Tree Improvement Classification models for New York City

Introduction ¶

New York city has over 680,000 trees planted on "the street" (sidewalk, medians, etc.). It's no surprise that it takes a substantial Parks Department to manage these trees, and ensure optimal health and growth. Maintaining an urban canopy is crucial to the health and success of a city's environment and human population - it's estimated that $60M is diverted from the healthcare system annually through the existence of our urban canopy (1).

Using data from NYC Opendata, create a machine-learning model to predict whether a street tree is in need of care and/or replacement. This will provide NYC Parks department with an optimized model to prioritize trees needing care, minimizing resources to fix and increase the canopy across the city.

Data Source: https://data.cityofnewyork.us/Environment/2015-Street-Tree-Census-Tree-Data/pi5s-9p35 (https://data.cityofnewyork.us/Environment/2015-Street-Tree-Census-Tree-Data/pi5s-9p35)

Outline

1. Import necessary packages, load dataset into a Pandas DataFrame, perform initial EDA
2. Creating Model's and pre-processing functions
3. Evaluation of best baseline model, fine-tuning hyperparameters
4. Final model selection, perform analysis on test data
5. Conclusion

In [1]:

```
#standard packages to import
import pandas as pd
import os
import numpy as np
import scipy.stats as stats
#import statsmodels.api as sm
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline

#sklearn modules
from sklearn.metrics import log_loss, confusion_matrix, accuracy_score, recall_sc
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split, cross_validate
from sklearn.preprocessing import StandardScaler, OneHotEncoder, LabelEncoder
from sklearn.tree import DecisionTreeClassifier, plot_tree
from imblearn.over_sampling import SMOTE
from sklearn.utils import resample
```

```
In [2]: #nycdf = pd.read_csv('data/pluto.csv')
In [3]: treedf.head()
        treedf = pd.read_csv('data/2015StreetTreesCensus_TREES.csv')
```

Out[3]:

	created_at	tree_id	block_id	the_geom	tree_dbh	stump_diam	curb_loc	status	heal
0	08/27/2015	180683	348711	POINT (-73.84421521958048 40.723091773924274)	3	0	OnCurb	Alive	F
1	09/03/2015	200540	315986	POINT (-73.81867945834878 40.79411066708779)	21	0	OnCurb	Alive	F
2	09/05/2015	204026	218365	POINT (-73.93660770459083 40.717580740099116)	3	0	OnCurb	Alive	Go

```
In [2]: #nycdf = pd.read_csv('data/pluto.csv')
In [3]: treedf.head()read_csv('data/2015StreetTreesCensus_TREES.csv')
```

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	created_at	tree_id	block_id	the_geom	tree_dbh	stump_diam	curb_loc	status	heal
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2	09/05/2015	204026	218365	POINT (-73.93660770459083 40.717580740099116)	3	0	OnCurb	Alive	Go
3	09/05/2015	204337	217969	POINT (-73.93445615919741 40.713537494833226)	10	0	OnCurb	Alive	Go
4	08/30/2015	189565	223043	POINT (-73.97597938483258 40.66677775537875)	21	0	OnCurb	Alive	Go

5 rows × 42 columns

```
In [4]: #other columns to be included in model:
        treedf.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 683788 entries, 0 to 683787
Data columns (total 42 columns):
 #   Column      Non-Null Count   Dtype 
---  ------      --------------   ----- 
 0   created_at  683788 non-null  object
 1   tree_id     683788 non-null  int64 
 2   block_id    683788 non-null  int64 
 3   the_geom    683788 non-null  object
 4   tree_dbh    683788 non-null  int64 
 5   stump_diam  683788 non-null  int64 
 6   curb_loc    683788 non-null  object
```

In [4]:
```
#other columns to be included in model:
treedf.info()
```

```
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---  ------      --------------   -----  
 0   created_at  683788 non-null  object 
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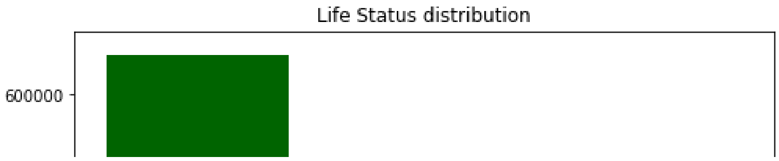
 2   block_id    683788 non-null  int64  
 3   the_geom    683788 non-null  object 
 4   tree_dbh    683788 non-null  int64  
 5   stump_diam  683788 non-null  int64  
 6   curb_loc    683788 non-null  object 
 7   status      683788 non-null  object 
 8   health      652172 non-null  object 
 9   spc_latin   652169 non-null  object 
 10  spc_common  652169 non-null  object 
 11  steward     652173 non-null  object 
 12  guards      652172 non-null  object 
 13  sidewalk    652172 non-null  object 
 14  user_type   683788 non-null  object 
 15  problems    652124 non-null  object 
 16  root_stone  683788 non-null  object 
 17  root_grate  683788 non-null  object 
 18  root_other  683788 non-null  object 
 19  trnk_wire   683788 non-null  object 
 20  trnk_light  683788 non-null  object 
 21  trnk_other  683788 non-null  object 
 22  brnch_ligh  683788 non-null  object 
 23  brnch_shoe  683788 non-null  object 
 24  brnch_othe  683788 non-null  object 
 25  address     683788 non-null  object 
 26  zipcode     683788 non-null  int64  
 27  zip_city    683788 non-null  object 
 28  cb_num      683788 non-null  int64  
 29  borocode    683788 non-null  int64  
 30  boroname    683788 non-null  object 
 31  cncldist    683788 non-null  int64  
 32  st_assem    683788 non-null  int64  
 33  st_senate   683788 non-null  int64  
 34  nta         683788 non-null  object 
 35  nta_name    683788 non-null  object 
 36  boro_ct     683788 non-null  int64  
 37  state       683788 non-null  object 
 38  Latitude    683788 non-null  float64
 39  longitude   683788 non-null  float64
 40  x_sp        683788 non-null  float64
 41  y_sp        683788 non-null  float64
dtypes: float64(4), int64(11), object(27)
memory usage: 219.1+ MB
```

In [5]:
```
bardata = treedf['status'].value_counts()

plt.figure(figsize=(8, 6))
plt.bar(bardata.index, bardata.values, color='darkgreen')
plt.xlabel('Life status')
plt.ylabel('Count')
plt.title('Life Status distribution')
plt.show()
```



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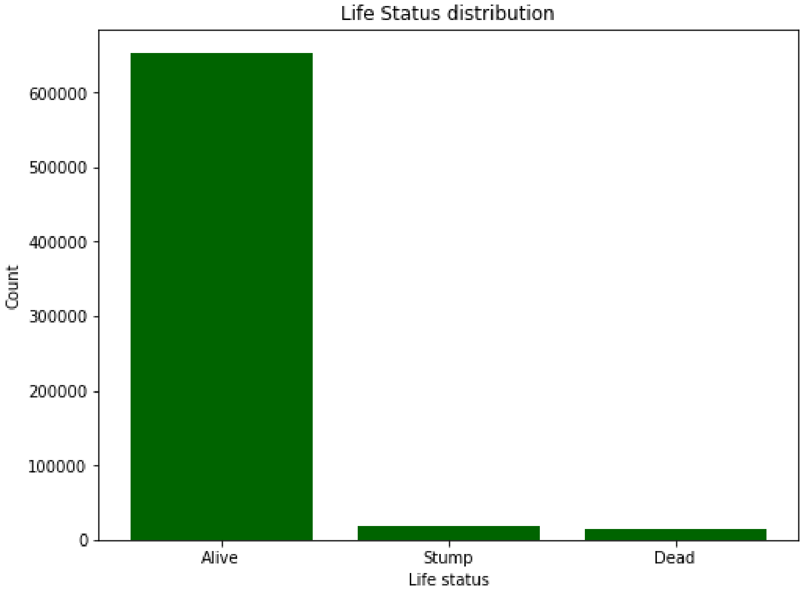
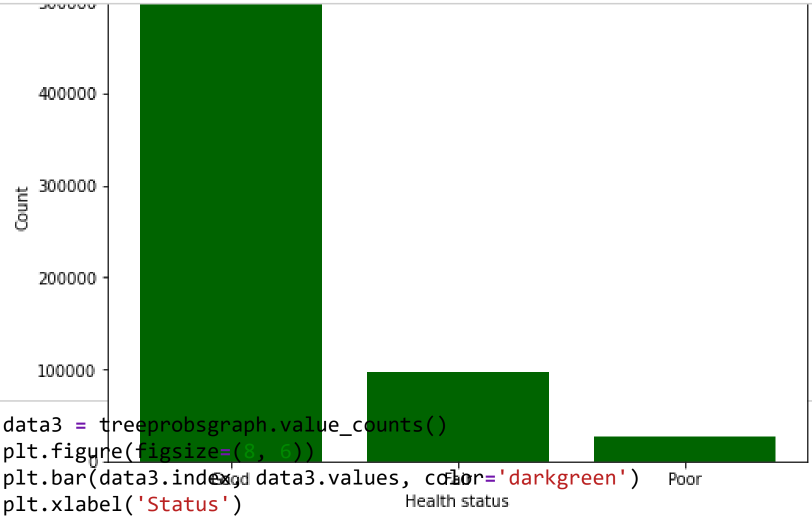


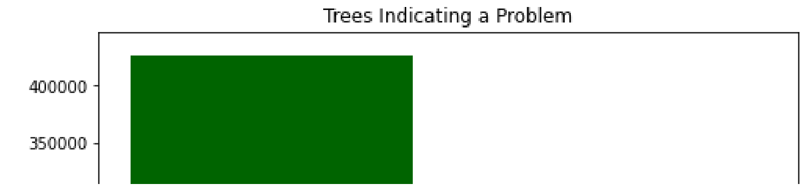
In [6]:
```
bardata2 = treedf['health'].value_counts()

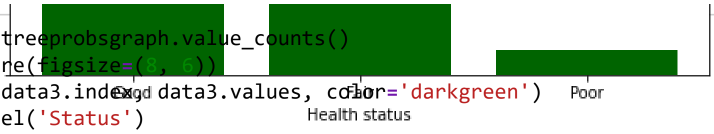
plt.figure(figsize=(8, 6))
plt.bar(bardata2.index, bardata2.values, color='darkgreen')
plt.xlabel('Health status')
plt.ylabel('Count')
plt.title('Health Status distribution')
plt.show()
```



In [8]:
```
data3 = treeprobsgraph.value_counts()
plt.figure(figsize=(8, 6))
plt.bar(data3.index, data3.values, color='darkgreen')
plt.xlabel('Status')
plt.ylabel('Count')
plt.title('Trees Indicating a Problem')
plt.show()
```

In [7]:
```
treeprobsgraph = treedf['problems'].apply(lambda x: 'Normal' if x is None or x ==
```





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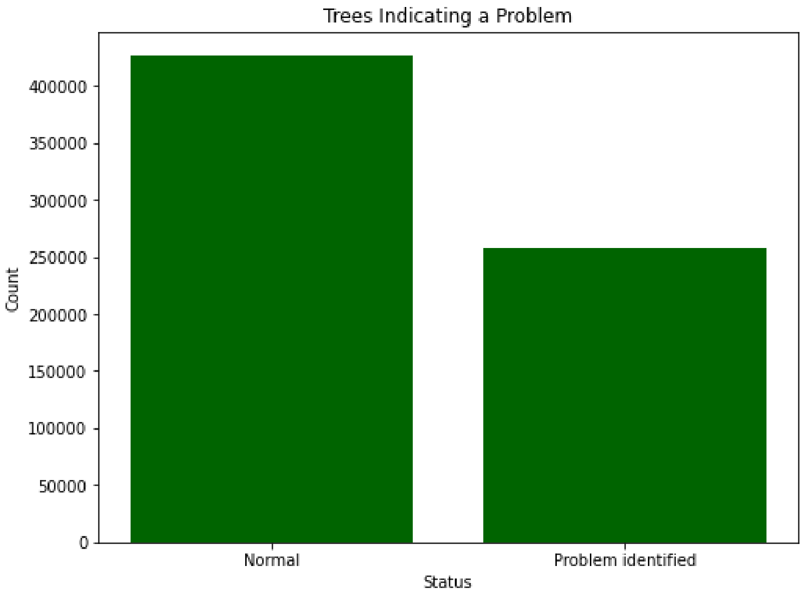

Processing the main dataframe for models

In [9]:
```
treedf['status'].value_counts()
```

Out[9]:
```
Alive    652173
Stump     17654
Dead      13961
Name: status, dtype: int64
```

In [10]:
```
treedf['problems'].value_counts()
```

Out[10]:
```
None                                                         426280
Stones                                                        95673
BranchLights                                                  29452
Stones,BranchLights                                           17808
RootOther                                                     11418
                                                              ...
TrunkLights,TrunkOther,BranchOther                                1
Stones,MetalGrates,RootOther,WiresRope,TrunkOther,BranchLights    1
MetalGrates,TrunkOther,BranchLights,BranchOther                   1
MetalGrates,RootOther,TrunkLights,TrunkOther                      1
Stones,MetalGrates,RootOther,WiresRope,BranchLights               1
Name: problems, Length: 232, dtype: int64
```

In [13]:
```
treedf['target_p'].value_counts()
```

Out[13]:
```
0    426280
1    257508
Name: target_p, dtype: int64
```

In [11]:
```
#create a "target" column, 1 is tree is good, 0 is tree needs to be replaced
treedf['target'] = treedf['status'].replace({'Alive': 1, 'Stump': 0, 'Dead': 0})
#target column whether there is a problem with a tree:
treedf['target_p'] = treedf['problems'].apply(lambda x: 0 if x is None or x == '
```

In [14]:
```
#manual imputing of the data - no need to keep it in original values:
treedf['root_stone'] = treedf['root_stone'].replace({'Yes': 1, 'No': 0})
treedf['root_grate'] = treedf['root_grate'].replace({'Yes': 1, 'No': 0})
treedf['health'] = treedf['health'].replace({'Good': 3, 'Fair': 2, 'Poor': 1})
```

In [12]:
```
treedf['target'].value_counts()
```

Out[12]:
```
1    652173
0     31615
Name: target, dtype: int64
```

In [15]:
```
#brief EDA on trees where target value is "dead/stump"
dead_bar = treedf[treedf['target']==0].groupby('target')['boroname'].value_counts
```

```
Stones,MetalGrates,RootOther,WiresRope,BranchLights                1
Name: problems, Length: 232, dtype: int64
```

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```
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```

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0    426280
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1    652173
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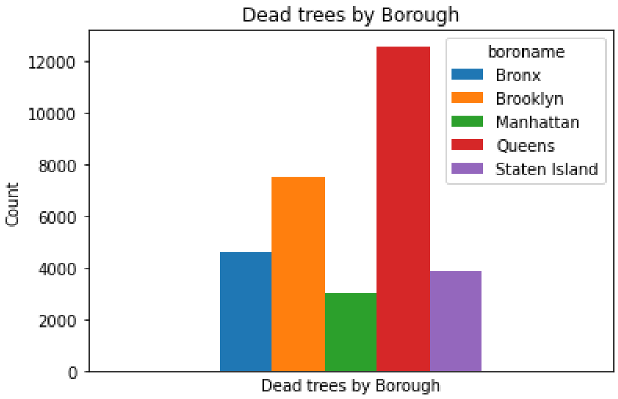
In [15]:
```
#brief EDA on trees where target value is "dead/stump"
dead_bar = treedf[treedf['target']==0].groupby('target')['boroname'].value_counts

dead_bar.unstack().plot(kind='bar')
plt.xlabel('Dead trees by Borough')
plt.ylabel('Count')
plt.xticks([])
plt.title('Dead trees by Borough')

# Show the plot
plt.show()
```



Building the first model

In [16]:
```
#Writing functions to process the data - this is fairly standard across model typ

def train_process(trainset, categoricalx, numericx, classifiersx, ohex, ssx):

    #creating dummies
    train_dummies = ohex.fit_transform(trainset[categoricalx])
    # Creating the new Dataframe from OneHotEncoder
    X_train_onehot = pd.DataFrame(train_dummies, columns=ohex.get_feature_names_o
    # Apply StandardScaler to the specified numeric columns
    trainset[numericx] = ssx.fit_transform(trainset[numericx])
    #concatenate the processed datasets
    X_train_df = pd.concat([trainset[numericx], X_train_onehot, trainset[classifi
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    #concatenate the processed datasets
    X_train_df = pd.concat([trainset[numericx], X_train_onehot, trainset[classifi

    return X_train_df

def test_process(testset, categoricalx, numericx, classifiersx, ohex, ssx):
    #creating dummies
    test_dummies = ohex.transform(testset[categoricalx])
    # Creating the new Dataframe from OneHotEncoder
    X_test_onehot = pd.DataFrame(test_dummies, columns=ohex.get_feature_names_out
    # Apply StandardScaler to the specified numeric columns
    testset[numericx] = ssx.transform(testset[numericx])
    #concatenate the processed datasets
    X_test_df = pd.concat([testset[numericx], X_test_onehot, testset[classifiersx

    return X_test_df
```

In [17]:

```
#deciding which columns to keep
log_df = treedf.copy()

categorical = ['guards', 'steward', 'boroname', 'spc_common'] #'cb_num', 'block_i
numeric = ['tree_dbh', 'Latitude', 'longitude']
classifiers = ['root_stone', 'root_grate', 'health', 'target_p']
target = ['target']
columns = categorical + numeric + classifiers + target

#create a subset DataFrame
log_df = log_df[columns]

#quick filter on blocks with more than 20 trees - did not end up using this, but
#block_id_counts = log_df3['block_id'].value_counts()
#log_df = log_df[log_df['block_id'].isin(block_id_counts.index[block_id_counts >=
```

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#block_id_counts = log_df3['block_id'].value_counts()
#log_df = log_df[log_df['block_id'].isin(block_id_counts.index[block_id_counts >=

#drop missing values
log_df['steward'] = log_df['steward'].fillna('No_Steward')
log_df['spc_common'] = log_df['spc_common'].fillna('Not_Avail')
#log_df['problems'] = log_df['problems'].fillna('No_problems')
log_df['health'] = log_df['health'].fillna(0)
log_df['guards'] = log_df['guards'].fillna('Unknown')

#ensure no missing values
log_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 683788 entries, 0 to 683787
Data columns (total 12 columns):
 #   Column      Non-Null Count   Dtype  
---  ------      --------------   -----  
 0   guards      683788 non-null  object 
 1   steward     683788 non-null  object 
 2   boroname    683788 non-null  object 
 3   spc_common  683788 non-null  object 
 4   tree_dbh    683788 non-null  int64  
 5   Latitude    683788 non-null  float64
 6   longitude   683788 non-null  float64
 7   root_stone  683788 non-null  int64  
 8   root_grate  683788 non-null  int64  
 9   health      683788 non-null  float64
 10  target_p    683788 non-null  int64  
 11  target      683788 non-null  int64  
dtypes: float64(3), int64(5), object(4)
memory usage: 62.6+ MB
```

In [18]:

```
#define the X and y variables
X = log_df.drop(target, axis=1)
y = log_df[target]

#do a train-test split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_s

#instantiate a new standard scaler and one-hot encoder
ss = StandardScaler()
ohe = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

# Convert 'None' strings to a unique label using LabelEncoder - only needed when
#keeping for future analyses
#label_encoder = LabelEncoder()
```

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# Convert 'None' strings to a unique label using LabelEncoder - only needed when
#keeping for future analyses
#label_encoder = LabelEncoder()

# Apply label encoding to each column in the DataFrame - see note above
#for column in X_train.columns:
#    if X_train[column].dtype == 'O':  # Check if column contains object (string)
 #       X_train[column] = label_encoder.fit_transform(X_train[column])

#running the SMOTE - given large dataset, not needed.
#smote = SMOTE(random_state=53)
#X_train_sm, y_train_sm = smote.fit_resample(X_train, y_train)
```

In [19]:
```
X_train_df = train_process(X_train, categorical, numeric, classifiers, ohe, ss)
X_test_df = test_process(X_test, categorical, numeric, classifiers, ohe, ss)
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\preproce
ssing\_encoders.py:975: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored unless yo
u leave `sparse` to its default value.
  warnings.warn(
```

In [20]:
```
X_train_df
```

Out[20]:

	tree_dbh	Latitude	longitude	guards_Helpful	guards_None	guards_Unknown	guards_Un
388930	-0.606654	-0.776401	-1.880071	0.0	1.0	0.0	
668243	-0.836171	-1.334534	0.768239	0.0	1.0	0.0	
406827	0.426172	-0.849981	-0.455524	0.0	1.0	0.0	
421211	0.999965	0.545221	1.073628	0.0	1.0	0.0	
300720	-0.950930	1.704516	1.082277	0.0	1.0	0.0	
...	...	...	...	...	...	...	
216253	-0.377137	-2.184911	-2.573171	0.0	1.0	0.0	
177915	1.229482	-0.861320	-0.097740	0.0	1.0	0.0	
317861	-0.606654	1.140619	-0.175556	0.0	1.0	0.0	
559989	-0.950930	-0.752730	-0.346102	1.0	0.0	0.0	
189213	-0.721413	-1.995299	-2.470034	0.0	1.0	0.0	

547030 rows × 151 columns

In [21]:
```
# Create the logistic regression object
log = LogisticRegression()

# Train the logistic regression model
clf = log.fit(X_train_df, y_train)

# Predict the target class based on p > 0.5 criteria
y_pred = clf.predict(X_train_df)

# Predict the probability with the training data set
clf.predict_proba(X_train_df)

# Calculate the model fit
acc1 = clf.score(X_train_df, y_train)
recall1 = recall_score(y_train, y_pred)
```

```
547030 rows × 151 columns
```

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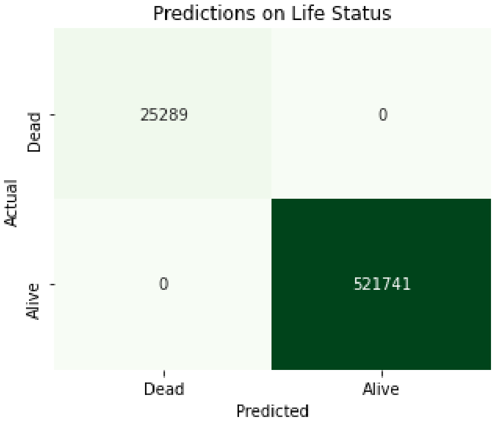
# Calculate the model fit
acc1 = clf.score(X_train_df, y_train)
recall1 = recall_score(y_train, y_pred)
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\utils\va
lidation.py:1183: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for example
using ravel().
  y = column_or_1d(y, warn=True)
```

In [22]:
```
# Calculate the confusion matrix
conf_matrix = confusion_matrix(y_train, y_pred)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['Dead', 'Alive'],
            yticklabels=['Dead', 'Alive'])
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.title('Predictions on Life Status')
plt.show()
```



Clearly, the model has something going on.

...Turns out, almost no data is recorded for dead trees & stumps. Need to find another target variable.

Model #2 - changing the target variable

In [23]:
```
#model 2 - there has to be a better way to streamline this...

categorical2 = ['steward', 'spc_common', 'status', 'cb_num', 'boroname']
numeric2 = ['tree_dbh', 'Latitude', 'longitude']
classifiers2 = ['health']
target2 = ['target_p']
columns2 = categorical2 + numeric2 + classifiers2 + target2

#create a subset DataFrame
log_df2 = treedf[columns2]

#ensure no missing values
```

Model #2 - changing the target variable

In [23]:
```
#model 2 - there has to be a better way to streamline this...

categorical2 = ['steward', 'spc_common', 'status', 'cb_num', 'boroname']
numeric2 = ['tree_dbh', 'Latitude', 'longitude']
classifiers2 = ['health']
target2 = ['target_p']
columns2 = categorical2 + numeric2 + classifiers2 + target2

#create a subset DataFrame
log_df2 = treedf[columns2]

#ensure no missing values
log_df2.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 683788 entries, 0 to 683787
Data columns (total 10 columns):
 #   Column      Non-Null Count   Dtype  
---  ------      --------------   -----  
 0   steward     652173 non-null  object 
 1   spc_common  652169 non-null  object 
 2   status      683788 non-null  object 
 3   cb_num      683788 non-null  int64  
 4   boroname    683788 non-null  object 
 5   tree_dbh    683788 non-null  int64  
 6   Latitude    683788 non-null  float64
 7   longitude   683788 non-null  float64
 8   health      652172 non-null  float64
 9   target_p    683788 non-null  int64  
dtypes: float64(3), int64(3), object(4)
memory usage: 52.2+ MB
```

In [24]:
```
#fill na values
log_df2['steward'] = log_df2['steward'].fillna('No_Steward')
log_df2['health'] = log_df2['health'].fillna(0)
log_df2['spc_common'] = log_df2['spc_common'].fillna('Not_Avail')
```

```
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/
stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pand
as.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-v
ersus-a-copy)
  log_df2['steward'] = log_df2['steward'].fillna('No_Steward')
<ipython-input-24-df0909064b44>:3: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/
stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pand
as.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-v
ersus-a-copy)
  log_df2['health'] = log_df2['health'].fillna(0)
<ipython-input-24-df0909064b44>:4: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead
```

In [26]:
```
#define the X and y variables
X2 = log_df2.drop(target2, axis=1)
y2 = log_df2[target2]
```

```
#do a train-test split
X_train2, X_test2, y_train2, y_test2 = train_test_split(X2, y2, test_size=0.2, ra
```

In [25]:
```
log_df2['health'].value_counts()
```

Out[25]:
```
3.0    528850
2.0     96504
0.0     31616
1.0     26818
Name: health, dtype: int64
```

In [27]:
```
#instantiate a new standard scaler and one-hot encoder
ss2 = StandardScaler()
ohe2 = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

#run pre-processing functions
X_train_df2 = train_process(X_train2, categorical2, numeric2, classifiers2, ohe2,
X_test_df2 = test_process(X_test2, categorical2, numeric2, classifiers2, ohe2, ss
  log_df2['health'] = log_df2['health'].fillna(0)
```

In [26]:

```
#define the X and y variables
X2 = log_df2.drop(target2, axis=1)
y2 = log_df2[target2]
```

```
<ipython-input-24-df0909064b44>:4: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead
```

In [25]:

```
log_df2["health"].value_counts()
```

Out[25]:

```
3.0    528850
2.0     96504
0.0     31616
1.0     26818
Name: health, dtype: int64
```

```
#do a train-test split
X_train2, X_test2, y_train2, y_test2 = train_test_split(X2, y2, test_size=0.2, ra
```

In [27]:

```
#instantiate a new standard scaler and one-hot encoder
ss2 = StandardScaler()
ohe2 = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

#run pre-processing functions
X_train_df2 = train_process(X_train2, categorical2, numeric2, classifiers2, ohe2,
X_test_df2 = test_process(X_test2, categorical2, numeric2, classifiers2, ohe2, ss
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\preproce
ssing\_encoders.py:975: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored unless yo
u leave `sparse` to its default value.
  warnings.warn(
```

In [28]:

```
# Create the logistic regression object
log2 = LogisticRegression(max_iter=1000)

# Train the logistic regression model
clf2 = log2.fit(X_train_df2, y_train2)

# Predict the target class based on p > 0.5 criteria
y_pred2 = clf2.predict(X_train_df2)

# Predict the probability with the training data set
clf2.predict_proba(X_train_df2)

# Calculate the model fit
acc2 = clf2.score(X_train_df2, y_train2)
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\utils\va
lidation.py:1183: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for example
using ravel().
  y = column_or_1d(y, warn=True)
```

In [29]:

```
recall2 = recall_score(y_train2, y_pred2)
print('accuracy: '+str(acc2)+' -----  recall: '+str(recall2))
```

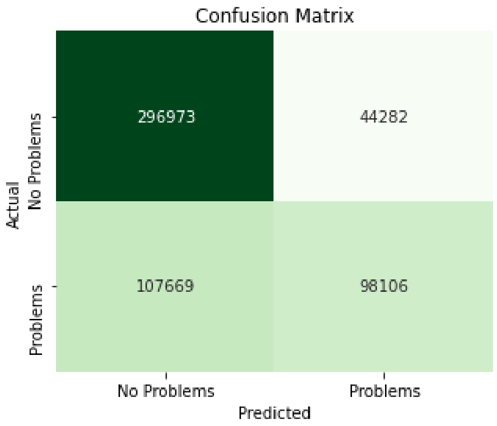
```
accuracy: 0.7222254720947663 -----  recall: 0.4767634552302272
```

In [30]:

```
# Calculate the confusion matrix
conf_matrix2 = confusion_matrix(y_train2, y_pred2)
labels = ('No Problems', 'Problems')
plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix2, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.title('Confusion Matrix')
plt.show()
```

In [30]:

```python
# Calculate the confusion matrix
conf_matrix2 = confusion_matrix(y_train2, y_pred2)
labels = ('No Problems', 'Problems')
plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix2, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.title('Confusion Matrix')
plt.show()
```



ok, this model seems to be running average at best. Going to add more columns to see if we can reduce the false positives...

Model #3 - add other columns

In [31]:

```python
#model 3 - there has to be a better way to streamline this...

categorical3 = ['guards', 'steward', 'boroname', 'spc_common', 'cb_num', 'status
numeric3 = ['tree_dbh', 'Latitude', 'longitude']
classifiers3 = ['root_stone', 'root_grate']
target3 = ['target_p']
columns3 = categorical3 + numeric3 + classifiers3 + target3

#create a subset DataFrame
log_df3 = treedf[columns3]

#ensure no missing values
```

Model #3 - add other columns

In [31]:

```
#model 3 - there has to be a better way to streamline this...

categorical3 = ['guards', 'steward', 'boroname', 'spc_common', 'cb_num', 'status'
numeric3 = ['tree_dbh', 'Latitude', 'longitude']
classifiers3 = ['root_stone', 'root_grate']
target3 = ['target_p']
columns3 = categorical3 + numeric3 + classifiers3 + target3

#create a subset DataFrame
log_df3 = treedf[columns3]

#ensure no missing values
log_df3.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 683788 entries, 0 to 683787
Data columns (total 15 columns):
 #   Column      Non-Null Count   Dtype  
---  ------      --------------   -----  
 0   guards      652172 non-null  object 
 1   steward     652173 non-null  object 
 2   boroname    683788 non-null  object 
 3   spc_common  652169 non-null  object 
 4   cb_num      683788 non-null  int64  
 5   status      683788 non-null  object 
 6   sidewalk    652172 non-null  object 
 7   user_type   683788 non-null  object 
 8   cncldist    683788 non-null  int64  
 9   tree_dbh    683788 non-null  int64  
 10  Latitude    683788 non-null  float64
 11  longitude   683788 non-null  float64
 12  root_stone  683788 non-null  int64  
 13  root_grate  683788 non-null  int64  
 14  target_p    683788 non-null  int64  
dtypes: float64(2), int64(6), object(7)
memory usage: 78.3+ MB
```

In [32]:

```
#fill in null values
log_df3['guards'] = log_df3['guards'].fillna('Unknown')
log_df3['steward'] = log_df3['steward'].fillna('No_Steward')
log_df3['spc_common'] = log_df3['spc_common'].fillna('Not_Avail')
log_df3['sidewalk'] = log_df3['sidewalk'].fillna('No_issue')
```

```
<ipython-input-32-b034f7b3f9d1>:2: SettingWithCopyWarning: 
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy)
  log_df3['guards'] = log_df3['guards'].fillna('Unknown')
```

In [32]:
```
#fill in null values
log_df3['guards'] = log_df3['guards'].fillna('Unknown')
log_df3['steward'] = log_df3['steward'].fillna('No_Steward')
log_df3['spc_common'] = log_df3['spc_common'].fillna('Not_Avail')
log_df3['sidewalk'] = log_df3['sidewalk'].fillna('No_issue')
```

```
<ipython-input-32-b034f7b3f9d1>:2: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/sta
ble/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pandas.pyd
ata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-c
opy)
  log_df3['guards'] = log_df3['guards'].fillna('Unknown')
<ipython-input-32-b034f7b3f9d1>:3: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/sta
ble/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pandas.pyd
ata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-c
opy)
  log_df3['steward'] = log_df3['steward'].fillna('No_Steward')
<ipython-input-32-b034f7b3f9d1>:4: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/sta
ble/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pandas.pyd
ata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-c
opy)
  log_df3['spc_common'] = log_df3['spc_common'].fillna('Not_Avail')
<ipython-input-32-b034f7b3f9d1>:5: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/sta
ble/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pandas.pyd
ata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-c
opy)
  log_df3['sidewalk'] = log_df3['sidewalk'].fillna('No_issue')
```

In [33]:
```
log_df3.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 683788 entries, 0 to 683787
Data columns (total 15 columns):
 #   Column      Non-Null Count   Dtype  
---  ------      --------------   -----  
 0   guards      683788 non-null  object 
 1   steward     683788 non-null  object 
 2   boroname    683788 non-null  object 
 3   spc_common  683788 non-null  object 
 4   cb_num      683788 non-null  int64  
 5   status      683788 non-null  object 
 6   sidewalk    683788 non-null  object 
 7   user_type   683788 non-null  object 
 8   cncldist    683788 non-null  int64  
 9   tree_dbh    683788 non-null  int64  
 10  Latitude    683788 non-null  float64
 11  longitude   683788 non-null  float64
 12  root_stone  683788 non-null  int64  
 13  root_grate  683788 non-null  int64  
 14  target_p    683788 non-null  int64  
dtypes: float64(2), int64(6), object(7)
memory usage: 78.3+ MB
```

In [34]:
```
#Instantiate transformers
ss3 = StandardScaler()
ohe3 = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

#define the X and y variables
X3 = log_df3.drop(target3, axis=1)
y3 = log_df3[target3]

#do a train-test split
X_train3, X_test3, y_train3, y_test3 = train_test_split(X3, y3, test_size=0.2, ra
```

In [35]:
```
#run the processing functions:
X_train_df3 = train_process(X_train3, categorical3, numeric3, classifiers3, ohe3,
X_test_df3 = test_process(X_test3, categorical3, numeric3, classifiers3, ohe3, ss
 6   sidewalk    683788 non-null  object
 7   user_type   683788 non-null  object
 8   cncldist    683788 non-null  int64
 9   tree_dbh    683788 non-null  int64
 10  Latitude    683788 non-null  float64
 11  longitude   683788 non-null  float64
 12  root_stone  683788 non-null  int64
 13  root_grate  683788 non-null  int64
 14  target_p    683788 non-null  int64
dtypes: float64(2), int64(6), object(7)
memory usage: 78.3+ MB
```

In [34]:

```
#Instantiate transformers
ss3 = StandardScaler()
ohe3 = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

#define the X and y variables
X3 = log_df3.drop(target3, axis=1)
y3 = log_df3[target3]

#do a train-test split
X_train3, X_test3, y_train3, y_test3 = train_test_split(X3, y3, test_size=0.2, ra
```

In [35]:

```
#run the processing functions:
X_train_df3 = train_process(X_train3, categorical3, numeric3, classifiers3, ohe3,
X_test_df3 = test_process(X_test3, categorical3, numeric3, classifiers3, ohe3, ss
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\preproce
ssing\_encoders.py:975: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored unless yo
u leave `sparse` to its default value.
  warnings.warn(
```

In [36]:

```
X_train_df3.shape
```

Out[36]:

```
(547030, 263)
```

In [37]:

```
# Create the logistic regression object
log3 = LogisticRegression(max_iter=10000, n_jobs=8)#, penalty='l1', solver='libl

# Train the logistic regression model
clf3 = log3.fit(X_train_df3, y_train3)

# Predict the target class based on p > 0.5 criteria
y_pred3 = clf3.predict(X_train_df3)

# Predict the probability with the training data set
clf3.predict_proba(X_train_df3)

# Calculate the model fit
acc3 = clf3.score(X_train_df3, y_train3)
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\utils\va
lidation.py:1183: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for example
using ravel().
  y = column_or_1d(y, warn=True)
```

In [38]:

```
recall3 = recall_score(y_train3, y_pred3)
print('accuracy: '+str(acc3)+' -----  recall: '+str(recall3)+' -----  precision:
```

```
accuracy: 0.8801564813629965 -----  recall: 0.6980828574899769 -----  precisio
n: 0.976672400546645
```

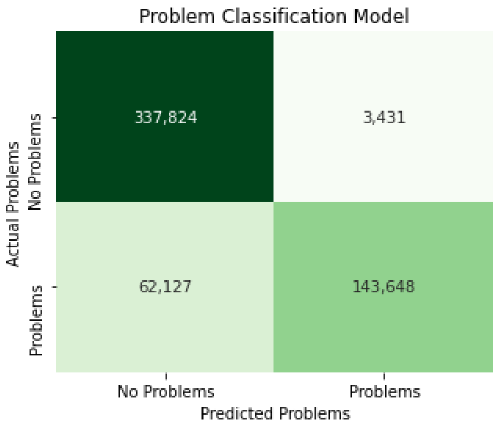
In [39]:

```
conf_matrix3 = confusion_matrix(y_train3, y_pred3,)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix3, annot=True, cmap='Greens', cbar=False, fmt=',',
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted Problems')
plt.ylabel('Actual Problems')
plt.title('Problem Classification Model')
plt.show()
```

In [39]:
```
conf_matrix3 = confusion_matrix(y_train3, y_pred3,)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix3, annot=True, cmap='Greens', cbar=False, fmt=',',
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted Problems')
plt.ylabel('Actual Problems')
plt.title('Problem Classification Model')
plt.show()
```



this base-model has the highest accuracy so far, so we will tune the hyper-parameters along these columns. Using notation '--3a' for future models to prevent data-leakage.

- Next step is to try balancing the data
- Then, try tuning hyper-parameters

after running into memory issues running the model, we need to down-sample the majority class. once the model runs successfully, will tune the amount of data to increase as much as possible before running into the memory issue

In [40]:
```
# Separate majority and minority classes
majority_class = log_df3[log_df3['target_p'] == 0]
minority_class = log_df3[log_df3['target_p'] == 1]

# Downsample majority class
downsampled_majority = resample(majority_class, replace=False, n_samples=len(minc

# Combine the dataframes
balanced_df = pd.concat([downsampled_majority, minority_class])

# Shuffle the rows
log_df3_bal = balanced_df.sample(frac=1, random_state=53).reset_index(drop=True)
```

In [41]:
```
log_df3_bal['target_p'].value_counts()
```

Out[41]:
```
1    257508
0    257508
Name: target_p, dtype: int64
```

In [42]:
```
#Instantiate transformers
ss3a = StandardScaler()
ohe3a = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

#define the X and y variables
X3a = log_df3_bal.drop(target3, axis=1)
y3a = log_df3_bal[target3]

#do a train-test split
X_train3a, X_test3a, y_train3a, y_test3a = train_test_split(X3a, y3a, test_size=(
```

In [43]:
```
#run the processing functions:
X_train_df3a = train_process(X_train3a, categorical3, numeric3, classifiers3, ohe
X_test_df3a = test_process(X_test3a, categorical3, numeric3, classifiers3, ohe3a,
```

Out[41]:

```
1    257508
0    257508
Name: target_p, dtype: int64
```

In [42]:

```python
#Instantiate transformers
ss3a = StandardScaler()
ohe3a = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

#define the X and y variables
X3a = log_df3_bal.drop(target3, axis=1)
y3a = log_df3_bal[target3]

#do a train-test split
X_train3a, X_test3a, y_train3a, y_test3a = train_test_split(X3a, y3a, test_size=(
```

In [43]:

```python
#run the processing functions:
X_train_df3a = train_process(X_train3a, categorical3, numeric3, classifiers3, ohe
X_test_df3a = test_process(X_test3a, categorical3, numeric3, classifiers3, ohe3a,
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\preproce
ssing\_encoders.py:975: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored unless yo
u leave `sparse` to its default value.
  warnings.warn(
```

In [44]:

```python
X_train_df3a.shape
```

Out[44]:

```
(412012, 263)
```

In [45]:

```python
# Create the logistic regression object
log3a = LogisticRegression(max_iter=10000, n_jobs=8)

# Train the logistic regression model
clf3a = log3a.fit(X_train_df3a, y_train3a)

# Predict the target class based on p > 0.5 criteria
y_pred3a = clf3a.predict(X_train_df3a)

# Predict the probability with the training data set
clf3a.predict_proba(X_train_df3a)

# Calculate the model fit
acc3a = clf3a.score(X_train_df3a, y_train3a)
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\utils\va
lidation.py:1183: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for example
using ravel().
  y = column_or_1d(y, warn=True)
```

In [46]:

```python
recall3a = recall_score(y_train3a, y_pred3a)
print('accuracy: '+str(acc3a)+' -----  recall: '+str(recall3a))
```

```
accuracy: 0.8478976340494937 -----  recall: 0.7358698608844331
```

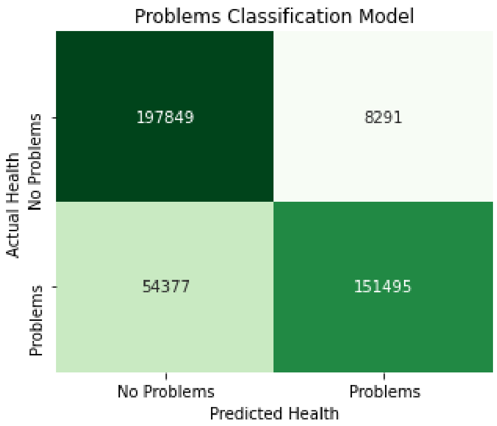
In [47]:

```python
conf_matrix3a = confusion_matrix(y_train3a, y_pred3a)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix3a, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted Health')
plt.ylabel('Actual Health')
plt.title('Problems Classification Model')
plt.show()
```

In [47]:
```
conf_matrix3a = confusion_matrix(y_train3a, y_pred3a)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix3a, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted Health')
plt.ylabel('Actual Health')
plt.title('Problems Classification Model')
plt.show()
```



Balancing the dataset did not help the model, so we will continue with the unbalanced dataset.

Tuning hyper-parameters on model #3

In [48]:
```
#starting with C-value
#do a train-test split
X_train3b, X_test3b, y_train3b, y_test3b = train_test_split(X3, y3, test_size=0.

#set new processors
ss3b = StandardScaler()
ohe3b = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

#run the processing functions:
X_train_df3b = train_process(X_train3b, categorical3, numeric3, classifiers3, ohe
X_test_df3b = test_process(X_test3b, categorical3, numeric3, classifiers3, ohe3b,
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\preproce
ssing\_encoders.py:975: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored unless yo
u leave `sparse` to its default value.
  warnings.warn(
```

In [49]:
```
X_train_df3b.shape
```

Out[49]:
```
(547030, 263)
```

In [50]:
```
# Create the logistic regression object
log3b = LogisticRegression(max_iter=10000, n_jobs=8, C=100)

# Train the logistic regression model
clf3b = log3b.fit(X_train_df3b, y_train3b)

# Predict the target class based on p > 0.5 criteria
y_pred3b = clf3b.predict(X_train_df3b)

# Predict the probability with the training data set
prob3b = clf3b.predict_proba(X_train_df3b)

# Calculate the model fit
acc3b = clf3b.score(X_train_df3b, y_train3b)
```

In [49]:
```
X_train_df3b.shape
```

Out[49]:
```
(547030, 263)
```

In [50]:
```
# Create the logistic regression object
log3b = LogisticRegression(max_iter=10000, n_jobs=8, C=100)

# Train the logistic regression model
clf3b = log3b.fit(X_train_df3b, y_train3b)

# Predict the target class based on p > 0.5 criteria
y_pred3b = clf3b.predict(X_train_df3b)

# Predict the probability with the training data set
prob3b = clf3b.predict_proba(X_train_df3b)

# Calculate the model fit
acc3b = clf3b.score(X_train_df3b, y_train3b)
```

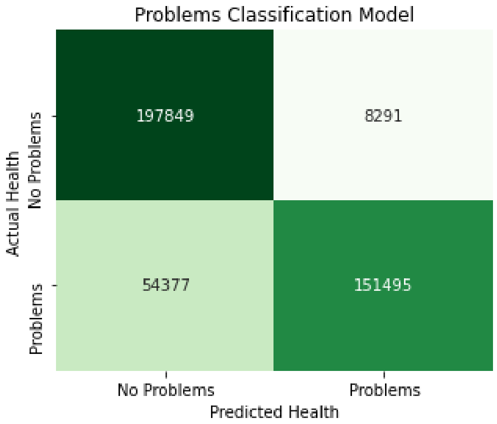
```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\utils\va
lidation.py:1183: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for example
using ravel().
  y = column_or_1d(y, warn=True)
```

In [51]:
```
recall3b = recall_score(y_train3b, y_pred3b)
print('accuracy: '+str(acc3b)+' -----  recall: '+str(recall3b))
```

```
accuracy: 0.8801692777361387 -----  recall: 0.6982043494107641
```

In [52]:
```
conf_matrix3b = confusion_matrix(y_train3b, y_pred3b)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix3a, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted Health')
plt.ylabel('Actual Health')
plt.title('Problems Classification Model')
plt.show()
```



Changing C worked better, now shifting from lasso to ridge penalty:

In [53]:
```
#set C to 100
#next hyper-parameter: change from l2 to l1 penalty
#do a train-test split
X_train3c, X_test3c, y_train3c, y_test3c = train_test_split(X3, y3, test_size=0.

#set new processors
ss3c = StandardScaler()
ohe3c = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

X_train_df3c = train_process(X_train3c, categorical3, numeric3, classifiers3, ohe
X_test_df3c = test_process(X_test3c, categorical3, numeric3, classifiers3, ohe3c,

# Create the logistic regression object with penalty l1
log3c = LogisticRegression(max_iter=10000, penalty='l1', solver='liblinear', C=1
```

Changing C worked better, now shifting from lasso to ridge penalty:

In [53]:
```
#set C to 100
#next hyper-parameter: change from l2 to l1 penalty
#do a train-test split
X_train3c, X_test3c, y_train3c, y_test3c = train_test_split(X3, y3, test_size=0.2

#set new processors
ss3c = StandardScaler()
ohe3c = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

X_train_df3c = train_process(X_train3c, categorical3, numeric3, classifiers3, ohe
X_test_df3c = test_process(X_test3c, categorical3, numeric3, classifiers3, ohe3c,

# Create the logistic regression object with penalty l1
log3c = LogisticRegression(max_iter=10000, penalty='l1', solver='liblinear', C=10

# Train the logistic regression model
clf3c = log3c.fit(X_train_df3c, y_train3c)
# Predict the target class based on p > 0.5 criteria
y_pred3c = clf3c.predict(X_train_df3c)
# Predict the probability with the training data set
clf3c.predict_proba(X_train_df3c)
# Calculate the model fit
acc3c = clf3c.score(X_train_df3c, y_train3c)
```

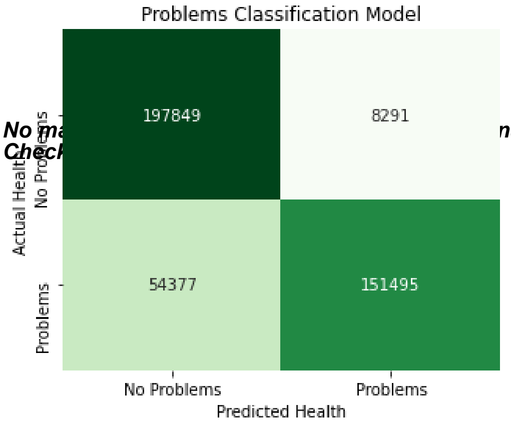
```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\preproce
ssing\_encoders.py:975: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored unless yo
u leave `sparse` to its default value.
  warnings.warn(
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\utils\va
lidation.py:1183: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for example
using ravel().
  y = column_or_1d(y, warn=True)
```

In [54]:
```
recall3c = recall_score(y_train3c, y_pred3c)
print('accuracy: '+str(acc3c)+' -----  recall: '+str(recall3c))
```

```
accuracy: 0.8801674496828328 -----  recall: 0.6981897703802697
```

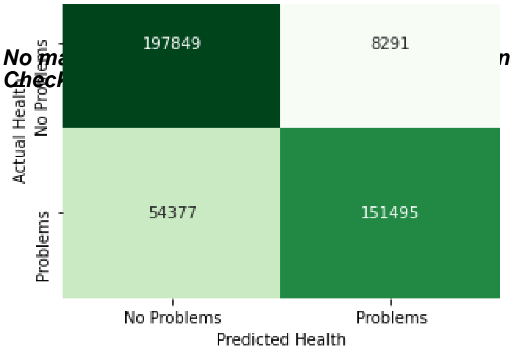
In [55]:
```
conf_matrix3b = confusion_matrix(y_train3b, y_pred3b)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix3a, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted Health')
plt.ylabel('Actual Health')
plt.title('Problems Classification Model')
plt.show()
```



No ma nalties, will stick with lasso for simplicity.
Check

No ma



nalties, will stick with lasso for simplicity.
Check

```
In [56]: #check cross-validation
         log3d = LogisticRegression(max_iter=10000)

         #do a train-test split
         X_train3d, X_test3d, y_train3d, y_test3d = train_test_split(X3, y3, test_size=0.

         #set new processors
         ss3d = StandardScaler()
         ohe3d = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

         #run the processing functions:
         X_train_df3d = train_process(X_train3d, categorical3, numeric3, classifiers3, ohe
         X_test_df3d = test_process(X_test3d, categorical3, numeric3, classifiers3, ohe3d,

         #5-fold cross-validation
```

In [56]:

```
#check cross-validation
log3d = LogisticRegression(max_iter=10000)

#do a train-test split
X_train3d, X_test3d, y_train3d, y_test3d = train_test_split(X3, y3, test_size=0.

#set new processors
ss3d = StandardScaler()
ohe3d = OneHotEncoder(handle_unknown="ignore", drop = 'first', sparse = False)

#run the processing functions:
X_train_df3d = train_process(X_train3d, categorical3, numeric3, classifiers3, ohe
X_test_df3d = test_process(X_test3d, categorical3, numeric3, classifiers3, ohe3d,

#5-fold cross-validation
log3d = LogisticRegression(max_iter=10000, n_jobs=8, C=100)
scores = cross_validate(log3d, X_train_df3d, y_train3d, cv=5, n_jobs=8)

# Print cross-validation scores and mean score
print("Cross-Validation Scores:", scores)
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\preproce
ssing\_encoders.py:975: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored unless yo
u leave `sparse` to its default value.
  warnings.warn(

Cross-Validation Scores: {'fit_time': array([332.80013156, 371.11125803,  40.21
44196 , 412.00748277,
       395.5266819 ]), 'score_time': array([0.62764955, 0.53343058, 0.        ,
0.42180777, 0.4061532 ]), 'test_score': array([0.87909255, 0.87970495,        n
an, 0.87968667, 0.88103943])}
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\model_se
lection\_validation.py:425: FitFailedWarning:
1 fits failed out of a total of 5.
The score on these train-test partitions for these parameters will be set to na
n.
If these failures are not expected, you can try to debug them by setting error_
score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
-
1 fits failed with the following error:
Traceback (most recent call last):
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn
\model_selection\_validation.py", line 729, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
```

```
C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn\model_se
lection\_validation.py:425: FitFailedWarning: 
1 fits failed out of a total of 5.
The score on these train-test partitions for these parameters will be set to na
n.
If these failures are not expected, you can try to debug them by setting error_
score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
-
1 fits failed with the following error:
Traceback (most recent call last):
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn
\model_selection\_validation.py", line 729, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn
\base.py", line 1152, in wrapper
    return fit_method(estimator, *args, **kwargs)
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn
\linear_model\_logistic.py", line 1208, in fit
    X, y = self._validate_data(
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn
\base.py", line 622, in _validate_data
    X, y = check_X_y(X, y, **check_params)
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn
\utils\validation.py", line 1146, in check_X_y
    X = check_array(
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn
\utils\validation.py", line 915, in check_array
    array = _asarray_with_order(array, order=order, dtype=dtype, xp=xp)
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\sklearn
\utils\_array_api.py", line 380, in _asarray_with_order
    array = numpy.asarray(array, order=order, dtype=dtype)
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\pandas\c
ore\generic.py", line 1781, in __array__
    return np.asarray(self._values, dtype=dtype)
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\pandas\c
ore\generic.py", line 5348, in _values
    return self.values
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\pandas\c
ore\generic.py", line 5343, in values
    return self._mgr.as_array(transpose=self._AXIS_REVERSED)
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\pandas\c
ore\internals\managers.py", line 853, in as_array
    arr = self._interleave(dtype=dtype, na_value=na_value)
  File "C:\Users\Reid Majka\anaconda3\envs\learn-env\lib\site-packages\pandas\c
ore\internals\managers.py", line 882, in _interleave
    result = np.empty(self.shape, dtype=dtype)
numpy.core._exceptions._ArrayMemoryError: Unable to allocate 878. MiB for an ar
ray with shape (263, 437624) and data type float64

  warnings.warn(some_fits_failed_message, FitFailedWarning)
```

Try a Decision Tree classifier on model #3

In [57]:

```
tree_df = log_df2.copy()
```

In [58]:

```
# Convert 'None' strings to a unique label using LabelEncoder
label_encoder = LabelEncoder()

# Apply label encoding to each column in the DataFrame
for column in tree_df.columns:
    if tree_df[column].dtype == 'O':  # Check if the column contains object (str
        tree_df[column] = label_encoder.fit_transform(tree_df[column])
```

In [59]:

```
#define the X and y variables
X4 = tree_df.drop(target3, axis=1)
y4 = tree_df[target3]
#do a train-test split
X_train4, X_test4, y_train4, y_test4 = train_test_split(X4, y4, test_size=0.2, ra
tree_clf = DecisionTreeClassifier(criterion = 'gini', max_depth=5, random_state=5
tree_clf.fit(X_train4, y_train4)
```

Out[59]:

```
▾                 DecisionTreeClassifier
DecisionTreeClassifier(max_depth=5, random_state=53)
```

In [57]:
```
tree_df = log_df2.copy()
```

In [58]:
```
# Convert 'None' strings to a unique label using LabelEncoder
label_encoder = LabelEncoder()
# Apply label encoding to each column in the DataFrame
for column in tree_df.columns:
    if tree_df[column].dtype == 'O':  # Check if the column contains object (stri
        tree_df[column] = label_encoder.fit_transform(tree_df[column])
```

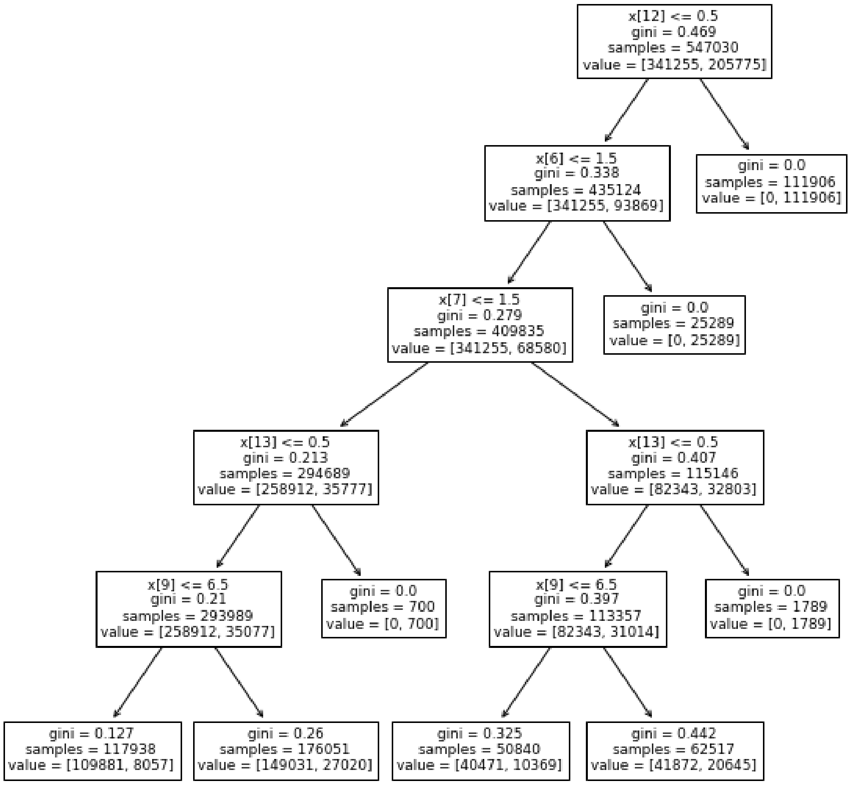
In [59]:
```
#define the X and y variables
X4 = tree_df.drop(target3, axis=1)
y4 = tree_df[target3]
#do a train-test split
X_train4, X_test4, y_train4, y_test4 = train_test_split(X4, y4, test_size=0.2, ra
tree_clf = DecisionTreeClassifier(criterion = 'gini', max_depth=5, random_state=5
tree_clf.fit(X_train4,y_train4)
```

Out[59]:
```
▾                DecisionTreeClassifier
DecisionTreeClassifier(max_depth=5, random_state=53)
```

In [60]:
```
X_train4.shape
```

Out[60]:
```
(547030, 14)
```

In [61]:
```
f, ax = plt.subplots(figsize=(10, 10))
plot_tree(tree_clf, ax=ax);
```



In [64]:
```
acc = accuracy_score(y_train4, y_pred4) * 100
recall = recall_score(y_train4, y_pred4)
print("Accuracy: {0}".format(acc))
print("Recall: {0}".format(recall))
```

In [62]:
```
y_pred4 = tree_clf.predict(X_train4)
acc4 = accuracy_score(y_train4, y_pred4)
recall4 = recall_score(y_train4, y_pred4)
```

```
Accuracy: 87.91821289508802
Recall: 0.6788190985299477
```

In [63]:
```
y_pred4 = tree_clf.predict(X_train4)
y_pred4
```

Out[63]:
```
array([0, 0, 1, ..., 0, 0, 0], dtype=int64)
```

In [65]:
```
conf_matrix4 = confusion_matrix(y_train4, y_pred4)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix4, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted Problems')
```

In [64]:
```
acc = accuracy_score(y_train4, y_pred4) * 100
rec4 = recall_score(y_train4, y_pred4)
print("Accuracy: {0}".format(acc))
print("Recall: {0}".format(rec4))
```

In [62]:
```
y_pred4 = tree_clf.predict(X_train4)
acc4 = accuracy_score(y_train4, y_pred4)
recall4 = recall_score(y_train4, y_pred4)
```

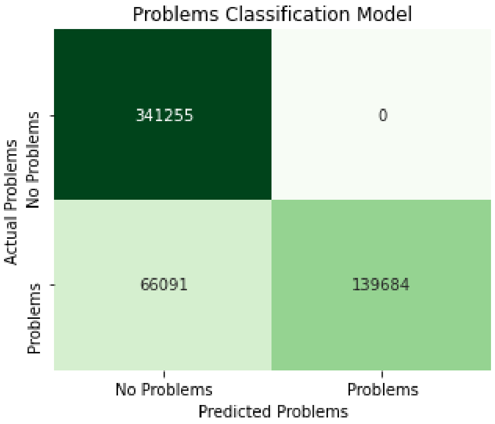
```
Accuracy: 87.91821289508802
Recall: 0.6788190985299477
```

In [63]:
```
y_pred4 = tree_clf.predict(X_train4)
y_pred4
```

Out[63]:
```
array([0, 0, 1, ..., 0, 0, 0], dtype=int64)
```

In [65]:
```
conf_matrix4 = confusion_matrix(y_train4, y_pred4)

plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix4, annot=True, fmt='d', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted Problems')
plt.ylabel('Actual Problems')
plt.title('Problems Classification Model')
plt.show()
```



Conclusion:

the tuned logistic regression model #3 produces the highest scores, lets take a look in summary:

In [66]:
```
scorestot = [('model1', acc1, recall1), ('model2', acc2, recall2), ('model3', acc
 ('model3b', acc3b, recall3b), ('model3c', acc3c, recall3c), ('model4', acc4, rec
for (name, x, y) in scorestot:
    print(name+' accuracy: '+str(x)+' -----  recall: '+str(y))
```

```
model1 accuracy: 1.0 -----  recall: 1.0
model2 accuracy: 0.7222254720947663 -----  recall: 0.47676345523O2272
model3 accuracy: 0.8801564813629965 -----  recall: 0.6980828574899769
model3a accuracy: 0.8478976340494937 -----  recall: 0.7358698608844331
model3b accuracy: 0.8801692777361387 -----  recall: 0.6982043494107641
model3c accuracy: 0.8801674496828328 -----  recall: 0.6981897703802697
model4 accuracy: 0.8791821289508802 -----  recall: 0.6788190985299477
```

In [67]:
```
#using model 3b, attempt to increase recall
threshold = [0.45, 0.4, 0.35, 0.3, 0.25, 0.2]

for x in threshold:
    predictions = (prob3b[:, 1] > x).astype(int)
    # Calculate accuracy using the adjusted threshold
    accuracy_scores = accuracy_score(y_train3b, predictions)
    recall_scores = recall_score(y_train3b, predictions)
    precision_scores = precision_score(y_train3b, predictions)
    print("Accuracy with adjusted threshold of "+str(x)+": {:.2f}".format(accurac
    print("Recall with adjusted threshold of "+str(x)+": {:.2f}".format(recall_sc
    print("Precision with adjusted threshold of "+str(x)+": {:.2f}".format(precis
    print('----------------')
```

```
Accuracy with adjusted threshold of 0.45: 0.88
```

In [67]:

```
#using model 3b, attempt to increase recall
threshold = [0.45, 0.4, 0.35, 0.3, 0.25, 0.2]

for x in threshold:
    predictions = (prob3b[:, 1] > x).astype(int)
    # Calculate accuracy using the adjusted threshold
    accuracy_scores = accuracy_score(y_train3b, predictions)
    recall_scores = recall_score(y_train3b, predictions)
    precision_scores = precision_score(y_train3b, predictions)
    print("Accuracy with adjusted threshold of "+str(x)+": {:.2f}".format(accurac
    print("Recall with adjusted threshold of "+str(x)+": {:.2f}".format(recall_sc
    print("Precision with adjusted threshold of "+str(x)+": {:.2f}".format(precis
    print('----------------')
```

```
Accuracy with adjusted threshold of 0.45: 0.88
Recall with adjusted threshold of 0.45: 0.71
Precision with adjusted threshold of 0.45: 0.96
----------------
Accuracy with adjusted threshold of 0.4: 0.88
Recall with adjusted threshold of 0.4: 0.73
Precision with adjusted threshold of 0.4: 0.93
----------------
Accuracy with adjusted threshold of 0.35: 0.87
Recall with adjusted threshold of 0.35: 0.75
Precision with adjusted threshold of 0.35: 0.90
----------------
Accuracy with adjusted threshold of 0.3: 0.86
Recall with adjusted threshold of 0.3: 0.77
Precision with adjusted threshold of 0.3: 0.85
----------------
Accuracy with adjusted threshold of 0.25: 0.84
Recall with adjusted threshold of 0.25: 0.81
Precision with adjusted threshold of 0.25: 0.78
----------------
Accuracy with adjusted threshold of 0.2: 0.81
Recall with adjusted threshold of 0.2: 0.85
Precision with adjusted threshold of 0.2: 0.70
----------------
```

Ok, lowering the threshold keeps accuracy relatively stable, and increases recall, but lowers precision. this is intuitive. So we are going to run the model one last time with a threshold of 0.35 to maintain an "A+" precision, while raising recall:

In [68]:

```
#time to run through the test data!
# Predict the target class based on p > 0.5 criteria
y_pred3bFINAL = clf3b.predict(X_test_df3b)

# Predict the probability with the training data set
prob3bFINAL = clf3b.predict_proba(X_test_df3b)

# Calculate the model fit
acc3bFINAL = clf3b.score(X_test_df3b, y_test3b)

recall3bFINAL = recall_score(y_test3b, y_pred3bFINAL)
print('accuracy: '+str(acc3bFINAL)+' -----  recall: '+str(recall3bFINAL))
```

```
accuracy: 0.87914418169321 -----  recall: 0.6960547426207643
```

In [69]:

```
#get final y_pred's on a 0.35 threshold:
y_pred3b_final = (prob3bFINAL[:, 1] > 0.35).astype(int)
conf_matrix3b_final = confusion_matrix(y_test3b, y_pred3b_final)

#creating the confusion matrix
plt.figure(figsize=(5, 4))
sns.heatmap(conf_matrix3b_final, annot=True, fmt=',', cmap='Greens', cbar=False,
            xticklabels=['No Problems', 'Problems'],
            yticklabels=['No Problems', 'Problems'])
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.title('Problems Classification Model')
plt.show()
```

Problems Classification Model

```
accuracy: 0.87914418169321 -----  recall: 0.6960547426207643
```

In [69]:
```
#get final y_pred's on a 0.35 threshold:
y_pred3b_final = (prob3bFINAL[:, 1] > 0.35).astype(int)
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```

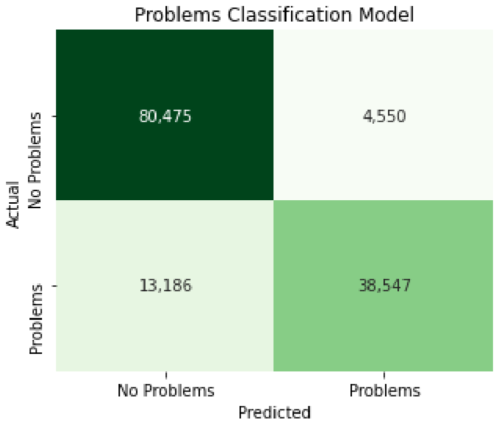

In [70]:
```
#find the column with the highest weight
X_train_df3b.columns[np.argmax(np.abs(clf3b.coef_))]
```

Out[70]:
```
'root_stone'
```

In [ ]: