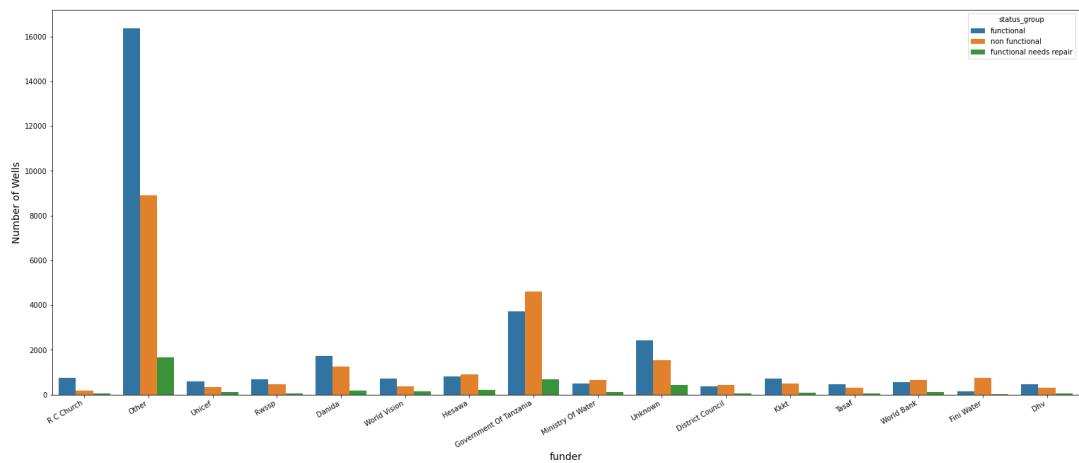
Categorical Variables

In [89]:

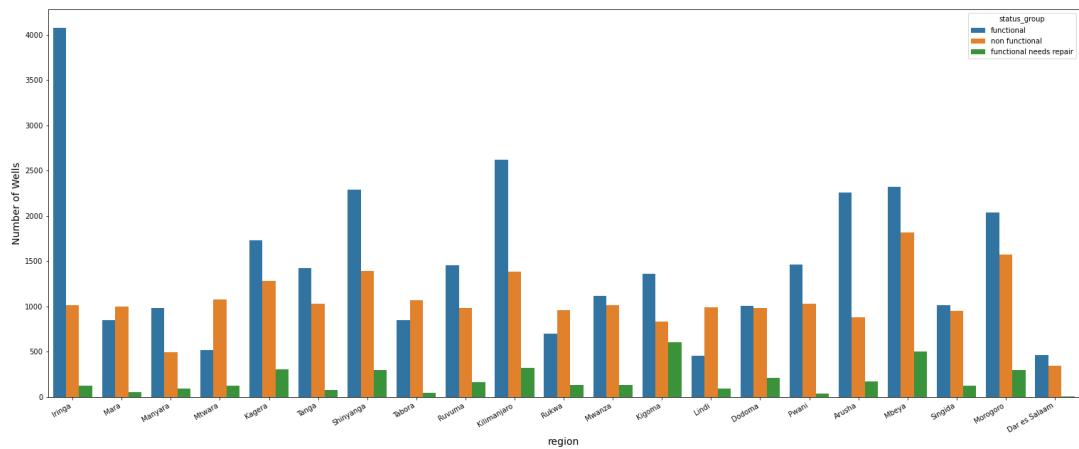
```
features = ['funder', 'region']

for feature in features:
    fig, ax = plt.subplots(figsize=(26, 10))
    ax = sns.countplot(data=df, x=df[feature], hue="status_group", palette="p�")
    fig.suptitle(f"Well {feature} by Functionality", fontsize=18)
    plt.xlabel(f"{feature}", fontsize=14)
    plt.ylabel("Number of Wells", fontsize=14)
    plt.xticks(rotation=30, ha='right')
    plt.show();
```

Well funder by Functionality



Well region by Functionality



The Government of Tanzania is one of the biggest funders of wells along with the Roman Catholic Church and Danida.

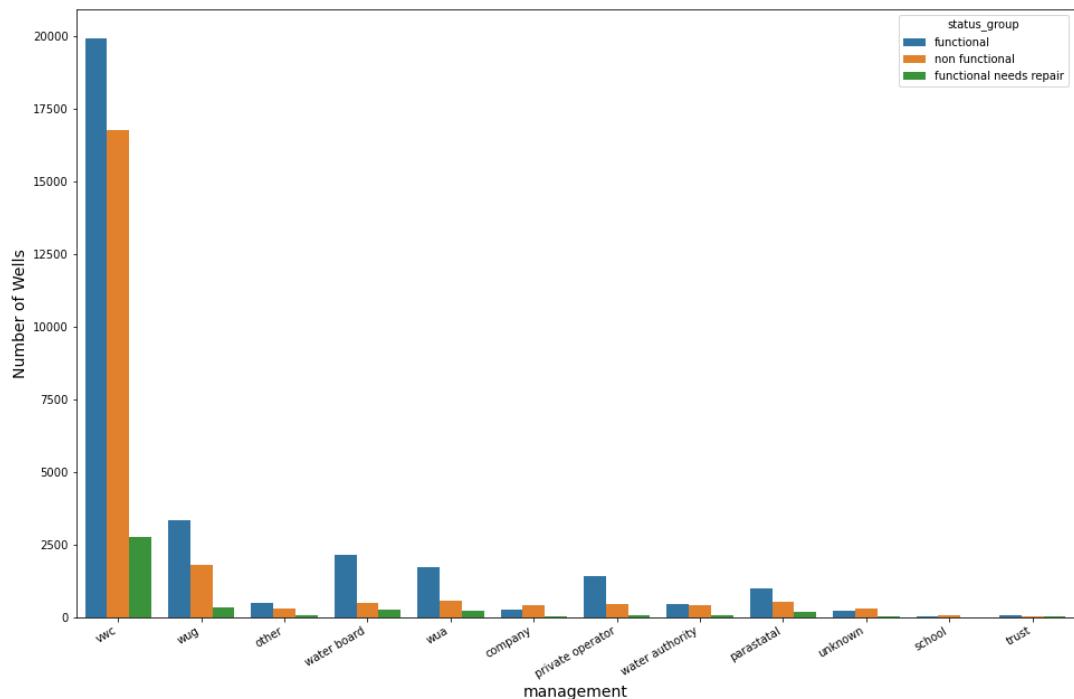
Most of the wells funded by the Government of Tanzania are non functional, while for the rest of the funders, there is a bigger proportion of functional wells compared to the non functional ones

Mtwara region and Lindi region stand out for having a higher proportion of non functional wells compared to the functional ones.

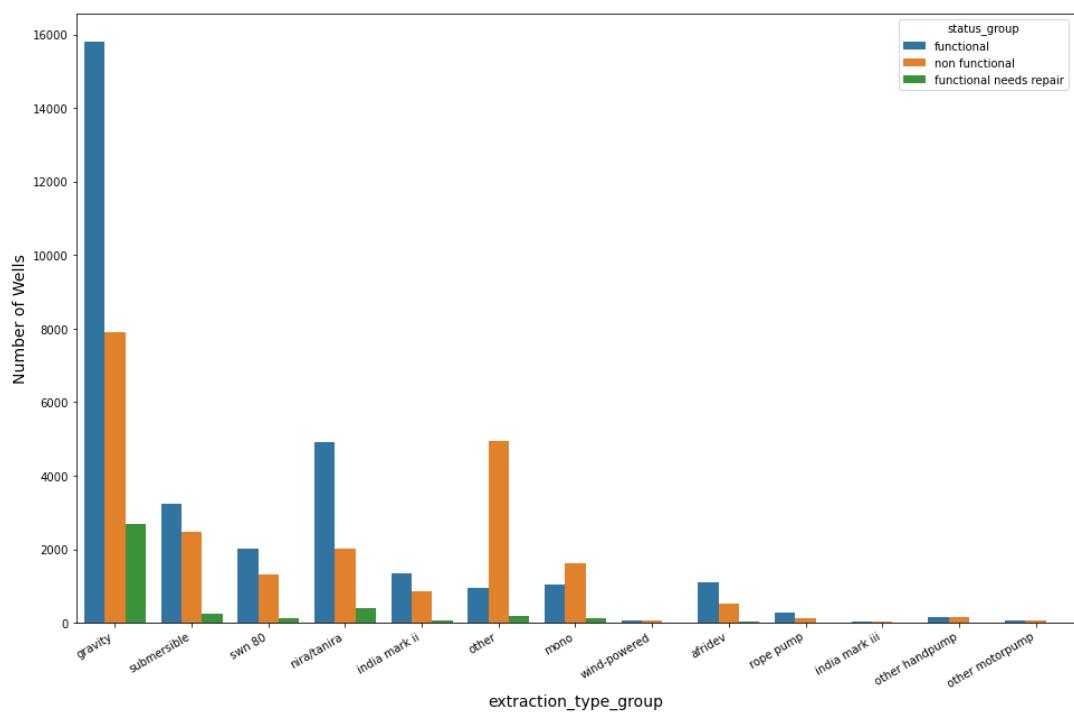
```
In [90]: ┌ features = ['management', 'extraction_type_group']

for feature in features:
    fig, ax = plt.subplots(figsize=(16,10))
    ax = sns.countplot(data=df, x=df[feature], hue="status_group", palette='pale雅色')
    fig.suptitle(f"Well {feature} by Functionality", fontsize=18)
    plt.xlabel(f"{feature}", fontsize=14)
    plt.ylabel("Number of Wells", fontsize=14)
    plt.xticks(rotation=30, ha='right')
    plt.show();
```

Well management by Functionality



Well extraction_type_group by Functionality

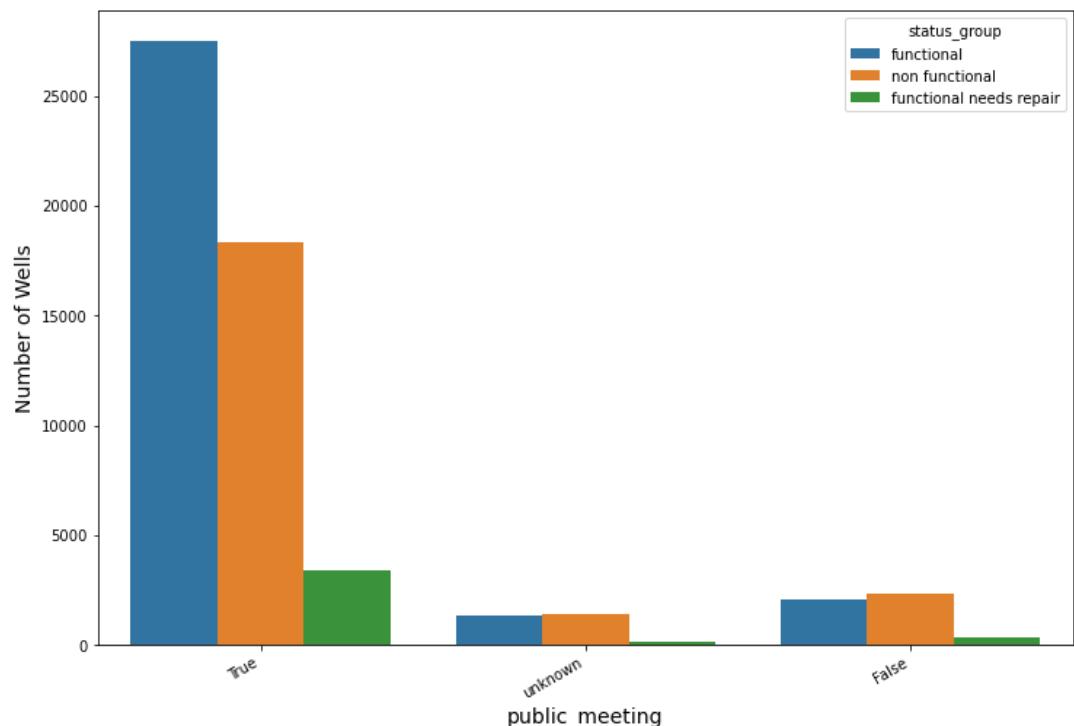


Wells managed by company and school have a higher proportion of non functional wells

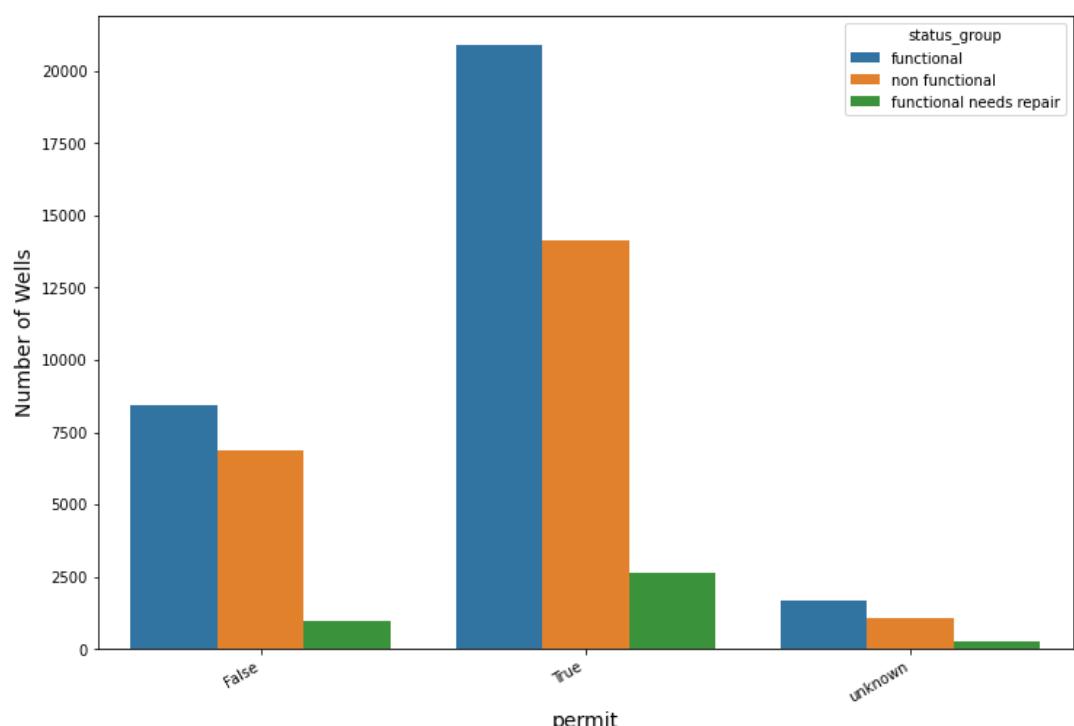
```
In [91]: ┏ features = ['public_meeting', 'permit', 'basin']

for feature in features:
    fig, ax = plt.subplots(figsize=(12, 8))
    ax = sns.countplot(data=df, x=df[feature], hue="status_group", palette='pale雅色')
    fig.suptitle(f"Well {feature} by Functionality", fontsize=18)
    plt.xlabel(f"{feature}", fontsize=14)
    plt.ylabel("Number of Wells", fontsize=14)
    plt.xticks(rotation=30, ha='right')
    plt.show();
```

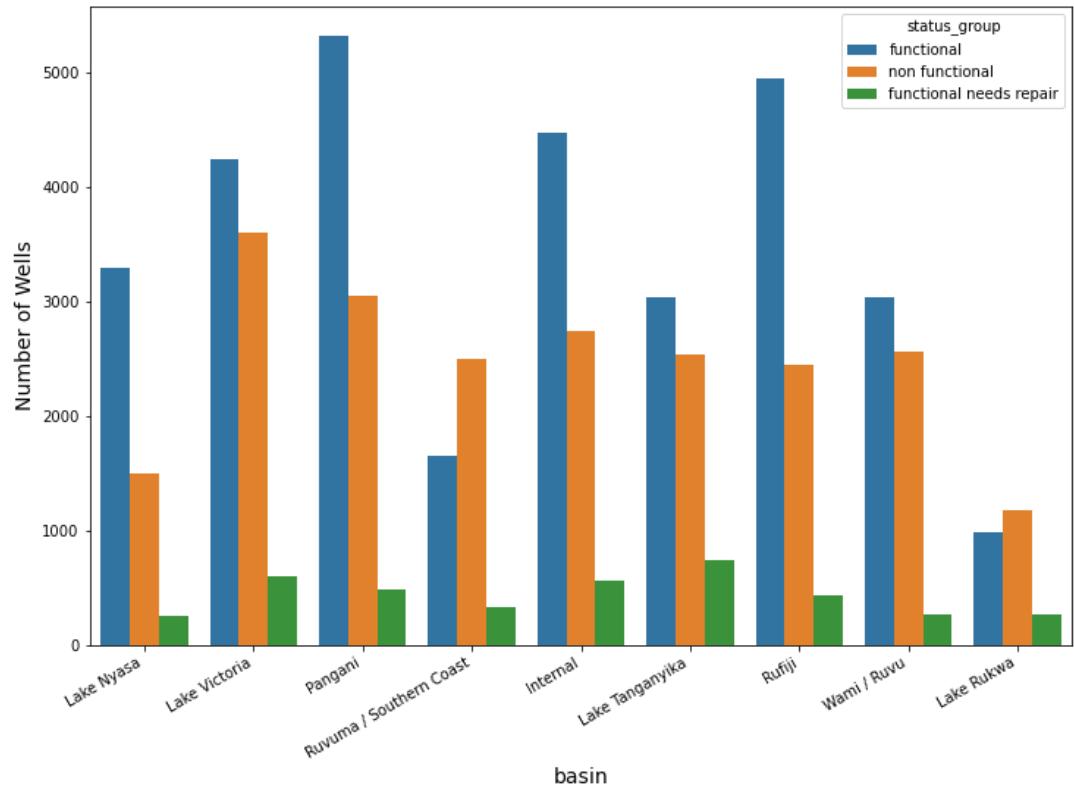
Well public_meeting by Functionality



Well permit by Functionality



Well basin by Functionality



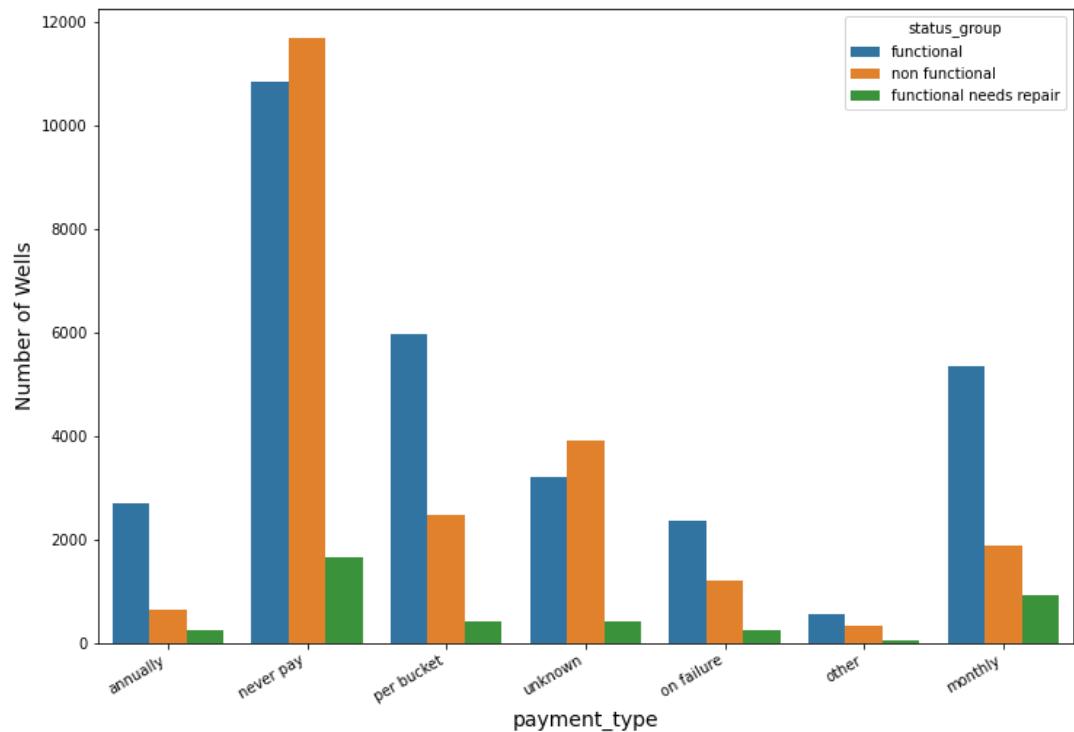
Wells where public meetings are held have a higher proportion of functional wells vs non functional ones whereas where there are no public meetings, more wells are non functional than functional

A higher proportion of non functional wells compared to functional wells are found in Ruvuma/Southern Coast and Lake Rukwa basin

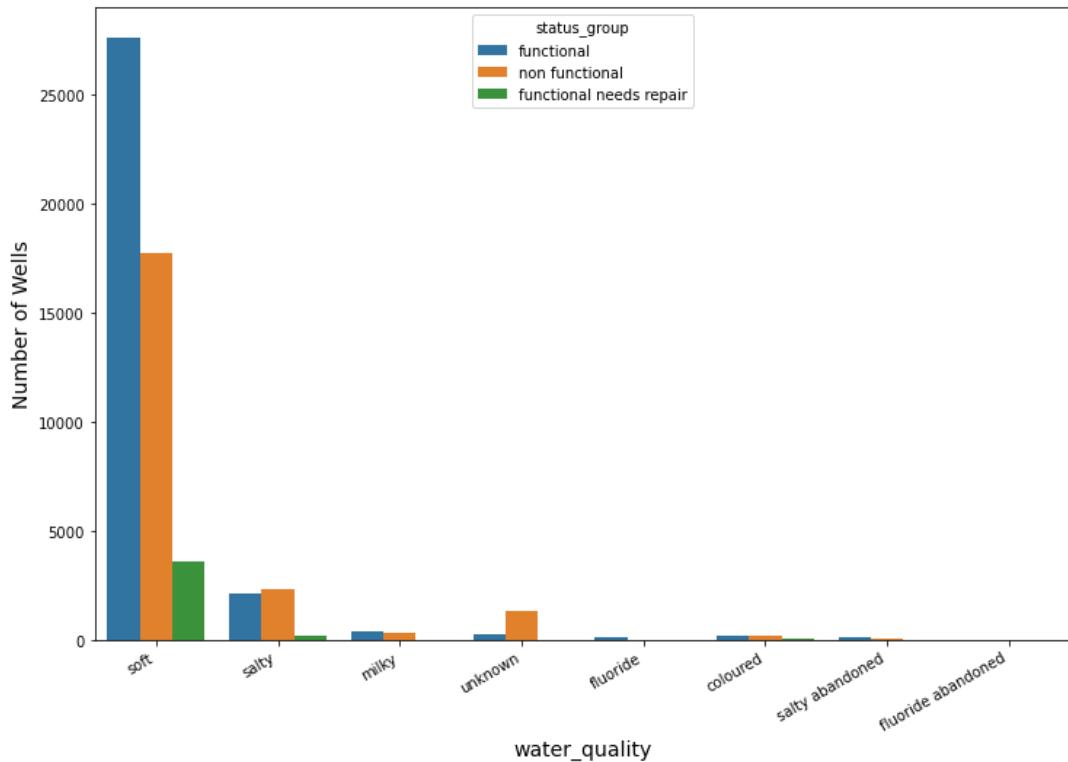
```
In [92]: ┏ features = ['payment_type', 'water_quality', 'quantity', 'source', 'water_level']

for feature in features:
    fig, ax = plt.subplots(figsize=(12, 8))
    ax = sns.countplot(data=df, x=df[feature], hue="status_group", palette='magma')
    fig.suptitle(f"Well {feature} by Functionality", fontsize=18)
    plt.xlabel(f"{feature}", fontsize=14)
    plt.ylabel("Number of Wells", fontsize=14)
    plt.xticks(rotation=30, ha='right')
    plt.show();
```

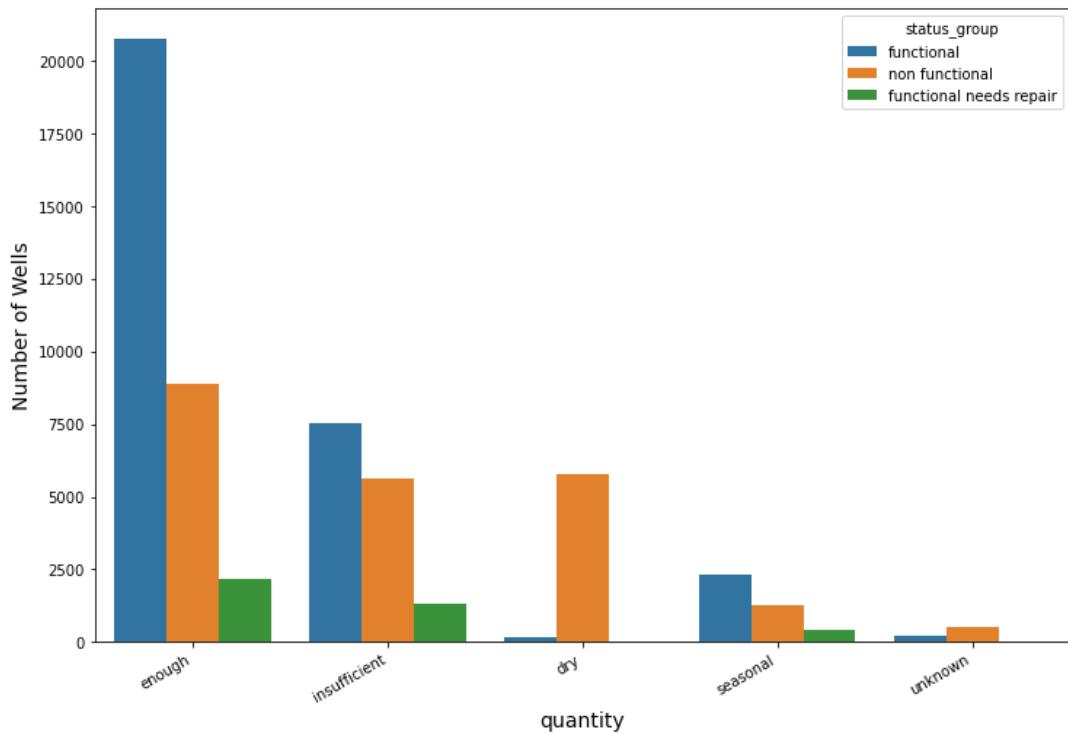
Well payment_type by Functionality



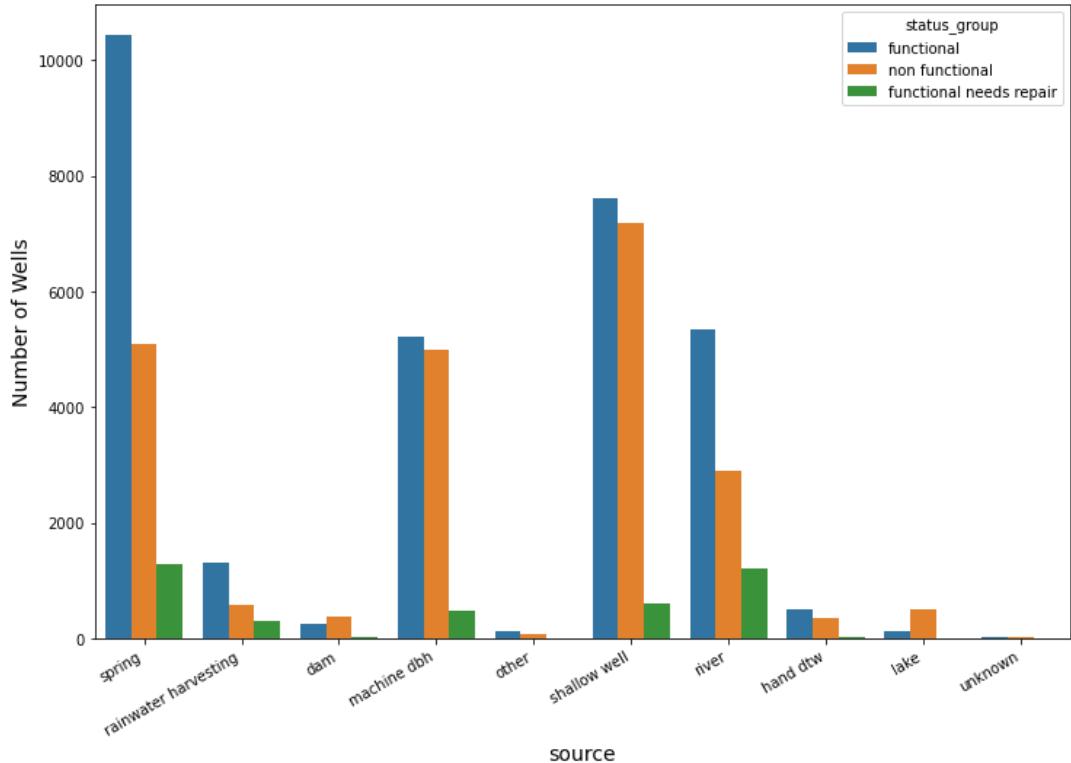
Well water_quality by Functionality



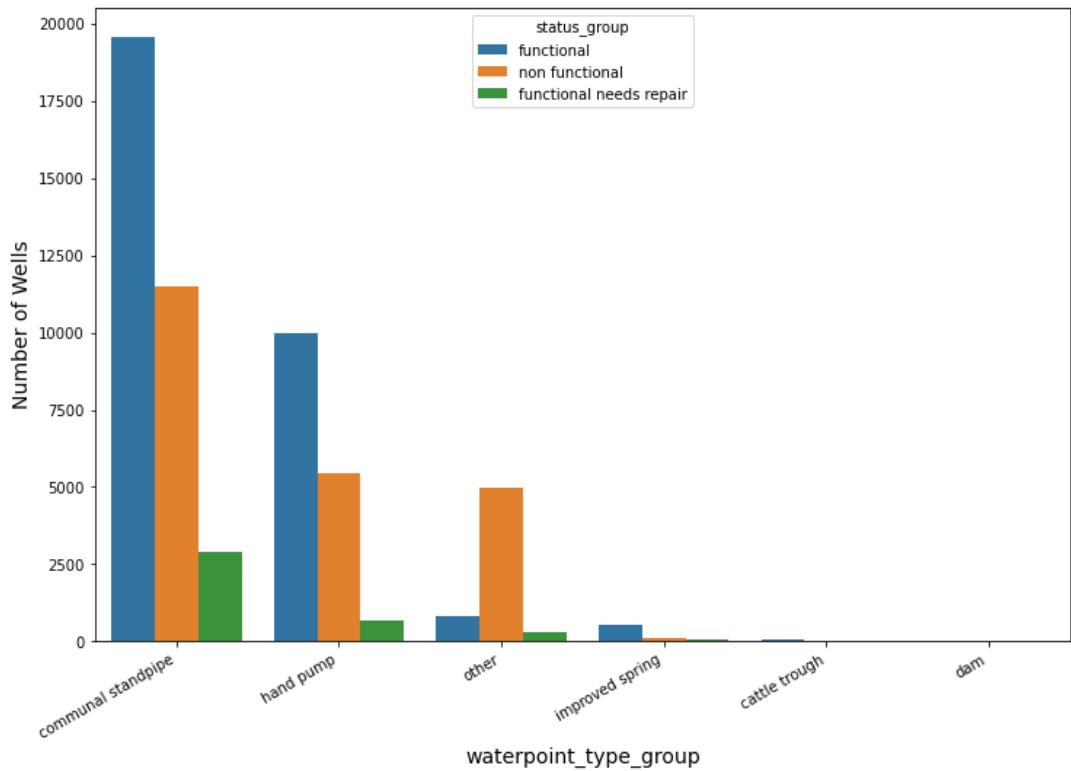
Well quantity by Functionality



Well source by Functionality



Well waterpoint_type_group by Functionality



Where no payments are made or payment details are unknown there is a higher proportion of non functional wells compared to the functional ones.

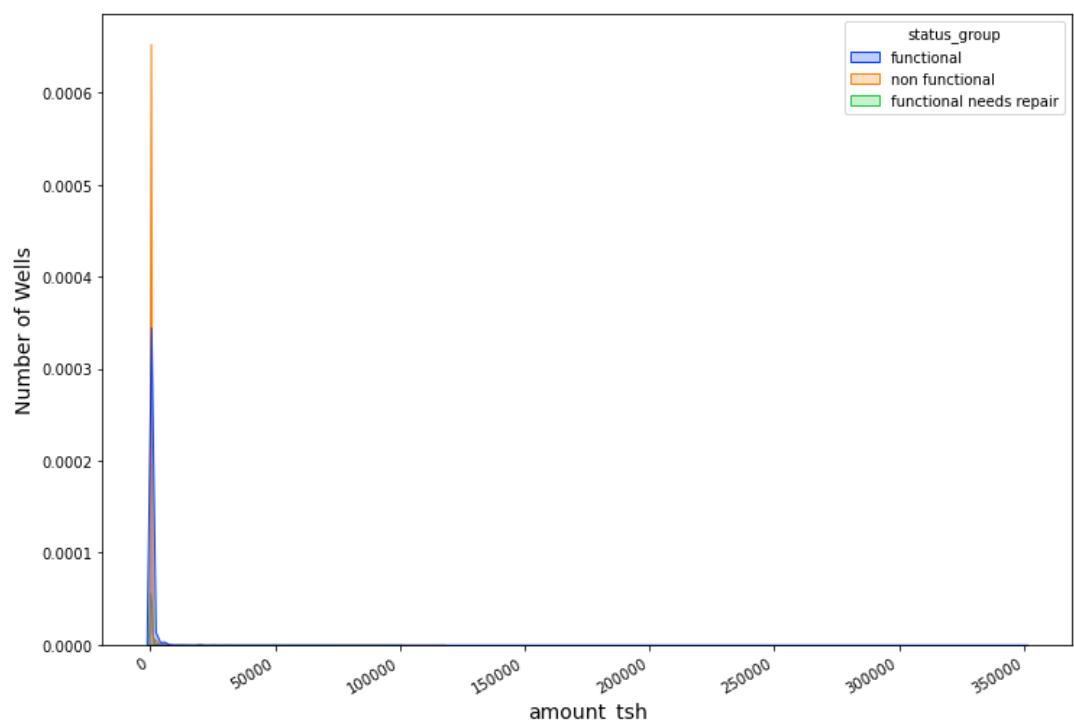
There are more non functional wells than functional ones where the source is dam or lake

Most of the wells known to be dry are non-functional

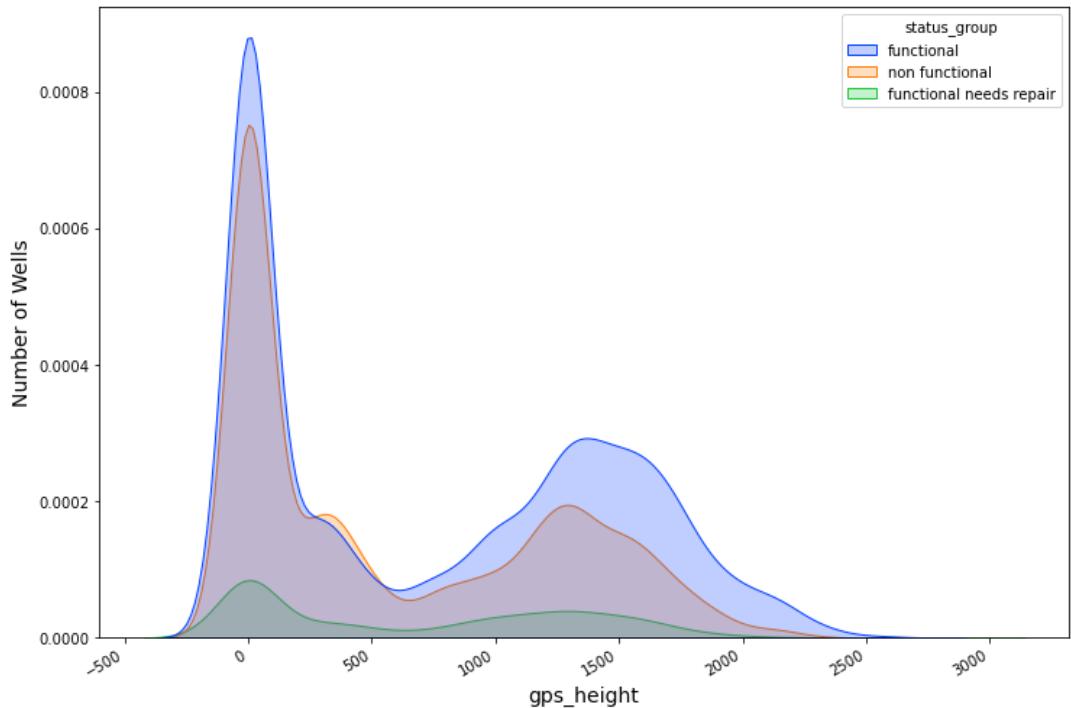
Numerical Variables

```
In [93]: ┏ features = ['amount_tsh', 'gps_height', 'population', 'age_of_well']
  ┏ for feature in features:
  ┏   fig, ax = plt.subplots(figsize=(12, 8))
  ┏   ax = sns.kdeplot(data=df, x=df[feature], fill=True, hue="status_group")
  ┏   fig.suptitle(f"Well {feature} by Functionality", fontsize=18)
  ┏   plt.xlabel(f"{feature}", fontsize=14)
  ┏   plt.ylabel("Number of Wells", fontsize=14)
  ┏   plt.xticks(rotation=30, ha='right')
  ┏   plt.show();
```

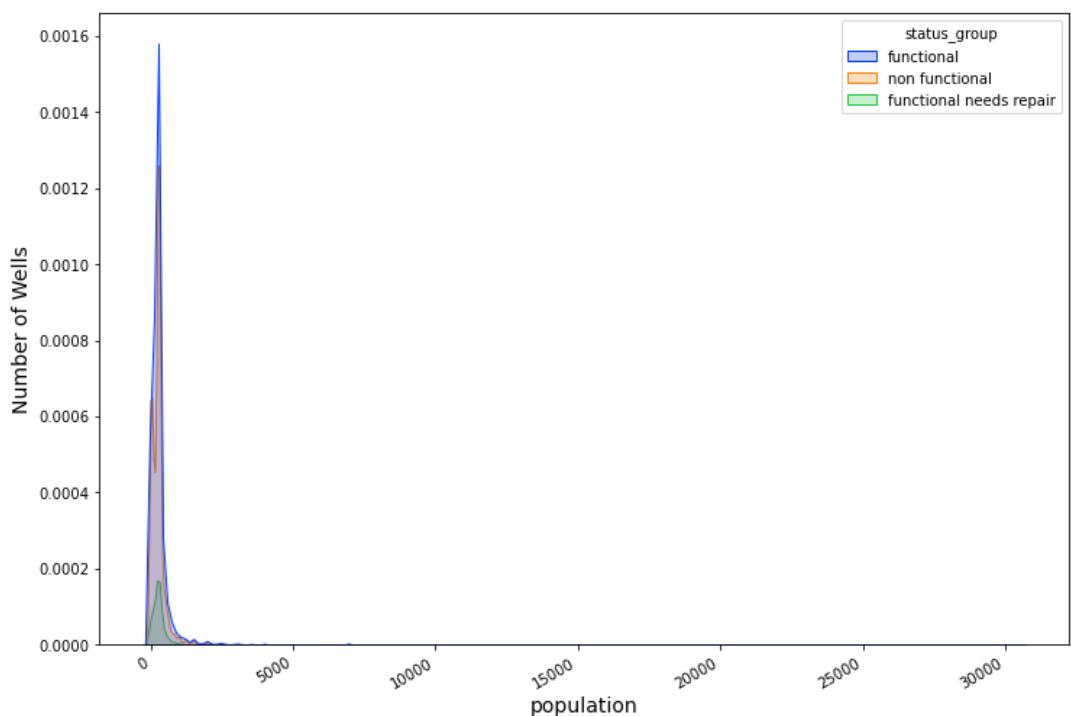
Well amount_tsh by Functionality



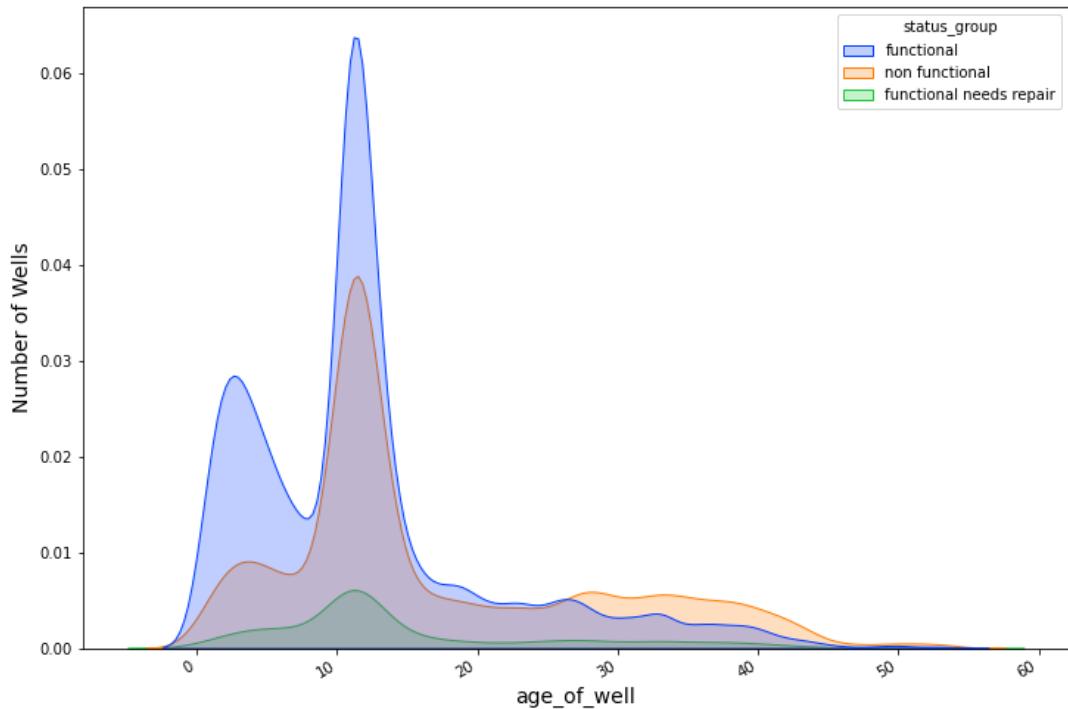
Well gps_height by Functionality



Well population by Functionality



Well age_of_well by Functionality



There is a higher proportion of functional wells between 0 and 15 years and a higher proportion of non functional wells from 30 years of age onwards.

Modeling

Data Preprocessing

We start by encoding the target variable to be able to model it.

```
In [94]: ┏ #Converting the target variable into a ternary variable
  vals = {'functional':1,
          'non functional': 0,
          'functional needs repair': 2}
  df['status_group'] = df['status_group'].replace(vals)
```

We'll then make a copy of our dataset to use in modeling and separate the X and y values.

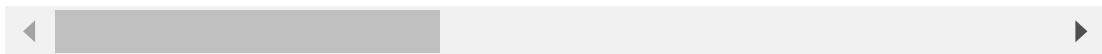
We'll also drop the longitude and latitude columns from the dataframe copy for modeling

```
In [95]: ┏ #Making a copy of our dataset
  df_model = df.copy()
```

In [96]: #Dropping the Longitude and Latitude columns
df_model = df_model.drop(columns=['longitude', 'latitude'], axis=1)
df_model.head()

Out[96]:

	status_group	amount_tsh	funder	gps_height	basin	region	population	public
0	1	6000.0	R C Church	1390	Lake Nyasa	Iringa	109	
1	1	0.0	Other	1399	Lake Victoria	Mara	280	
2	1	25.0	Other	686	Pangani	Manyara	250	
3	0	0.0	Unicef	263	Ruvuma / Southern Coast	Mtwara	58	
4	1	0.0	Other	0	Lake Victoria	Kagera	281	



We'll first identify the categorical and numerical columns for ease of one hot encoding

In [97]: cat_cols = ['funder', 'basin', 'region', 'public_meeting', 'permit', 'extraction_type_group', 'management', 'payment_type', 'water_quantity', 'source', 'waterpoint_type_group']
num_cols = ['amount_tsh', 'gps_height', 'population', 'age_of_well']

In [98]: dummy = pd.get_dummies(df_model, columns=cat_cols, drop_first=True)
dummy.shape

Out[98]: (56991, 106)

In [99]: #Defining the features and target
y = dummy['status_group']
X = dummy.drop(columns=['status_group'], axis=1)

In [100]: y.head()

Out[100]: 0 1
1 1
2 1
3 0
4 1
Name: status_group, dtype: int64

We'll then split the data before we carry out any further transformations to prevent data leakage. For the purposes of splitting, we'll use the test_size 0.25 and random_state 42

```
In [101]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2)
```

```
In [102]: #Scaling the training and test data
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
```

```
In [103]: X_train_scaled = pd.DataFrame(X_train_scaled, columns=X_train.columns)
X_train_scaled.head()
X_test_scaled = pd.DataFrame(X_test_scaled, columns=X_test.columns)
X_test_scaled.head()
```

Out[103]:

	amount_tsh	gps_height	population	age_of_well	funder_Dhv	funder_District Council	funder_Council	funder_District	funder_Council
0	-0.102852	0.215929	-0.495843	-0.019698	-0.119622	-0.1229	-0.1229	-0.1229	-0.1229
1	-0.104426	-0.992250	-0.001172	-0.309192	-0.119622	-0.1229	-0.1229	-0.1229	-0.1229
2	0.052952	1.101544	-0.485136	-0.405690	-0.119622	-0.1229	-0.1229	-0.1229	-0.1229
3	-0.104426	-0.528563	0.896087	-0.019698	8.359660	-0.1229	-0.1229	-0.1229	-0.1229
4	-0.104426	-0.992250	-0.001172	-0.309192	-0.119622	-0.1229	-0.1229	-0.1229	-0.1229

5 rows × 105 columns

Fitting the Models

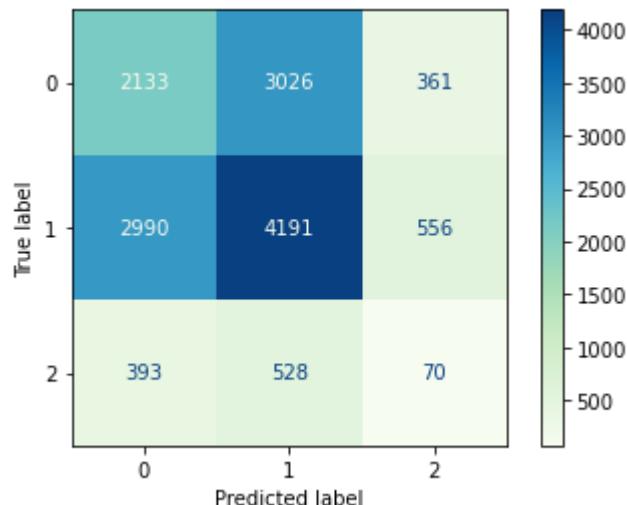
Dummy Model

We'll start by fitting a dummy classifier somewhat equal to guessing as a baseline model that we can how the rest of our models perform with.

```
In [104]: ┏ dummy = DummyClassifier(random_state=42)
dummy.fit(X_train, y_train)
print(dummy.score(X_test, y_test))

plot_confusion_matrix(dummy, X_test, y_test, cmap='GnBu');
```

0.4487647389107243



Our dummy model has an accuracy score of 0.448 which means it makes correct predictions 44% of the times. This is worse than random guessing.

To make evaluation of our models easier, we'll define an evaluation score function based on scikit learn's classification report, that also plots a confusion matrix.

```
In [105]: ┏ def eval_score(model, X, y_pred, y_true):
    target_labels= ['non_func', 'func', 'func need rep']
    print(classification_report(y_true, y_pred, target_names=target_labels))

    #Confusion matrix
    return plot_confusion_matrix(model, X, y_true, display_labels=target_labels)
```

Logistic Regression

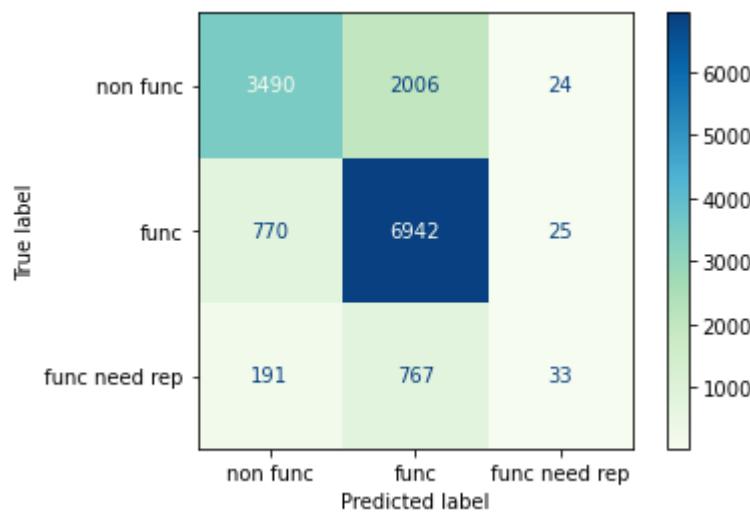
```
In [106]: ┏ #Fitting a Simple Logistic Regression Model
#Instantiating the model
log_base = LogisticRegression(multi_class='multinomial', random_state=42)
#fitting the model on training and testing data
log_base.fit(X_train_scaled, y_train)
```

Out[106]: LogisticRegression(multi_class='multinomial', random_state=42)

```
In [107]: ┏ y_hat_train = log_base.predict(X_train_scaled)
y_preds = log_base.predict(X_test_scaled)
```

```
In [108]: ┌─ print("Log_base model score:")
  log_base_score = eval_score(log_base, X_test_scaled, y_preds, y_test)
```

Log_base model score:					
	precision	recall	f1-score	support	
non func	0.78	0.63	0.70	5520	
func	0.71	0.90	0.80	7737	
func need rep	0.40	0.03	0.06	991	
accuracy			0.73	14248	
macro avg	0.63	0.52	0.52	14248	
weighted avg	0.72	0.73	0.71	14248	



```
In [109]: ┌─ print('Logistic Baseline Training Accuracy: ', accuracy_score(y_train,
  print('Logistic Bseline Validation Accuracy: ', accuracy_score(y_test,
```

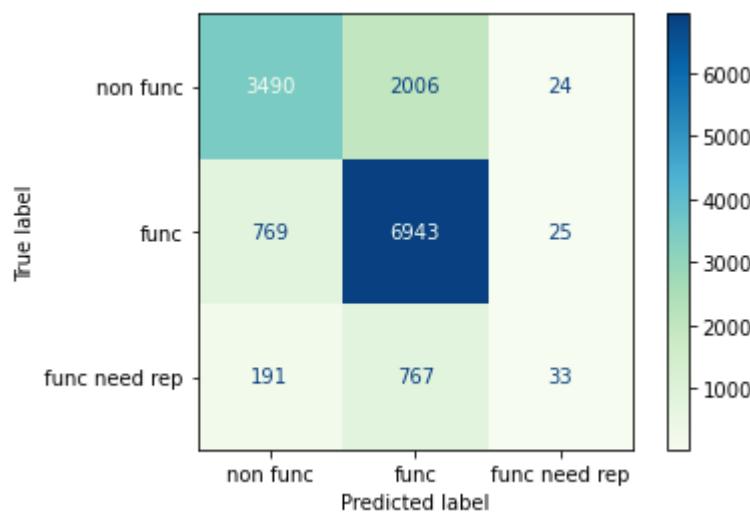
```
Logistic Baseline Training Accuracy:  0.738366516154692
Logistic Bseline Validation Accuracy:  0.7344890510948905
```

Our simple logistic regression model has an accuracy of 0.738. This means that it is predicting correctly 73% of the time. This is not bad for a vanilla model without any tuning.

We'll tune it further by adding an intercept and setting a high regularization parameter to see how it will perform

```
In [110]: ┆ log_reg = LogisticRegression(multi_class='multinomial', fit_intercept=T
log_reg.fit(X_train_scaled, y_train)
y_hat_train = log_reg.predict(X_train_scaled)
y_hat_test = log_reg.predict(X_test_scaled)
print("Log_reg model score:")
log_reg_score = eval_score(log_reg, X_test_scaled, y_hat_test, y_test)
```

	precision	recall	f1-score	support
non func	0.78	0.63	0.70	5520
func	0.71	0.90	0.80	7737
func need rep	0.40	0.03	0.06	991
accuracy			0.73	14248
macro avg	0.63	0.52	0.52	14248
weighted avg	0.72	0.73	0.71	14248



```
In [111]: ┆ print('Logistic Tuned Training Accuracy: ', accuracy_score(y_train, y_h
print('Logistic Tuned Validation Accuracy: ', accuracy_score(y_test, y_
```

Logistic Tuned Training Accuracy: 0.7382495379360363
 Logistic Tuned Validation Accuracy: 0.7344890510948905

Even with the tuning, our model performance is still the same and our accuracy has remained constant at 0.73

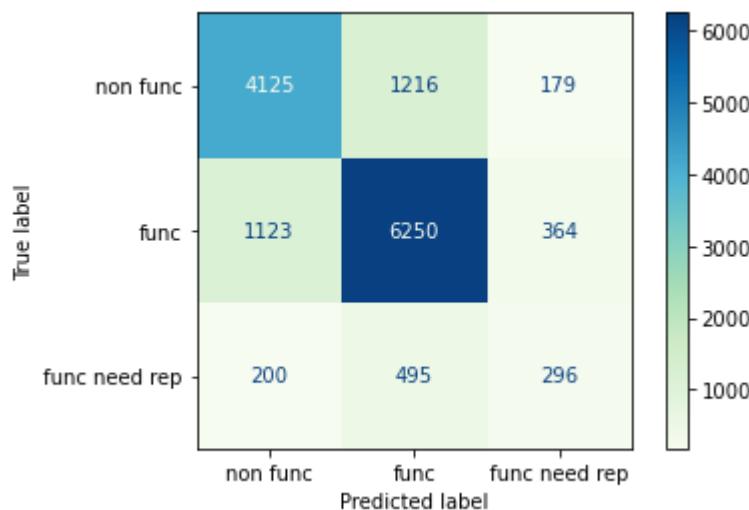
We'll proceed to explore other models to determine which one will fit our data the best and then we can fine tune that particular model.

Decision Trees

```
In [112]: # Instantiating the decision tree classifier
clf_b = DecisionTreeClassifier(criterion='entropy', random_state=42)
# fitting the classifier on training data
# Using the non scaled data since decision trees are not sensitive to di
clf_b.fit(X_train, y_train)
# Predicting on the testing set
y_preds = clf_b.predict(X_test)
# calculating y_hat_train for the eval_score training accuracy
y_hat_train = clf_b.predict(X_train)
```

```
In [113]: # Printing the model score
clf_b_score = eval_score(clf_b, X_test, y_preds, y_test)
```

	precision	recall	f1-score	support
non func	0.76	0.75	0.75	5520
func	0.79	0.81	0.80	7737
func need rep	0.35	0.30	0.32	991
accuracy			0.75	14248
macro avg	0.63	0.62	0.62	14248
weighted avg	0.74	0.75	0.75	14248



```
In [114]: print('CLF Baseline Training Accuracy: ', accuracy_score(y_train, y_hat_train))
print('CLF Baseline Validation Accuracy: ', accuracy_score(y_test, y_preds))
```

CLF Baseline Training Accuracy: 0.9482020447792621
 CLF Baseline Validation Accuracy: 0.7489472206625492

This model has a training accuracy of 0.94 and a validation accuracy of 0.74, which suggests overfitting. We are going to make use of GridSearchCV to find an optimal combination of parameters that we can use to tune the model.

```
In [115]: #Defining the parameter grid
grid = {"criterion": ["gini", "entropy"],
         "max_depth": [None, 2, 5, 10, 20, 30],
         "min_samples_split": [5, 10, 15, 20, 30],
         "min_samples_leaf": [2, 5, 10, 15]}

#Instantiating GridsearchCV
#gs_tree = GridSearchCV(clf_b, grid, cv=5)

# Fit to the data
#gs_tree.fit(X_train, y_train)

#print("Best Parameter Combination:")
#gs_tree.best_params_
```

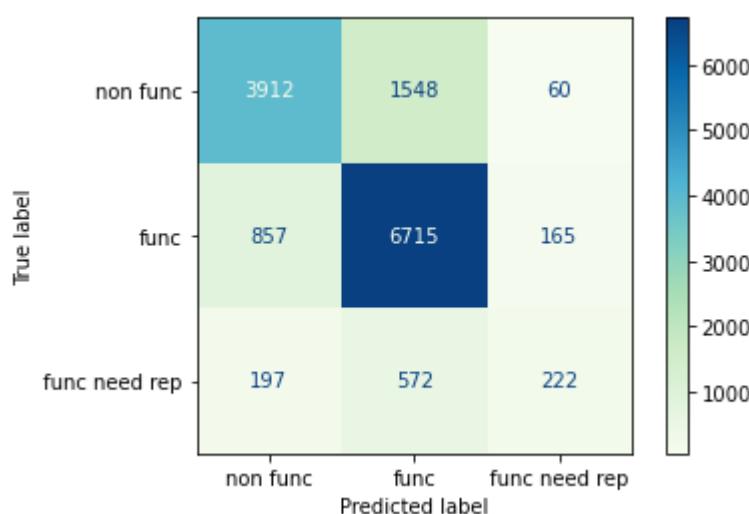
We are going to use the features above produced by GridSearch to tune our model.

Best Parameter Combination: {'criterion': 'entropy', 'max_depth': 20, 'min_samples_leaf': 5, 'min_samples_split': 20}

```
In [116]: clf = DecisionTreeClassifier(criterion='entropy', max_depth=20, min_samples_leaf=5)
clf.fit(X_train, y_train)
y_preds = clf.predict(X_test)
y_hat_train = clf.predict(X_train)
clf_score = eval_score(clf, X_test, y_preds, y_test)
clf_score
```

	precision	recall	f1-score	support
non func	0.79	0.71	0.75	5520
func	0.76	0.87	0.81	7737
func need rep	0.50	0.22	0.31	991
accuracy			0.76	14248
macro avg	0.68	0.60	0.62	14248
weighted avg	0.75	0.76	0.75	14248

Out[116]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1af8a9631c0>



```
In [117]: ┏ print('CLF Tuned Training Accuracy: ', accuracy_score(y_train, y_hat_tr  
print('CLF Tuned Validation Accuracy: ', accuracy_score(y_test, y_preds
```

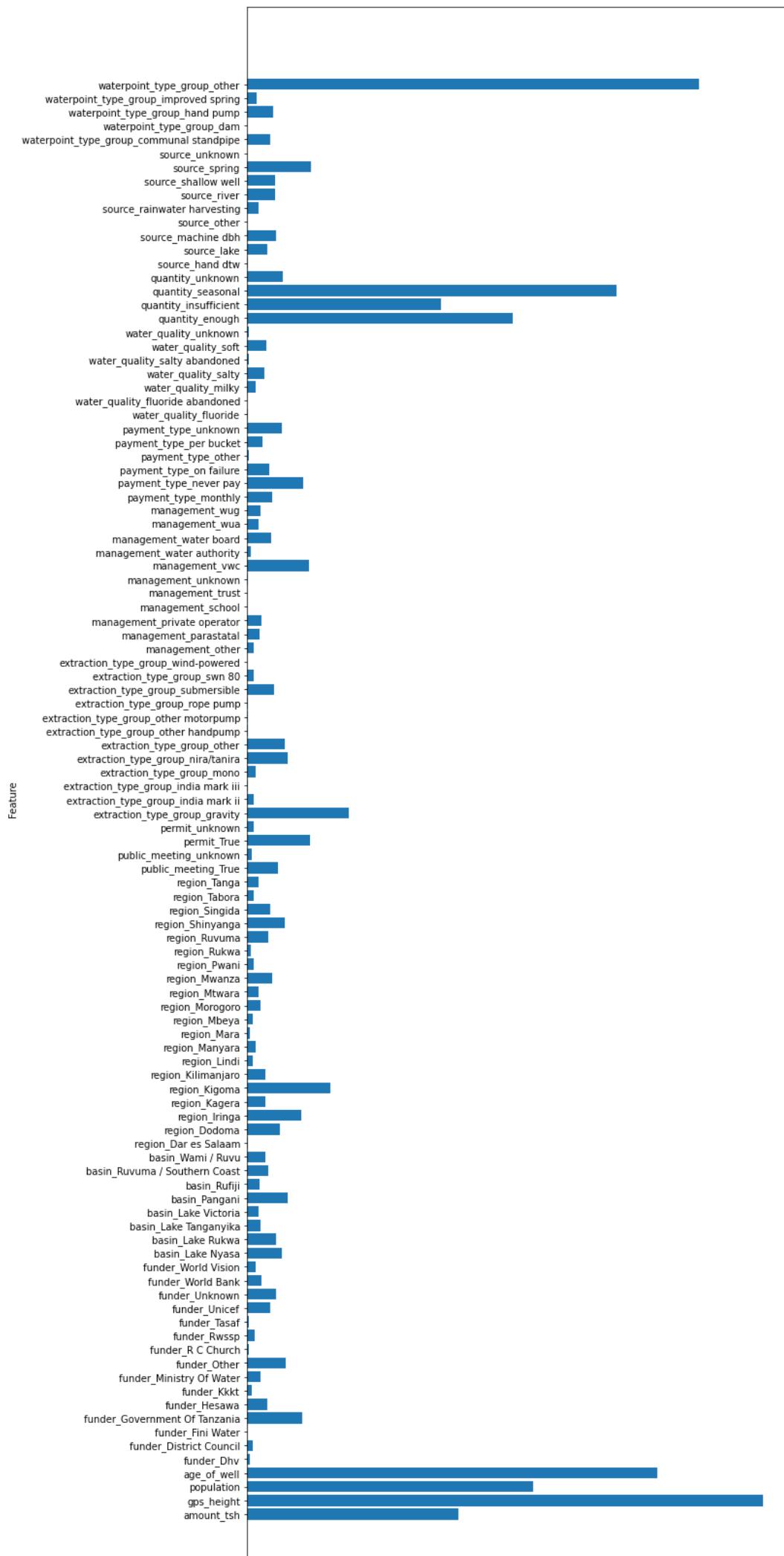
```
CLF Tuned Training Accuracy:  0.8158762838359498  
CLF Tuned Validation Accuracy:  0.7614402021336328
```

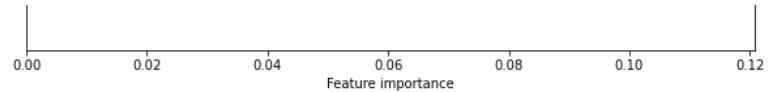
Tuning our model has slightly improved it. While training accuracy remains 0.81, validation accuracy has come up to 0.76. The closeness of the two values suggests the model is not overfitting.

We'll investigate feature importances by making use of the function code below adapted from content notes.

```
In [118]: ┆ #Investigating Feature Importances
def plot_feature_importances(model):
    n_features = X_train.shape[1]
    plt.figure(figsize=(10, 30))
    plt.barh(range(n_features), model.feature_importances_, align='center')
    plt.yticks(np.arange(n_features), X_train.columns.values)
    plt.xlabel('Feature importance')
    plt.ylabel('Feature')

plot_feature_importances(clf)
```



We'll try to make sense of the above features by picking the top 20 most important features

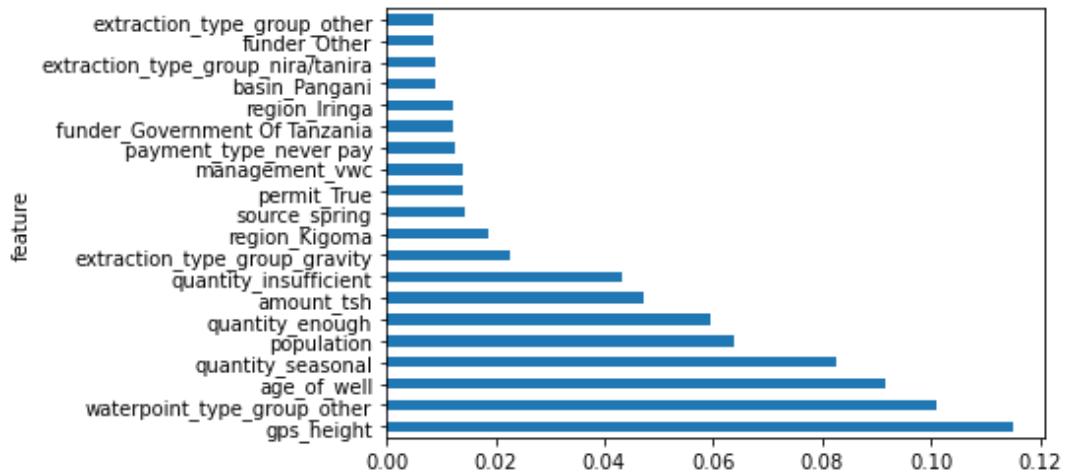
```
In [119]: ┌─ top_20_features = pd.DataFrame(columns=['feature', 'rank'])

top_20_features['feature'] = X_train.columns

top_20_features['rank'] = clf.feature_importances_

top_20_features = top_20_features.set_index('feature')

top_20_features['rank'].sort_values(ascending = False).head(20).plot(ki
```



Knn Model

```
In [120]: ┌─ # Instantiating the KNeighborsClassifier
knn = KNeighborsClassifier()

# Fit the classifier
knn.fit(X_train_scaled, y_train)

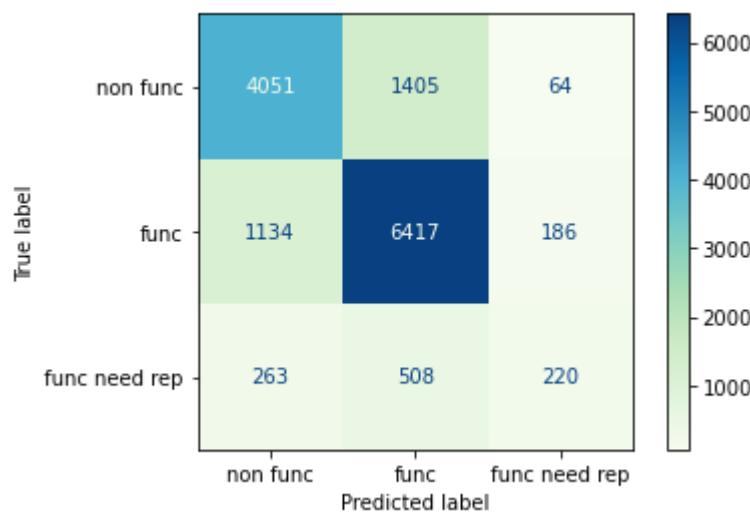
# Predict on the test set
y_preds = knn.predict(X_test_scaled)

#Predicting the y_hat_train
y_hat_train = knn.predict(X_train_scaled)
```

In [121]: ┌ knn_score = eval_score(knn, X_test_scaled, y_preds, y_test)
knn_score

	precision	recall	f1-score	support
non func	0.74	0.73	0.74	5520
func	0.77	0.83	0.80	7737
func need rep	0.47	0.22	0.30	991
accuracy			0.75	14248
macro avg	0.66	0.60	0.61	14248
weighted avg	0.74	0.75	0.74	14248

Out[121]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1af8ad987c0>



In [122]: ┌ print('KNN Training Accuracy: ', accuracy_score(y_train, y_hat_train))
print('KNN Validation Accuracy: ', accuracy_score(y_test, y_preds))

KNN Training Accuracy: 0.812834850150902
KNN Validation Accuracy: 0.7501403705783268

One of the ways of tuning a KNN model is by iterating through various values of K to find the value that gives the best results. We will make use of grid search to iterate through several values of k to find an optimal value of k that we can use to tune the model.

In [123]: ┌ # GridSearch
knn = KNeighborsClassifier()

knn_grid = {'n_neighbors' : [5, 10, 20, 30, 40]}

#knn_search = GridSearchCV(knn, knn_grid, cv=3)
#knn_search.fit(X_train_scaled, y_train)

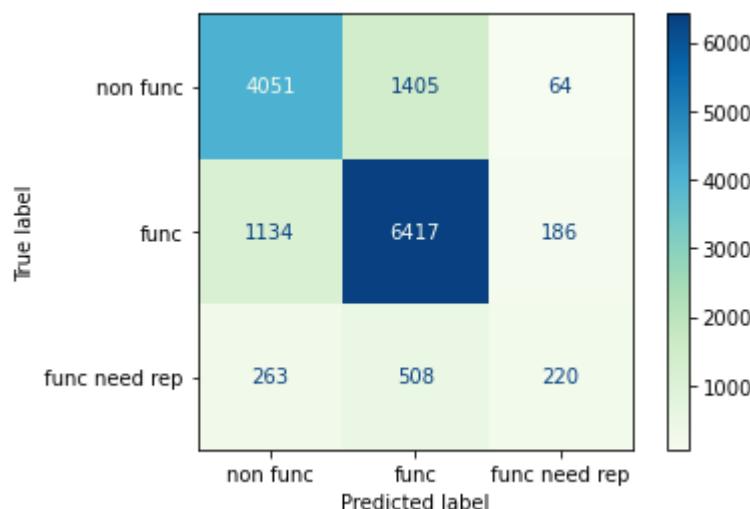
#knn_search.best_params_

In [124]: ┏ #Refitting the model with the best k value: {'n_neighbors': 5}
 knn2 = KNeighborsClassifier(n_neighbors=5)
 knn2.fit(X_train_scaled, y_train)
 y_preds = knn2.predict(X_test_scaled)
 y_hat_train = knn2.predict(X_train_scaled)

In [125]: ┏ #Printing the model score
 knn2_score = eval_score(knn2, X_test_scaled, y_preds, y_test)
 knn2_score

	precision	recall	f1-score	support
non func	0.74	0.73	0.74	5520
func	0.77	0.83	0.80	7737
func need rep	0.47	0.22	0.30	991
accuracy			0.75	14248
macro avg	0.66	0.60	0.61	14248
weighted avg	0.74	0.75	0.74	14248

Out[125]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1af8a8b6fd0>



In [126]: ┏ print('KNN Tuned Training Accuracy: ', accuracy_score(y_train, y_hat_train))
 print('KNN Tuned Validation Accuracy: ', accuracy_score(y_test, y_preds))

KNN Tuned Training Accuracy: 0.812834850150902
 KNN Tuned Validation Accuracy: 0.7501403705783268

Bagged Tree and Random Forest Models

```
In [127]: ┏ ━ #Instantiating the bagged tree classifier
bagged_tree = BaggingClassifier(DecisionTreeClassifier(criterion='gini',
                                                       n_estimators=20))
#Fitting the classifier
bagged_tree.fit(X_train, y_train)

# Training accuracy score
training_accuracy_score = bagged_tree.score(X_train, y_train)
print("Test Accuracy Score:", training_accuracy_score)

# Test accuracy score
test_accuracy_score = bagged_tree.score(X_test, y_test)
print("Test Accuracy Score:", test_accuracy_score)
```

```
Test Accuracy Score: 0.7216386308869288
Test Accuracy Score: 0.7188377316114543
```

```
In [128]: ┏ ━ # Instantiating a RandomForestClassifier
forest = RandomForestClassifier(n_estimators=100, max_depth= 5)

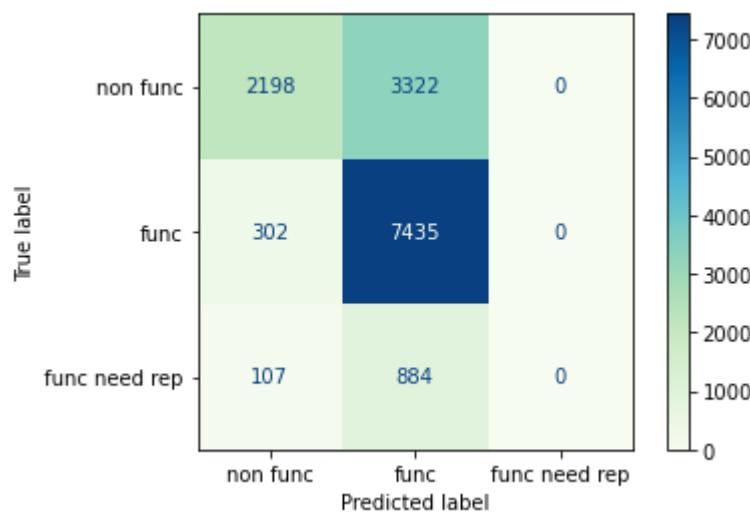
#Fitting the classifier
forest.fit(X_train, y_train)

#Predicting the train and test data
y_preds = forest.predict(X_test)
y_hat_train = forest.predict(X_train)
```

In [129]: █ rf_score = eval_score(forest, X_test, y_preds, y_test)
rf_score

	precision	recall	f1-score	support
non func	0.84	0.40	0.54	5520
func	0.64	0.96	0.77	7737
func need rep	0.00	0.00	0.00	991
accuracy			0.68	14248
macro avg	0.49	0.45	0.44	14248
weighted avg	0.67	0.68	0.63	14248

Out[129]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1af8ad97160>



In [130]: █ print('Forest Training Accuracy: ', accuracy_score(y_train, y_hat_train))
print('Forest Validation Accuracy: ', accuracy_score(y_test, y_preds))

Forest Training Accuracy: 0.679222328802377
Forest Validation Accuracy: 0.676094890510949

While bagged trees and random forests have not registered the highest accuracy scores, they are so far the ones with the most consistent performance in both the training and test sets.

We will use GridSearchCV to find optimal values to tune the parameters.

```
In [131]: #Specifying parameters
#forest = RandomForestClassifier()

#forest_grid = {
#    'criterion' : ['entropy', 'gini'],
#    'max_depth': [None, 5, 10, 15, 20],
#    'min_impurity_split' : [None, 0.1, 0.3, 0.5],
#    'min_impurity_decrease' : [0.0, 0.1, 0.2, 0.4, 0.5]}
#    'min_samples_leaf': [1, 2, 5],
#    'min_samples_split': [2, 4, 6]}

#forest_gs = GridSearchCV(forest, forest_grid, cv=3)
#forest_gs.fit(X_train, y_train)

#print("Random Forest Best Parameters")
#forest_gs.best_params_
```

We conducted two separate Gridsearches due to the time taken by a single search.

The following parameters were initially suggested by GridSearchCV

Random Forest Best Parameters {'criterion': 'entropy', 'min_samples_leaf': 1, 'min_samples_split': 6} {'criterion': 'entropy', 'max_depth': 20, 'min_impurity_decrease': 0.0, 'min_impurity_split': 0.3}

Random forest being our best performing model thus far, we tweaked them around a bit in the tuned model to come up with the below hyperparameters combination which gave us the best scores as well as a good balance between the training and validation accuracy.

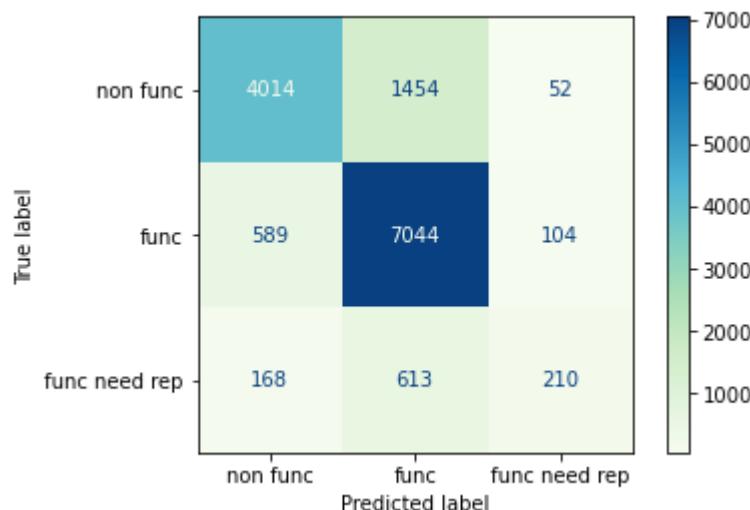
```
In [132]: ┏ ━ #Refitting the model with the best parameters identified by GridSearchCV
tuned_forest = RandomForestClassifier(bootstrap=True, criterion='entropy',
                                         min_impurity_split=0.2, random_st
                                         tuned_forest.fit(X_train_scaled, y_train)

#Predicting the train and test data
y_preds = tuned_forest.predict(X_test_scaled)
y_hat_train = tuned_forest.predict(X_train_scaled)

#Evaluating the model
tuned_rf_score = eval_score(tuned_forest, X_test_scaled, y_preds, y_te
tuned_rf_score
```

	precision	recall	f1-score	support
non func	0.84	0.73	0.78	5520
func	0.77	0.91	0.84	7737
func need rep	0.57	0.21	0.31	991
accuracy			0.79	14248
macro avg	0.73	0.62	0.64	14248
weighted avg	0.79	0.79	0.78	14248

Out[132]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1af89209160>



```
In [133]: ┏ ━ print('Tuned Forest Training Accuracy: ', accuracy_score(y_train, y_hat
print('Tuned Forest Validation Accuracy: ', accuracy_score(y_test, y_pr
```

Tuned Forest Training Accuracy: 0.8947196032098823
Tuned Forest Validation Accuracy: 0.7908478382930938

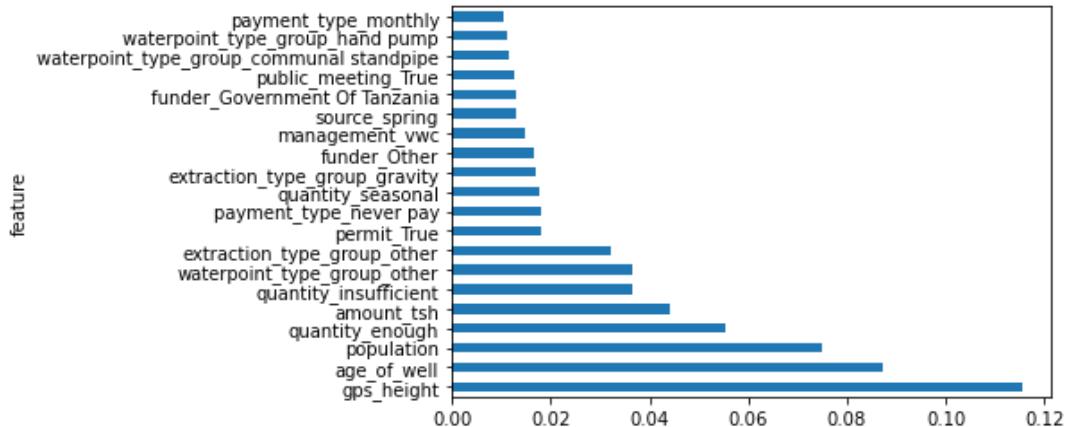
```
In [134]: #Investigating Features Importance
top_20_rf_features = pd.DataFrame(columns=['feature', 'rank'])

top_20_rf_features['feature'] = X_train.columns

top_20_rf_features['rank'] = tuned_forest.feature_importances_

top_20_rf_features = top_20_rf_features.set_index('feature')

top_20_rf_features['rank'].sort_values(ascending = False).head(20).plot
```



The tuned random forest model has a training accuracy of 0.89 and a test accuracy of 0.79. We'll tune it a little further in this section using SMOTE to account for the class imbalances in our target variable and evaluate its performance.

```
In [135]: smote = SMOTE()
X_train_resampled, y_train_resampled = smote.fit_resample(X_train_scaled)

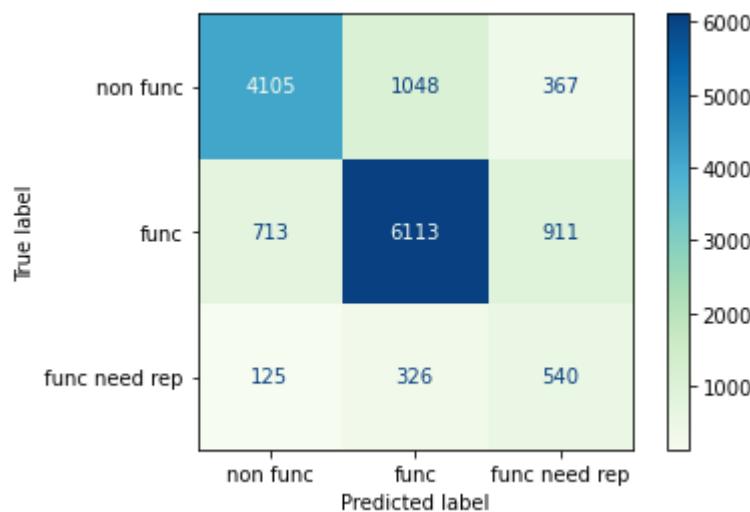
smote_rf = RandomForestClassifier(bootstrap=True, criterion='entropy',
#Fitting the model
smote_rf.fit(X_train_resampled, y_train_resampled)

y_preds = smote_rf.predict(X_test_scaled)
y_hat_train = smote_rf.predict(X_train_scaled)
```

```
In [136]: ┌─ smote_rf_score = eval_score(smote_rf, X_test_scaled, y_preds, y_test)
smote_rf_score
```

	precision	recall	f1-score	support
non func	0.83	0.74	0.78	5520
func	0.82	0.79	0.80	7737
func need rep	0.30	0.54	0.38	991
accuracy			0.76	14248
macro avg	0.65	0.69	0.66	14248
weighted avg	0.79	0.76	0.77	14248

Out[136]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x1af8602b5e0>



```
In [137]: ┌─ print('Smote Forest Training Accuracy: ', accuracy_score(y_train, y_hat))
print('Smote Forest Validation Accuracy: ', accuracy_score(y_test, y_pr
```

Smote Forest Training Accuracy: 0.8683995040123529
Smote Forest Validation Accuracy: 0.7550533408197642

```
In [138]: ┌─ scores = cross_val_score(smote_rf, X_train_resampled, y_train_resampled)
scores
```

Out[138]: array([0.77827989, 0.8343017 , 0.83444516, 0.84427229, 0.84269421])

SMOTE does not seem to be improving our model performance any further. On the contrary, it is making it worse. We will therefore take the tuned random forest as our best performing and final model.

Final Model

Our final model will be selected based on performance. To do this, we'll compare the training and testing accuracy of the various models that we fitted to find out which model gives the best scores without overfitting.

```
In [139]: ┆ data = {
    'Model': ['Logistic Regression', 'Tuned Logistic Regression', 'Decision Tree Classifier', 'K Nearest Neighbors', 'Bagged Trees', 'Random Forest', 'Tuned Random Forest', 'SMOTE Random Forest'],
    'Training Accuracy Score': [0.738, 0.738, 0.948, 0.815, 0.812, 0.894, 0.750, 0.750],
    'Testing Accuracy Score': [0.734, 0.734, 0.748, 0.760, 0.750, 0.790, 0.750, 0.750]
}
Model_outputs = pd.DataFrame(data)

Model_outputs
```

Out[139]:

	Model	Training Accuracy Score	Testing Accuracy Score
0	Logistic Regression	0.738	0.734
1	Tuned Logistic Regression	0.738	0.734
2	Decision Tree Classifier	0.948	0.748
3	Tuned Decision Tree Classifier	0.815	0.760
4	K Nearest Neighbors	0.812	0.750
5	Tuned K Nearest Neighbors	0.812	0.750
6	Bagged Trees	0.719	0.716
7	Random Forest	0.689	0.686
8	Tuned Random Forest	0.894	0.790
9	SMOTE Random Forest	0.871	0.750

The tuned random forest model is our best performing model with a training accuracy of 0.894 and a testing accuracy of 0.798. Although it's not the best performed in training accuracy, it has the best testing accuracy and minimal difference between the training and testing accuracy meaning that the training model had the less overfit.

Findings

There is a high proportion of non-functional wells accounting for 38% of the total wells. Together with the functioning wells that need repair, they account for 45% of all the wells.

The most important features in predicting well function as depicted by our final model are

1. Altitude of the well (gps_height)
2. Well age (age_of_well)
3. Population (population)
4. Enough water quantity (quantity_enough)
5. Amount of water in total static head (amount_tsh)
6. Insufficient water quantity (quantity_insufficient)
7. The waterpoint kind (waterpoint_type_group_other)
8. The kind of extraction used by the waterpoint(extraction_type_group_other)
9. Well having a permit(permit_True)
10. Well where payment is not made (payment_type_never pay)

The tuned Decision Tree Classifier which also scored highly also has the same 9 features being ranked as the most important in predicting well function.

Well projects funded by the Government of Tanzania and the Ministry of Water are more likely to be non functional.

Mtwara and Lindi Regions stand out for having a higher proportion of non-functional wells compared to the functional wells. Ruvuma/Southern Coast and L. Rukwa basin also have a higher proportion of non functional wells compared to the functional ones.

Well projects where people do not pay for well use or the payment details are unknown, and where public meetings are not held, have a higher proportion of non functional wells compared to the functional wells.

Well projects that are older have a higher proportion of non functional wells than the ones that are recent(0 - 15 years).

Dry wells, wells with salty water and wells with dam and lake as a source were more likely to be non-functional.

Recommendations

Well projects being funded by the government and its ministry should be thus be closely monitored during the installation and followed closely to ensure continued function

Mtwara and Lindi Regions and wells in Ruvuma/Southern Coast and L. Rukwa basin should be prioritized in repair of non functional and functional wells that need repair.

Introduce and promote well fees and public meetings to enhance community ownership which will translate to better maintenance and follow-up of wells. The money generated from the fees can aid in maintenance and repairs in a timely manner.

Older wells, dry wells and wells with salty water should be monitored more closely as they are more likely to fail

Further Analysis

Further hyperparameter tuning: Hyperparameter tuning can be explored further using GridSearch to further improve on the models used in prediction.

Exploring more model types Model types such as XGBoost, Adaboosting, Naive Bayes, SVM and model stacking that were not used here can be explored to find a better performing model.

More Information on Data Features Some symbols and abbreviations used in the data are not universal. More information on the data can enhance the data cleaning process especially in the funders and installers features to enhance the cleaning process and consequently the model outputs.