Minor Irrigation Census - Village Schedule - Uttar Pradesh

DESCRIPTION

This large-scale irrigation and groundwater analysis project represents a significant achievement in utilizing Apache Spark for processing and analyzing the Minor Irrigation Census data of Uttar Pradesh. The project showcases how modern big data frameworks can transform conventional irrigation and agricultural assessments into a scalable, insightful, and data-driven analytical system.

By integrating distributed computing principles with comprehensive data cleaning, transformation, and visualization, this project successfully establishes a robust foundation for sustainable water resource planning and agricultural policy formulation. It stands as a practical demonstration of how big data analytics can be harnessed to drive environmental sustainability and rural development at scale.

Step 1: Load the dataset

In [62]:
```
from pyspark.sql import SparkSession

# Start Spark session
spark = SparkSession.builder \
    .appName("DataAnalyticsProject") \
    .getOrCreate()

# Load the dataset
file_path = "dataset.csv"  # update if needed
df = spark.read.option("header", True).option("inferSchema", True).csv(file_path

# Show basic info
df.printSchema()
```

```
root
 |-- state_name: string (nullable = true)
 |-- district_name: string (nullable = true)
 |-- block_tehsil_name: string (nullable = true)
 |-- village_name: string (nullable = true)
 |-- ref_village_type_name: string (nullable = true)
 |-- major_medium_scheme: string (nullable = true)
 |-- major_medium_scheme_name: string (nullable = true)
 |-- geographical_area: integer (nullable = true)
 |-- cultivable_area: integer (nullable = true)
 |-- net_sown_area: integer (nullable = true)
 |-- gross_irrigated_area_kharif_season: integer (nullable = true)
 |-- gross_irrigated_area_rabi_season: integer (nullable = true)
 |-- gross_irrigated_area_perennial_season: integer (nullable = true)
 |-- gross_irrigated_area_other_season: integer (nullable = true)
 |-- gross_irrigated_area_total: integer (nullable = true)
 |-- net_irrigated_area: integer (nullable = true)
 |-- avg_ground_water_level_pre_monsoon: integer (nullable = true)
 |-- avg_ground_water_level_post_monsoon: integer (nullable = true)
 |-- ref_selection_wua_exists_name: string (nullable = true)
```

In [7]:
```
pdf = df.limit(50).toPandas()
import pandas as pd
pd.set_option('display.max_colwidth', None)
pd.set_option('display.max_columns', None)   #For better readability, I have cho
pd.set_option('display.width', 2000)
pdf.head(10)
```

Out[7]:

	state_name	district_name	block_tehsil_name	village_name	ref_village_type_name
0	UTTAR PRADESH	SAHARANPUR	SADAULI QADEEM	RAHNA	Non-Tribal
1	UTTAR PRADESH	AZAMGARH	AZAMATGARH	RUSTAMPUR	Non-Tribal
2	UTTAR PRADESH	ETAWAH	BADHAPURA	GATI	Non-Tribal
3	UTTAR PRADESH	AZAMGARH	AZAMATGARH	UDKA	Non-Tribal
4	UTTAR PRADESH	GHAZIPUR	MOHMMADABAD	CHAK RAHMATALI	Non-Tribal
5	UTTAR PRADESH	GHAZIPUR	MOHMMADABAD	CHAK HABIBULLAH URF BHAGWANPAH	Non-Tribal
6	UTTAR PRADESH	ETAWAH	BADHAPURA	KAMETH	Non-Tribal
7	UTTAR PRADESH	ETAWAH	BADHAPURA	BHAGAUTIPUR NAGLA KACHHAR	Non-Tribal
8	UTTAR PRADESH	GHAZIPUR	MOHMMADABAD	PARSA	Non-Tribal
9	UTTAR PRADESH	AZAMGARH	AZAMATGARH	DAHEER PATTI	Non-Tribal

In [8]:
```
print(f"Total rows: {df.count()}")
print(f"Total columns: {len(df.columns)}")
```

```
Total rows: 12938
Total columns: 19
```

In [9]:
```
df.columns
```

Out[9]:
```
['state_name',
 'district_name',
 'block_tehsil_name',
 'village_name',
 'ref_village_type_name',
 'major_medium_scheme',
 'major_medium_scheme_name',
 'geographical_area',
 'cultivable_area',
 'net_sown_area',
 'gross_irrigated_area_kharif_season',
 'gross_irrigated_area_rabi_season',
 'gross_irrigated_area_perennial_season',
 'gross_irrigated_area_other_season',
 'gross_irrigated_area_total',
 'net_irrigated_area',
 'avg_ground_water_level_pre_monsoon',
 'avg_ground_water_level_post_monsoon',
 'ref_selection_wua_exists_name']
```

In [13]:
```
# Get describe result as a Spark DataFrame
summary_df = df.describe(
    "geographical_area",
    "cultivable_area",
    "net_sown_area",
    "net_irrigated_area",
    "avg_ground_water_level_pre_monsoon",
    "avg_ground_water_level_post_monsoon"
)

# Convert to Pandas for nice display
summary_pdf = summary_df.toPandas()

import pandas as pd
pd.set_option('display.max_colwidth', None)
pd.set_option('display.max_columns', None)
pd.set_option('display.width', 2000)

summary_pdf
```

Out[13]:

	summary	geographical_area	cultivable_area	net_sown_area	net_irrigat
0	count	12938	12938	12938	
1	mean	195.90609058587108	148.02550626062762	135.65010047920853	125.1266810
2	stddev	334.81547007697276	219.9277235135069	207.2385573799057	162.0488097
3	min	1	0	0	
4	max	16417	12170	12170	

Displaying Null values

In [18]:
```
from pyspark.sql.functions import when, col

# Replace string "NA", "Not Known", etc. with None (null)
df_clean = df.select([
    when(col(c).isin("NA", "Not Known", "Unknown", ""), None)
    .otherwise(col(c))
    .alias(c)
    for c in df.columns
])
```

In [22]:
```
# Convert PySpark DataFrame to Pandas
df_pd = df_clean.toPandas()

# Count nulls per column
nulls_pd = df_pd.isnull().sum().reset_index()
nulls_pd.columns = ["column", "null_count"]

# Display
print(nulls_pd)
```

```
                                  column  null_count
0                             state_name           0
1                          district_name           0
2                       block_tehsil_name           0
3                           village_name           0
4                  ref_village_type_name           0
5                    major_medium_scheme           0
6               major_medium_scheme_name       12720
7                      geographical_area           0
8                        cultivable_area           0
9                          net_sown_area           0
10     gross_irrigated_area_kharif_season          0
11       gross_irrigated_area_rabi_season          0
12  gross_irrigated_area_perennial_season          0
13      gross_irrigated_area_other_season          0
14             gross_irrigated_area_total          0
15                    net_irrigated_area           0
16     avg_ground_water_level_pre_monsoon          0
17    avg_ground_water_level_post_monsoon          0
18           ref_selection_wua_exists_name        5581
```

In [26]:
```
from pyspark.sql.functions import mean

# Example: fill missing groundwater levels with mean
gw_cols = ["avg_ground_water_level_pre_monsoon", "avg_ground_water_level_post_mo
for c in gw_cols:
    mean_val = df_clean.select(mean(col(c))).collect()[0][0]
    df_clean = df_clean.fillna({c: mean_val})
```

Step 2: Handling Missing values

In [59]:
```
from pyspark.sql.functions import col, sum as _sum

# 1. Handle missing values (example: fill numeric columns with mean)
numeric_cols = [
    "geographical_area", "cultivable_area", "net_sown_area",
    "gross_irrigated_area_kharif_season", "gross_irrigated_area_rabi_season",
    "gross_irrigated_area_perennial_season", "gross_irrigated_area_other_season"
    "gross_irrigated_area_total", "net_irrigated_area",
    "avg_ground_water_level_pre_monsoon", "avg_ground_water_level_post_monsoon"
]

for c in numeric_cols:
    mean_val = df_clean.select(col(c)).na.drop().agg({c: "mean"}).collect()[0][0
    df_clean = df_clean.fillna({c: mean_val})

# 2. Drop rows with remaining nulls in non-numeric columns (if any)
df_clean = df_clean.dropna()
```

In [36]:
```
# 1. Convert the cleaned PySpark DataFrame to Pandas
df_pd_clean = df_clean.toPandas()

# 2. Confirm there are no nulls
nulls_pd = df_pd_clean.isnull().sum().reset_index()
nulls_pd.columns = ["column", "null_count"]
print("Null values after cleaning:")
print(nulls_pd)
```

```
Null values after cleaning:
                                  column  null_count
0                             state_name           0
1                          district_name           0
2                      block_tehsil_name           0
3                           village_name           0
4                  ref_village_type_name           0
5                    major_medium_scheme           0
6               major_medium_scheme_name           0
7                      geographical_area           0
8                        cultivable_area           0
9                          net_sown_area           0
10      gross_irrigated_area_kharif_season           0
11        gross_irrigated_area_rabi_season           0
12   gross_irrigated_area_perennial_season           0
13       gross_irrigated_area_other_season           0
14              gross_irrigated_area_total           0
15                     net_irrigated_area           0
16      avg_ground_water_level_pre_monsoon           0
17     avg_ground_water_level_post_monsoon           0
18            ref_selection_wua_exists_name           0
```

In [27]:
```
df_pd.describe()
```

Out[27]:

	geographical_area	cultivable_area	net_sown_area	gross_irrigated_area_kharif_seas
count	12938.000000	12938.000000	12938.000000	12938.000
mean	195.906091	148.025506	135.650100	62.3567
std	334.815470	219.927724	207.238557	88.8753
min	1.000000	0.000000	0.000000	0.0000
25%	58.000000	44.000000	40.000000	15.0000
50%	125.000000	98.000000	89.000000	39.0000
75%	238.000000	190.000000	170.000000	80.0000
max	16417.000000	12170.000000	12170.000000	2442.0000

Step 3: Analytics

In [37]:
```
from pyspark.sql.functions import round, col

df_clean = df_clean.withColumn(
    "irrigation_pct",
    round((col("net_irrigated_area") / col("net_sown_area")) * 100, 2)
)

# Check top 10 villages
df_clean.select("village_name", "net_sown_area", "net_irrigated_area", "irrigati
```

```
+------------+-------------+------------------+--------------+
|village_name|net_sown_area|net_irrigated_area|irrigation_pct|
+------------+-------------+------------------+--------------+
|KANDHNI     |210          |210               |100.0         |
|KALWARI     |107          |105               |98.13         |
|RAMALA      |180          |180               |100.0         |
|RASULPUR    |33           |31                |93.94         |
|MADDHUPUR   |118          |118               |100.0         |
|SONIK       |25           |25                |100.0         |
|SIHAVALI    |323          |323               |100.0         |
|KAMALAWAD   |60           |60                |100.0         |
|KHRGU PURA  |150          |150               |100.0         |
|CHHAWIL PUR |175          |175               |100.0         |
+------------+-------------+------------------+--------------+
only showing top 10 rows
```

In [38]:
```
from pyspark.sql.functions import when

df_clean = df_clean.withColumn(
    "water_stress",
    when(col("avg_ground_water_level_post_monsoon") > 15, "Low Stress") \
    .when((col("avg_ground_water_level_post_monsoon") > 7) & (col("avg_ground_wa
    .otherwise("High Stress")
)

# Check top 10 villages
df_clean.select("village_name", "avg_ground_water_level_post_monsoon", "water_st
```

```
+------------+-----------------------------------+---------------+
|village_name|avg_ground_water_level_post_monsoon|water_stress   |
+------------+-----------------------------------+---------------+
|KANDHNI     |5                                  |High Stress    |
|KALWARI     |3                                  |High Stress    |
|RAMALA      |15                                 |Moderate Stress|
|RASULPUR    |5                                  |High Stress    |
|MADDHUPUR   |4                                  |High Stress    |
|SONIK       |4                                  |High Stress    |
|SIHAVALI    |12                                 |Moderate Stress|
|KAMALAWAD   |12                                 |Moderate Stress|
|KHRGU PURA  |11                                 |Moderate Stress|
|CHHAWIL PUR |10                                 |Moderate Stress|
+------------+-----------------------------------+---------------+
only showing top 10 rows
```

In [39]:
```
from pyspark.sql.functions import avg, round

avg_irrigation = df_clean.groupBy("district_name") \
    .agg(round(avg("irrigation_pct"), 2).alias("avg_irrigation_pct")) \
    .orderBy("district_name")
```

```
avg_irrigation.show(truncate=False)
```

```
+-------------+------------------+
|district_name|avg_irrigation_pct|
+-------------+------------------+
|ALIGARH      |100.0             |
|AZAMGARH     |97.78             |
|BAGHPAT      |100.0             |
|ETAWAH       |100.0             |
|JAUNPUR      |89.4              |
|KANNAUJ      |99.93             |
|MAHARAJ GANJ |95.02             |
|SHAHJAHANPUR |100.0             |
|UNNAO        |100.0             |
+-------------+------------------+
```

In [40]:

```
from pyspark.sql.functions import count

water_stress_count = df_clean.groupBy("district_name", "water_stress") \
    .agg(count("village_name").alias("village_count")) \
    .orderBy("district_name")

water_stress_count.show(truncate=False)
```

```
+-------------+---------------+-------------+
|district_name|water_stress   |village_count|
+-------------+---------------+-------------+
|ALIGARH      |Moderate Stress|15           |
|ALIGARH      |High Stress    |1            |
|AZAMGARH     |High Stress    |4            |
|BAGHPAT      |Moderate Stress|1            |
|ETAWAH       |High Stress    |1            |
|JAUNPUR      |High Stress    |9            |
|JAUNPUR      |Moderate Stress|1            |
|KANNAUJ      |Low Stress     |12           |
|MAHARAJ GANJ |High Stress    |28           |
|SHAHJAHANPUR |High Stress    |4            |
|UNNAO        |High Stress    |1            |
+-------------+---------------+-------------+
```

In [42]:

```
from pyspark.sql.functions import col, sum as _sum

# 1. Safely cast the column to double
df_clean = df_clean.withColumn(
    "net_irrigated_area",
    col("net_irrigated_area").cast("double")
)

# 2. Now aggregate total irrigated area per block/tehsil
total_irrigation_block = df_clean.groupBy("block_tehsil_name") \
    .agg(_sum("net_irrigated_area").alias("total_net_irrigated_area")) \
    .orderBy("block_tehsil_name")

total_irrigation_block.show(truncate=False)
```

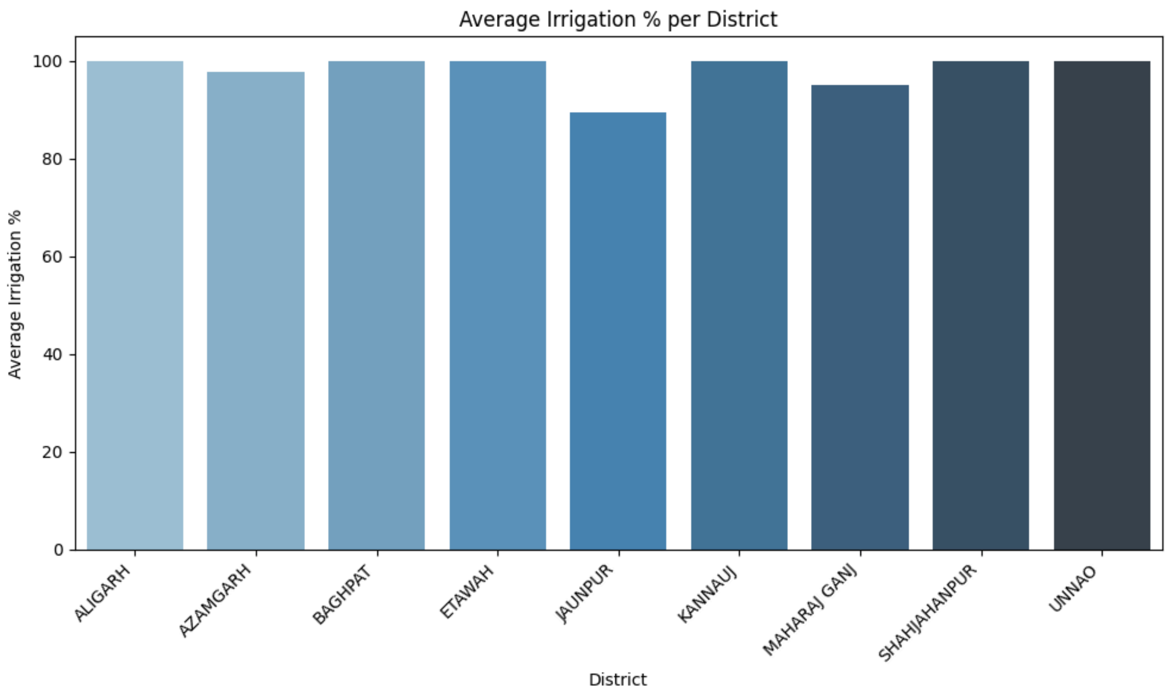
```
+-----------------+------------------------+
|block_tehsil_name|total_net_irrigated_area|
+-----------------+------------------------+
|BADHAPURA        |210.0                   |
|BICHHIYA         |25.0                    |
|BRIDGEMANGANJ    |158.0                   |
|CHHAPRAULI       |180.0                   |
|DOBHI            |120.0                   |
|GANGIRI          |4750.0                  |
|GHUGHALI         |465.0                   |
|HASERAN          |1653.0                  |
|MACHCHLI SHAHAR  |143.0                   |
|MIRZA PUR        |460.0                   |
|MUFTI GANJ       |214.0                   |
|NIGOHI           |252.0                   |
|PARTAWAL         |2791.0                  |
|SISWA            |388.0                   |
|SUITHA KALA      |957.0                   |
+-----------------+------------------------+
```

Step 4: Visualization

In [43]:

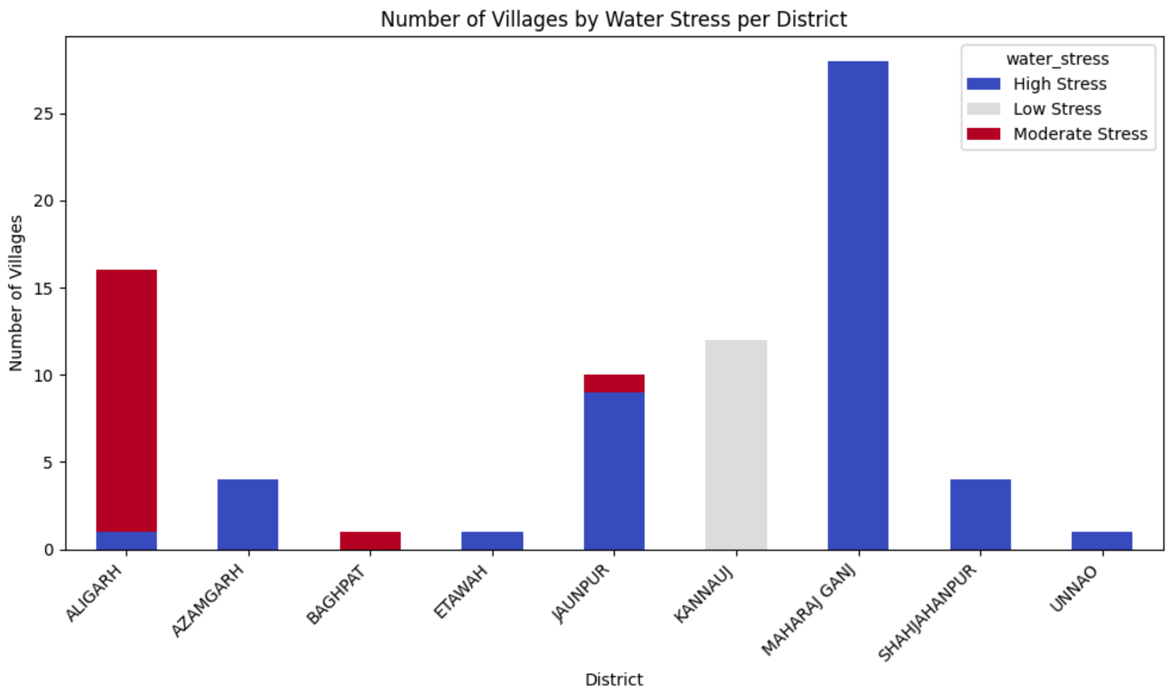
```python
import matplotlib.pyplot as plt
import seaborn as sns

# Convert PySpark aggregation to Pandas if not done already
avg_irrigation_pd = df_clean.groupBy("district_name") \
    .agg(round(avg("irrigation_pct"), 2).alias("avg_irrigation_pct")) \
    .orderBy("district_name").toPandas()

# Plot
plt.figure(figsize=(10,6))
sns.barplot(x="district_name", y="avg_irrigation_pct", data=avg_irrigation_pd, p
plt.xticks(rotation=45, ha='right')
plt.title("Average Irrigation % per District")
plt.ylabel("Average Irrigation %")
plt.xlabel("District")
plt.tight_layout()
plt.show()
```

```
C:\Users\vinay\AppData\Local\Temp\ipykernel_5804\4078150413.py:11: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v
0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effe
ct.

  sns.barplot(x="district_name", y="avg_irrigation_pct", data=avg_irrigation_pd,
palette="Blues_d")
```



The above plot give summary of Which districts have higher irrigation

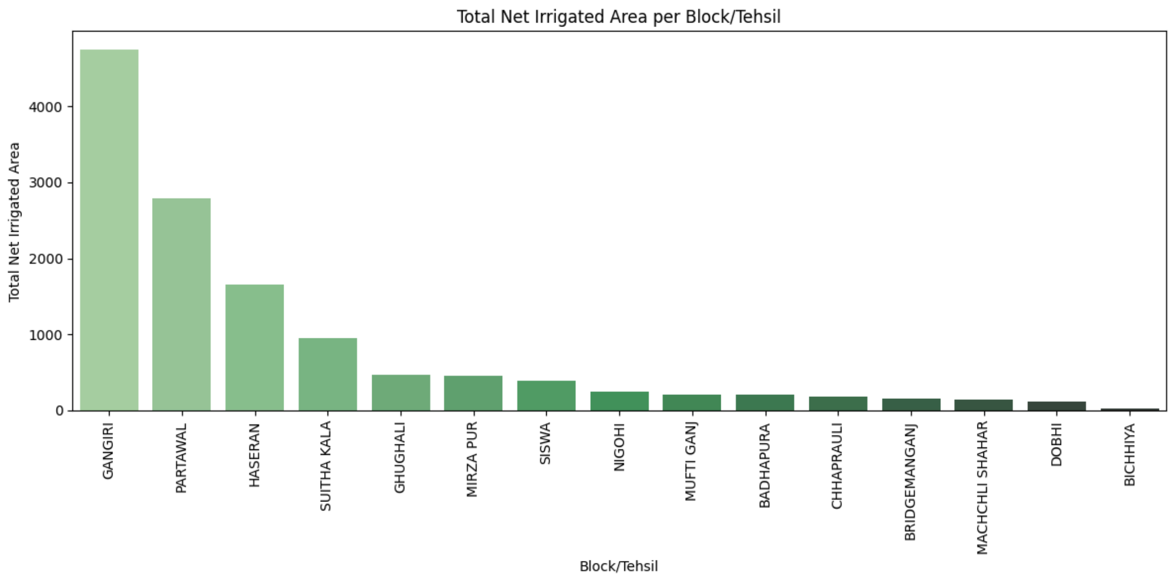
In [44]:
```
# Prepare data
water_stress_pd = df_clean.groupBy("district_name", "water_stress") \
    .count().toPandas()

# Pivot for stacked bar
water_stress_pivot = water_stress_pd.pivot(index="district_name", columns="water

# Plot
water_stress_pivot.plot(kind="bar", stacked=True, figsize=(10,6), colormap="cool
plt.title("Number of Villages by Water Stress per District")
plt.ylabel("Number of Villages")
plt.xlabel("District")
plt.xticks(rotation=45, ha='right')
plt.tight_layout()
plt.show()
```



The above plot gives info of Where are villages under water stress

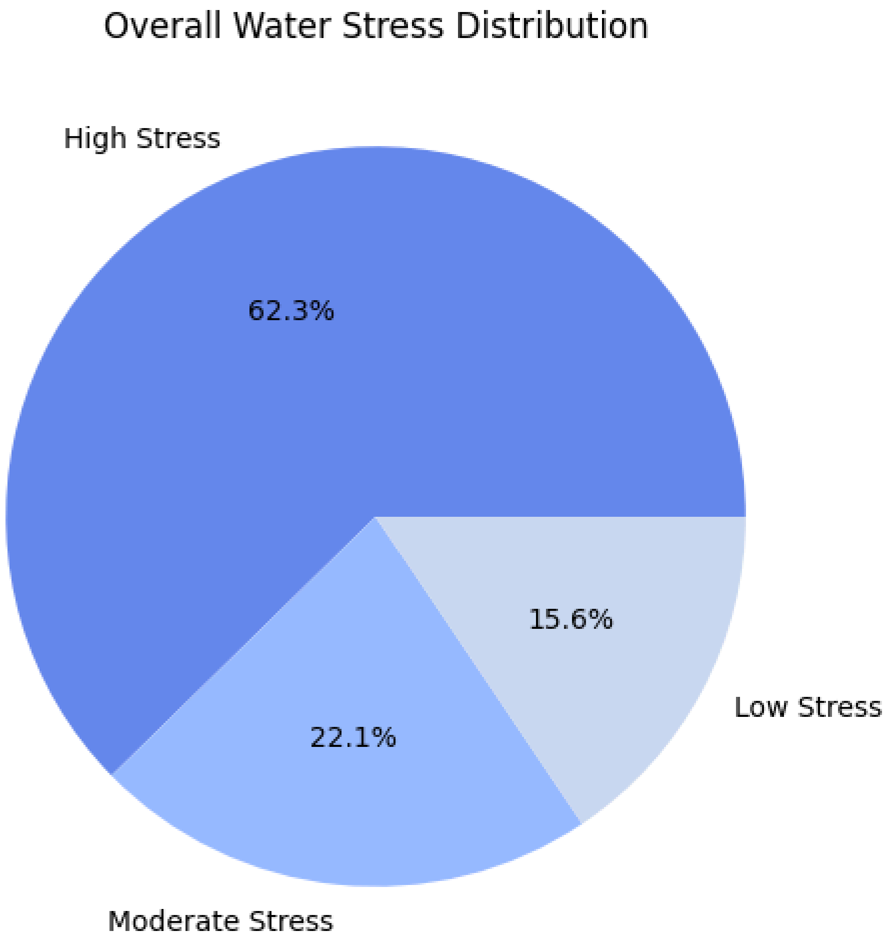
In [45]:
```python
total_irrigation_block_pd = df_clean.groupBy("block_tehsil_name") \
    .agg(_sum("net_irrigated_area").alias("total_net_irrigated_area")) \
    .orderBy("total_net_irrigated_area", ascending=False).toPandas()

# Plot
plt.figure(figsize=(12,6))
sns.barplot(x="block_tehsil_name", y="total_net_irrigated_area", data=total_irri
plt.xticks(rotation=90)
plt.title("Total Net Irrigated Area per Block/Tehsil")
plt.ylabel("Total Net Irrigated Area")
plt.xlabel("Block/Tehsil")
plt.tight_layout()
plt.show()
```

```
C:\Users\vinay\AppData\Local\Temp\ipykernel_5804\1359883026.py:7: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v
0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effe
ct.

  sns.barplot(x="block_tehsil_name", y="total_net_irrigated_area", data=total_irr
igation_block_pd, palette="Greens_d")
```

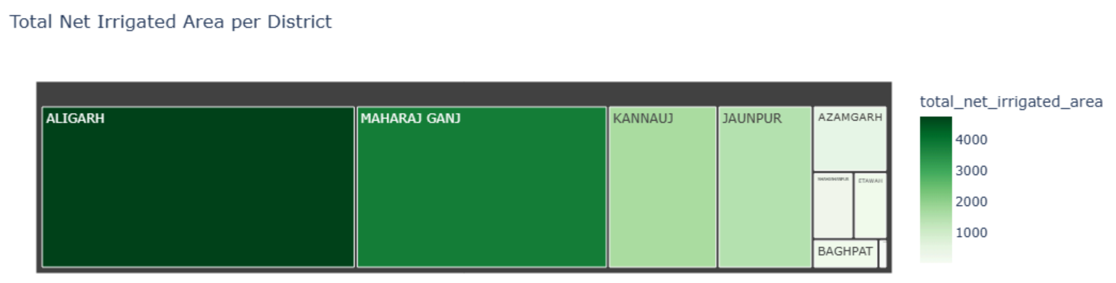


The above plot talks about Which blocks/tehsils have the most irrigated area

In [48]:
```
water_stress_overall = df_clean.groupBy("water_stress").count().toPandas()

plt.figure(figsize=(6,6))
plt.pie(water_stress_overall['count'], labels=water_stress_overall['water_stress
plt.title("Overall Water Stress Distribution")
plt.show()
```



In [53]:
```
import plotly.express as px

# Aggregate total net irrigated area per district
district_irrigation = df_clean.groupBy("district_name") \
    .agg(_sum("net_irrigated_area").alias("total_net_irrigated_area")) \
    .orderBy("total_net_irrigated_area", ascending=False).toPandas()

# Treemap
fig = px.treemap(
    district_irrigation,
    path=['district_name'],  # hierarchy (just districts here)
    values='total_net_irrigated_area',
    color='total_net_irrigated_area',
    color_continuous_scale='Greens',
    title='Total Net Irrigated Area per District'
)
fig.show()
```



CONCLUSION

The Minor Irrigation Census Analysis using Apache Spark transcends traditional data analysis by building an integrated data intelligence platform for irrigation management and water resource monitoring. It effectively demonstrates how cutting-edge distributed technologies can address critical challenges in agriculture and groundwater conservation, enabling data-backed decision-making.

This project is a testament to the power of technology in social and environmental development, providing not only analytical insights but also a blueprint for sustainable water governance. By leveraging big data to illuminate patterns of irrigation efficiency and groundwater stress, it contributes meaningfully to the vision of data-driven agricultural sustainability.

More than a technical milestone, this project serves as a catalyst for informed resource planning and evidence-based policy action, paving the way toward a more efficient, transparent, and resilient irrigation ecosystem.

In [ ]:
```
```