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GIS-based risk mapping of illegal discharges into stormwater drainage systems in Cape Town

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UMVOTO

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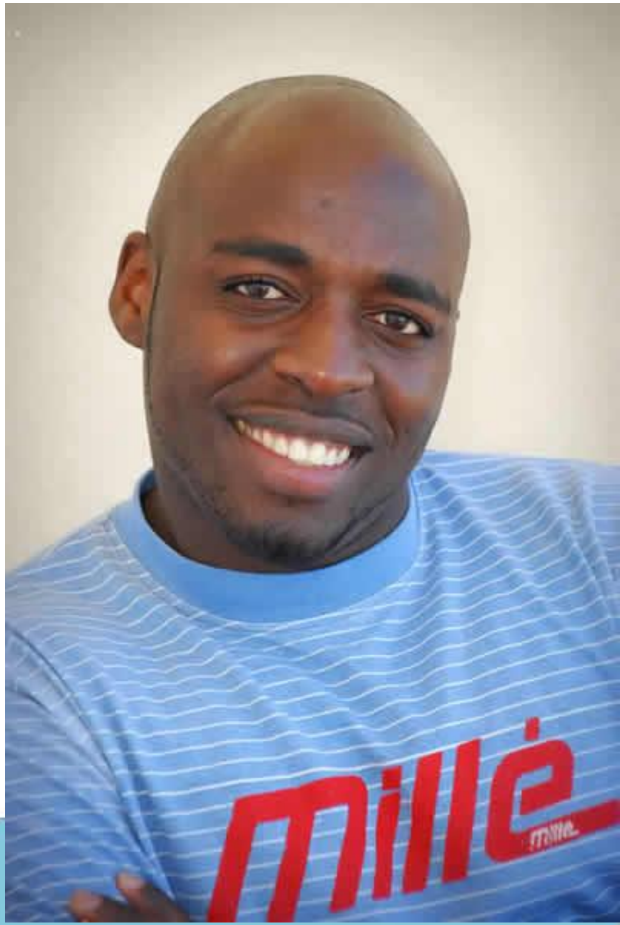
About the Presenter

- Geospatial Analyst at Umvoto Africa (2008)
- BSc Hons (UFH)
- MTech Cartography (CPUT)



- Black River (News24, October 2019)
- Discovered during the Peninsula Paddle, an annual event started in 2010 to highlight the state of canals, rivers and lakes between Muizenberg and Woodstock

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The Research Question, Aim and Objectives

- Where are the areas of the urban sub-catchment that are at risk of illegal discharge into waterways in the City of Cape Town Metro?

Aim

- Develop desktop procedures for identifying priority areas of illegal discharges in urban sub-catchments based on their low, medium and high-risk levels.

Objectives

- Carry out spatial analysis of hydraulic, hydrological and land use datasets to classify and identify areas at high risk of illegal discharge potential (IDP)
- Develop procedures for risk mapping of IDP

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What is Illegal Discharge

- “IDs are defined as a storm drain that has measurable dry weather flows containing pollutants” (CWP, 2011).

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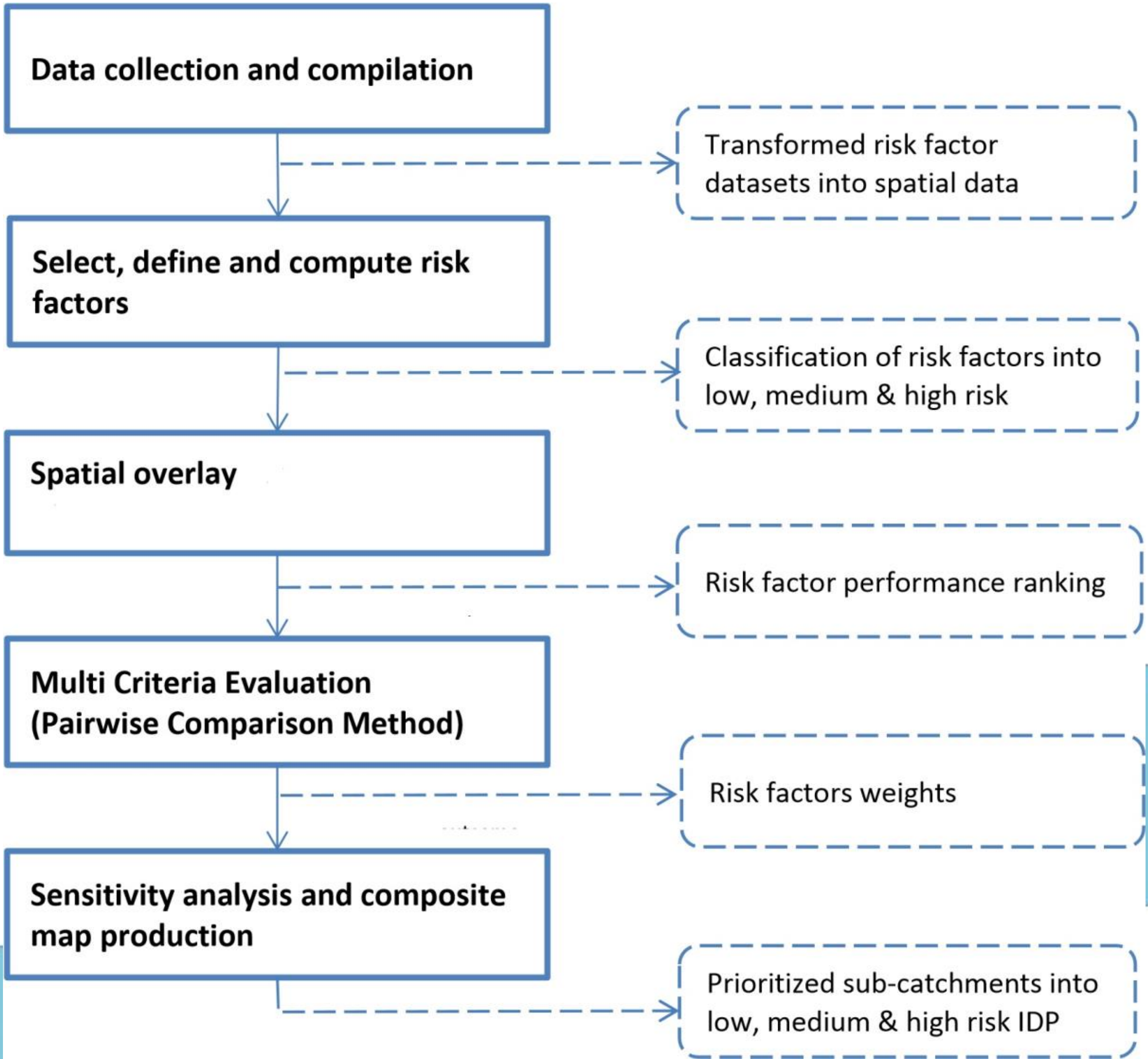
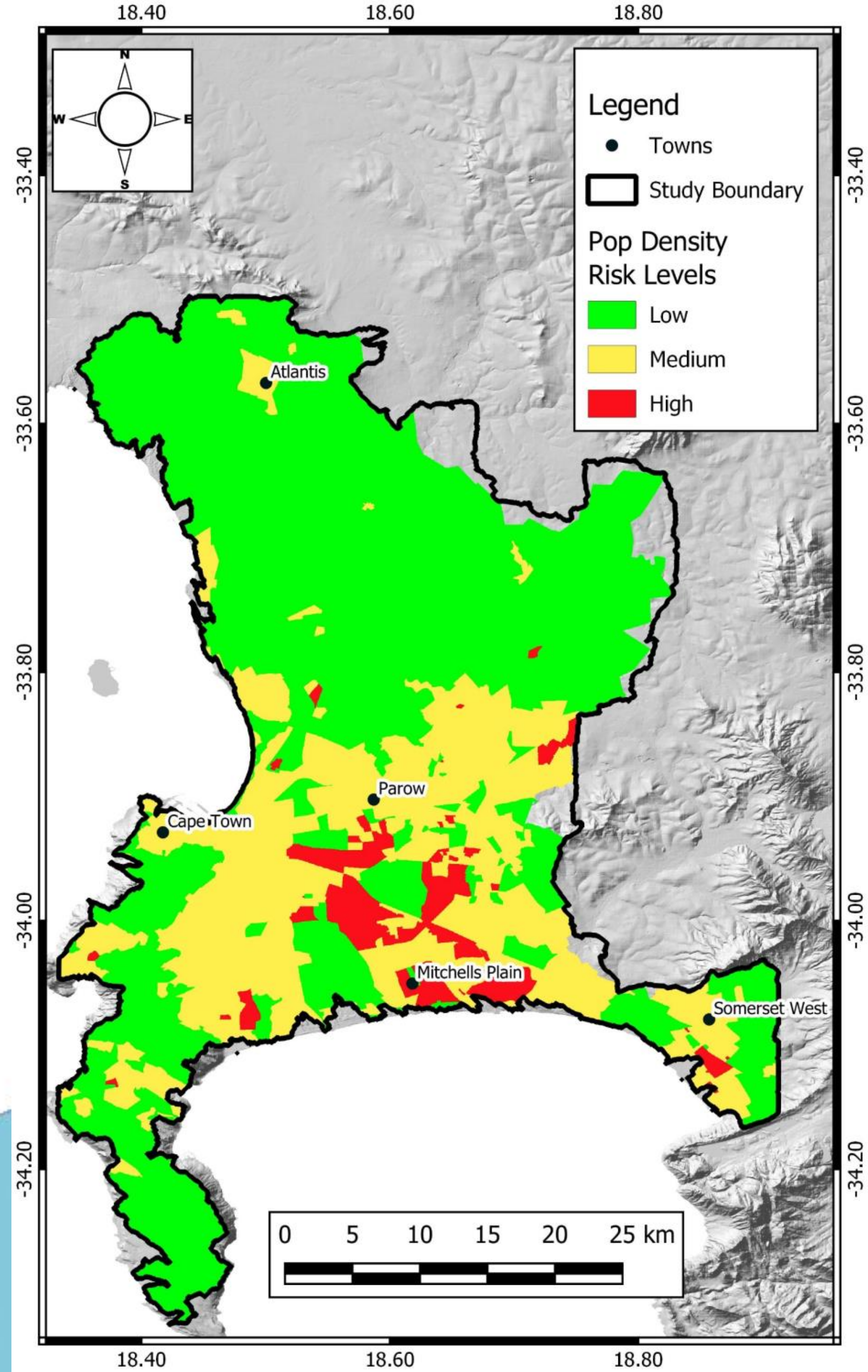
Methodology



Dataset 1 : Population Density (2011)

- Calculate Population Density (Pop total*1000000)/ (Shape Area)
- Symbolize and reclass into 3 using the Jenks Natural Breaks (low, medium, high)
- Jenks Natural Breaks is a data clustering method designed to determine the best arrangement of values into different classes



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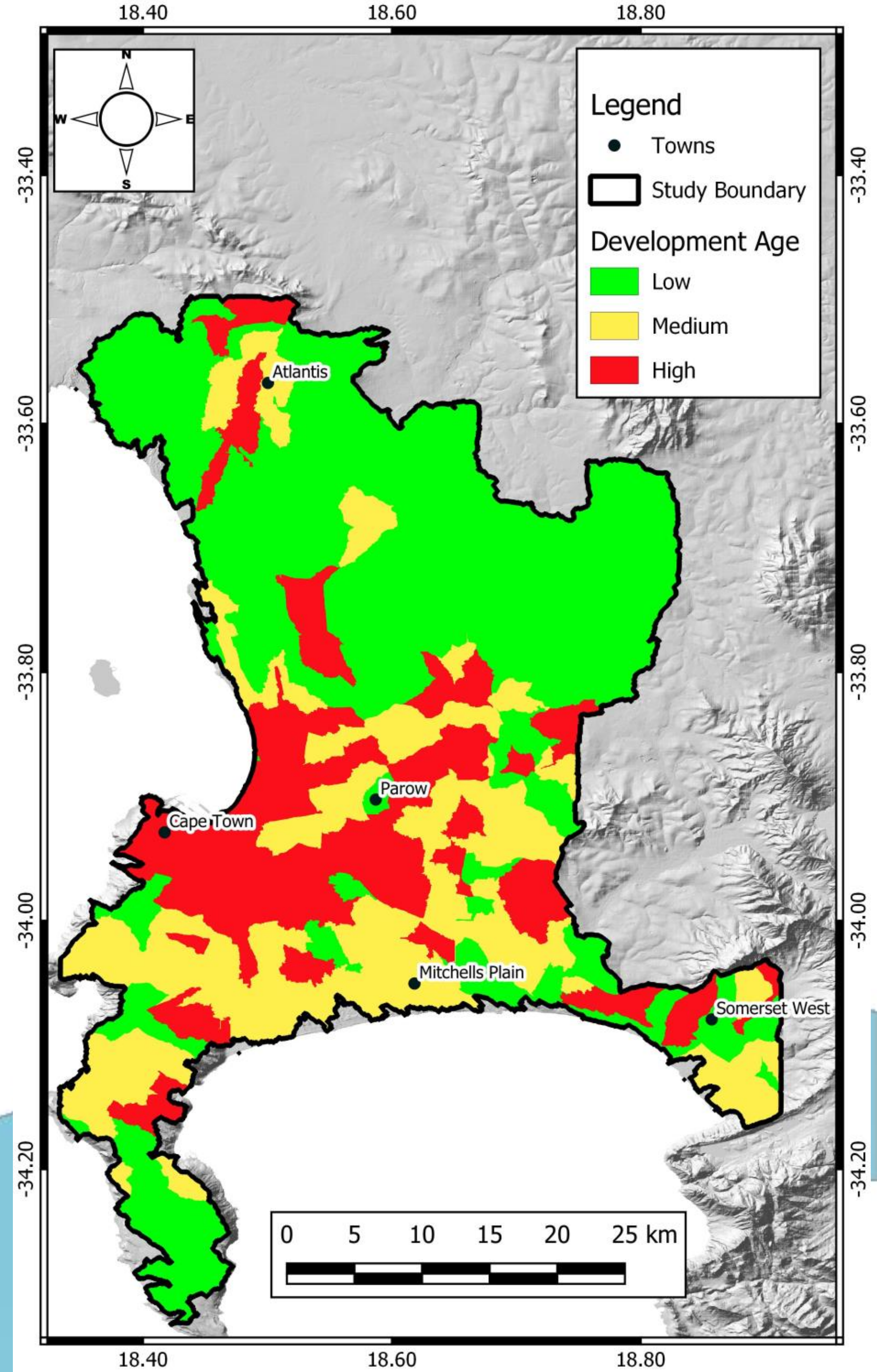
Dataset 2: Development Age (Stormwater)

- 2019 – age (to get age)
- Spatial join with sub catchments (average age in catchment)
- Symbolize using Jenks and reclass



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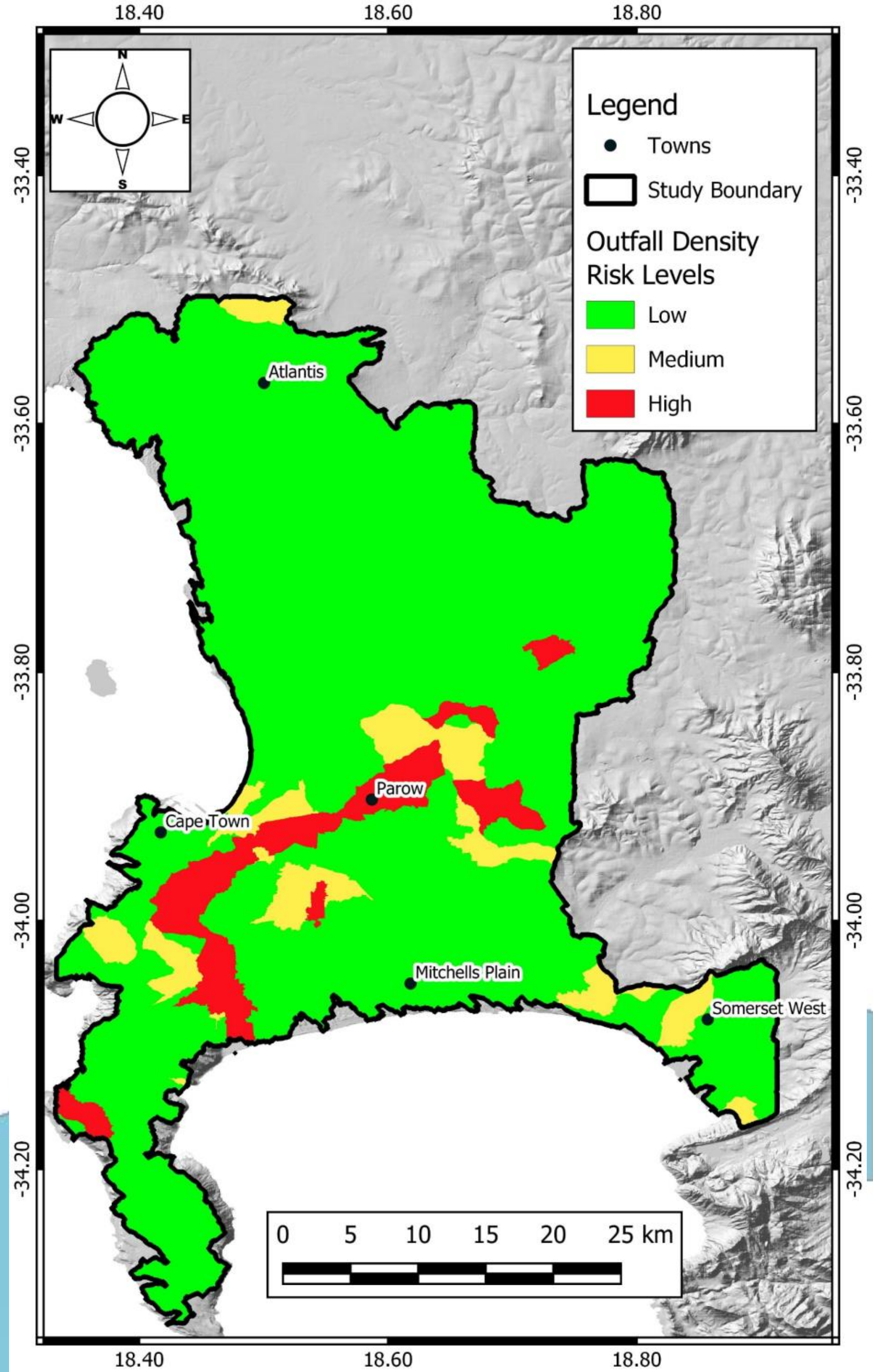
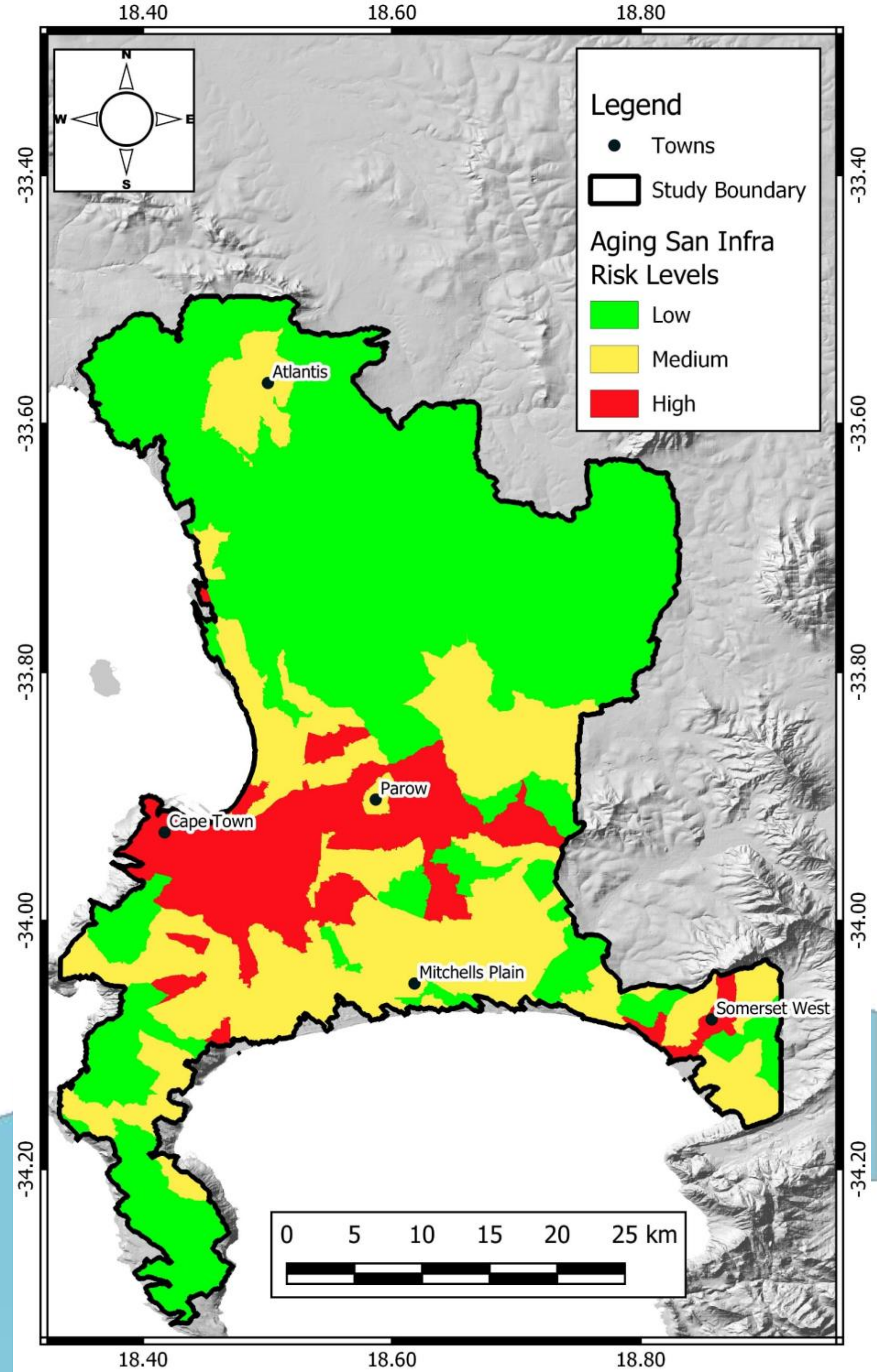
Dataset 3: Outfall Density

- Outfalls (input), rivers file and sub-drainage areas
- Create a 50m buffer around rivers, use the buffer to clip outfalls within the buffer
- Use result to perform spatial join with sub catchment areas
- Symbolize using Jenks and reclass (0-21, 25-106, >106)



Dataset 4: Aging Sanitary Infrastructure

- 2019 – age (to get age)
- Spatial join with sub catchments (average age in catchment)
- Symbolize using Jenks and reclass



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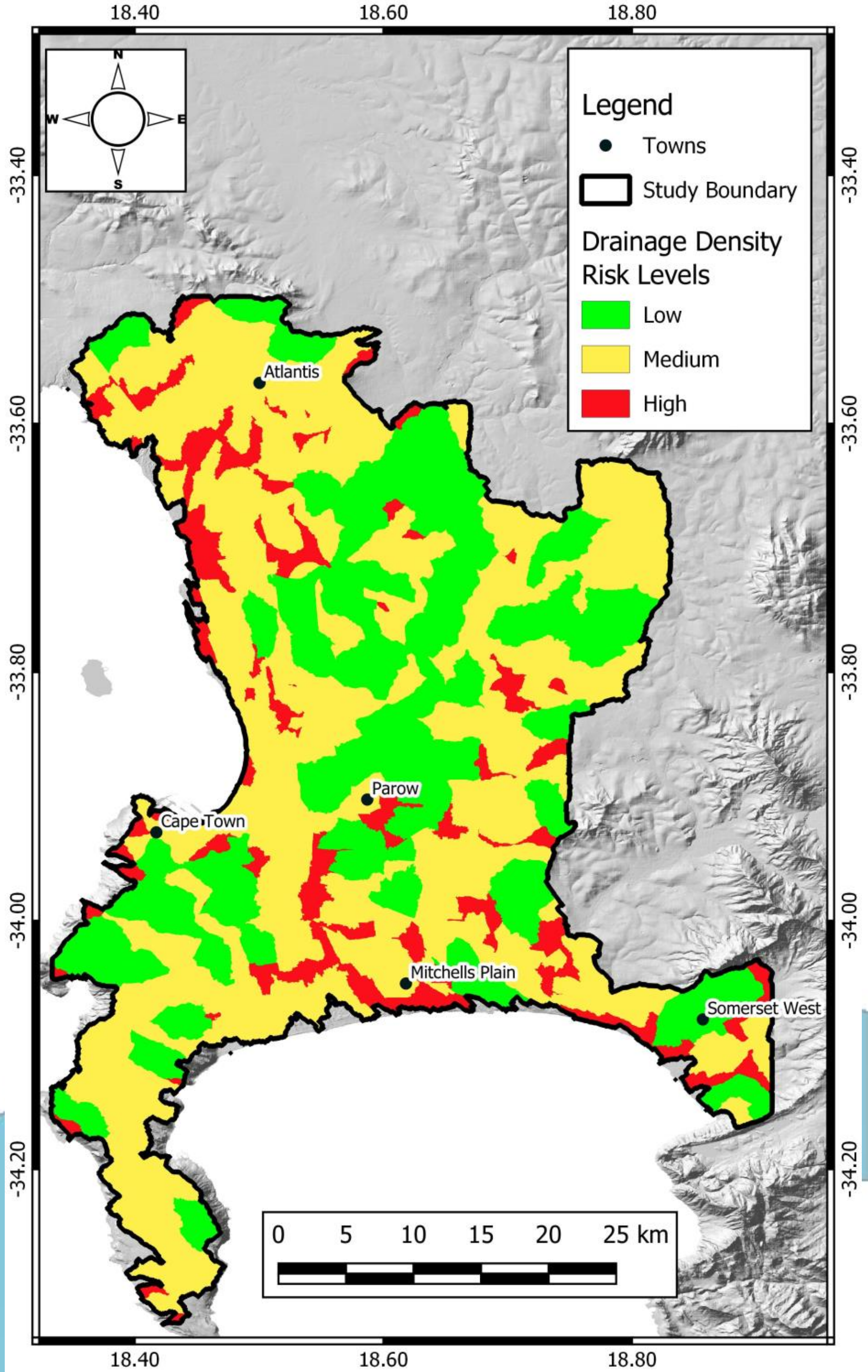
Dataset 5: Drainage Density

- Density of channels and pipes
- Spatial join with sub catchments to get sum
- Calculated density by dividing sum by area
- Symbolize using Jenks and reclass



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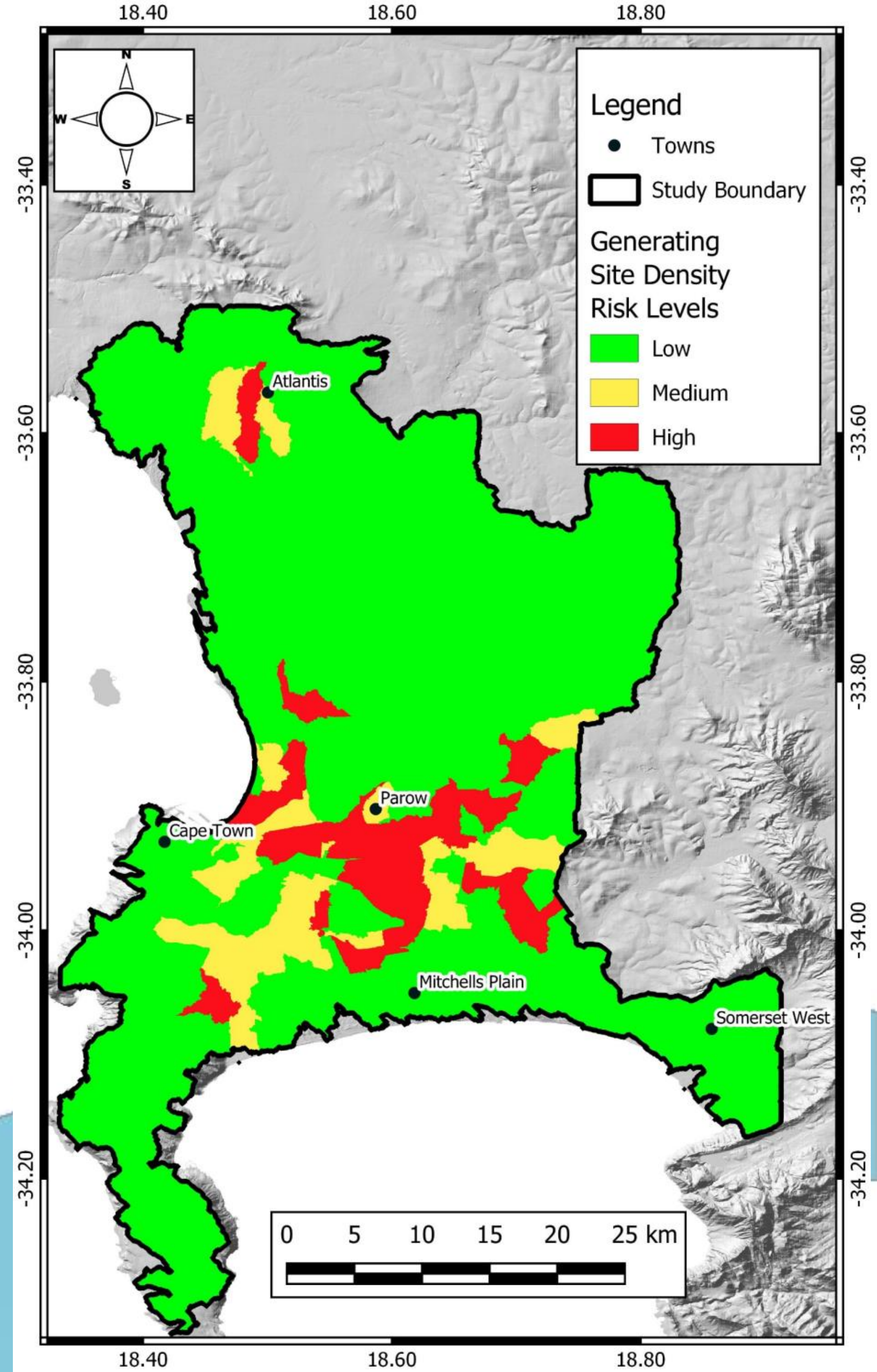
Dataset 6: Generating Site Density

- Convert polygons to points using central coordinates
- Spatial join with sub catchments (count of generating site points in each sub drainage)
- Symbolize using Jenks and reclass



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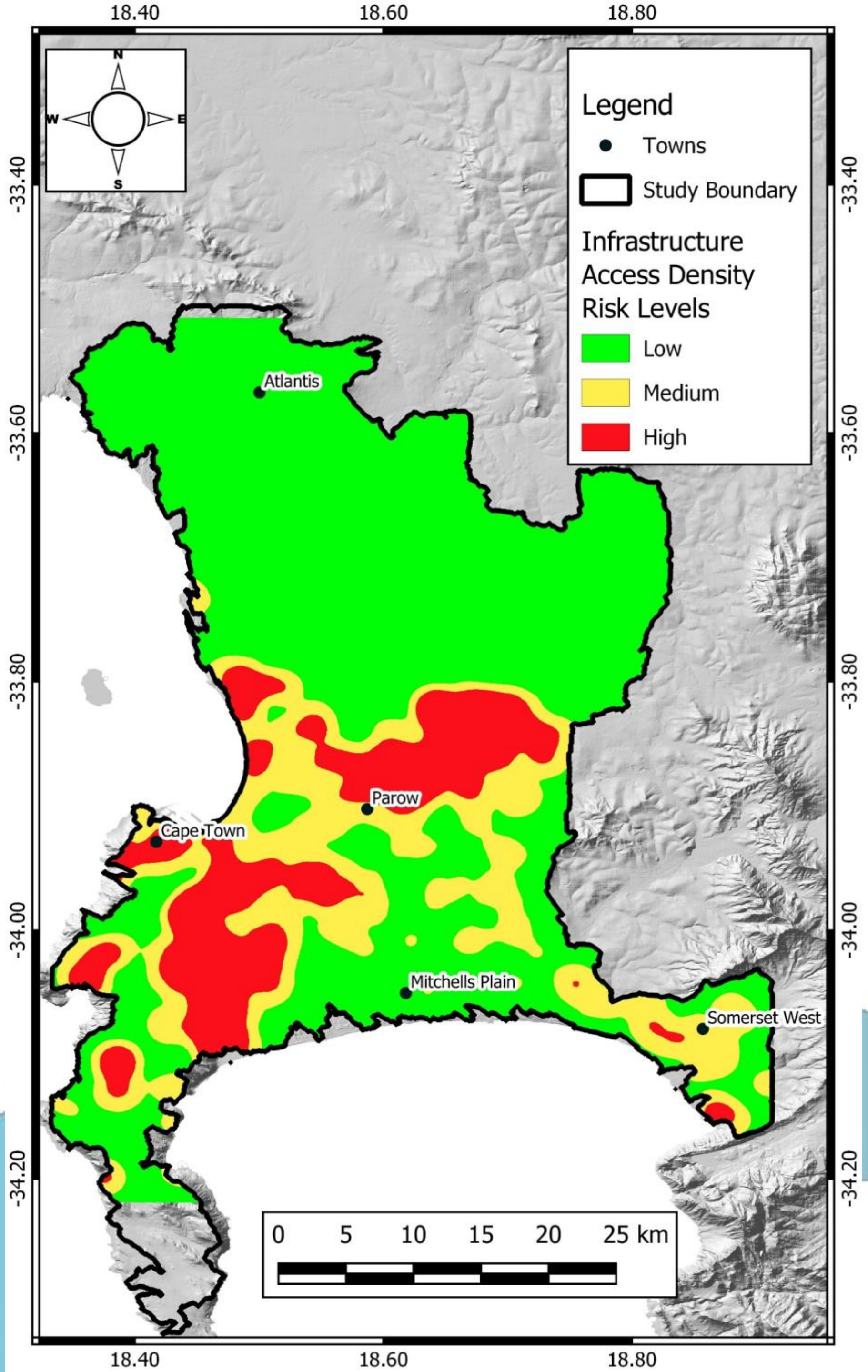
Dataset 7: Infrastructure Access Density

- Number of access points to storm drains (catch basins, pond outlet structures, pipe ends)
- Create a raster layer using the Kernel Density Function
- Symbolize using Jenks and reclass



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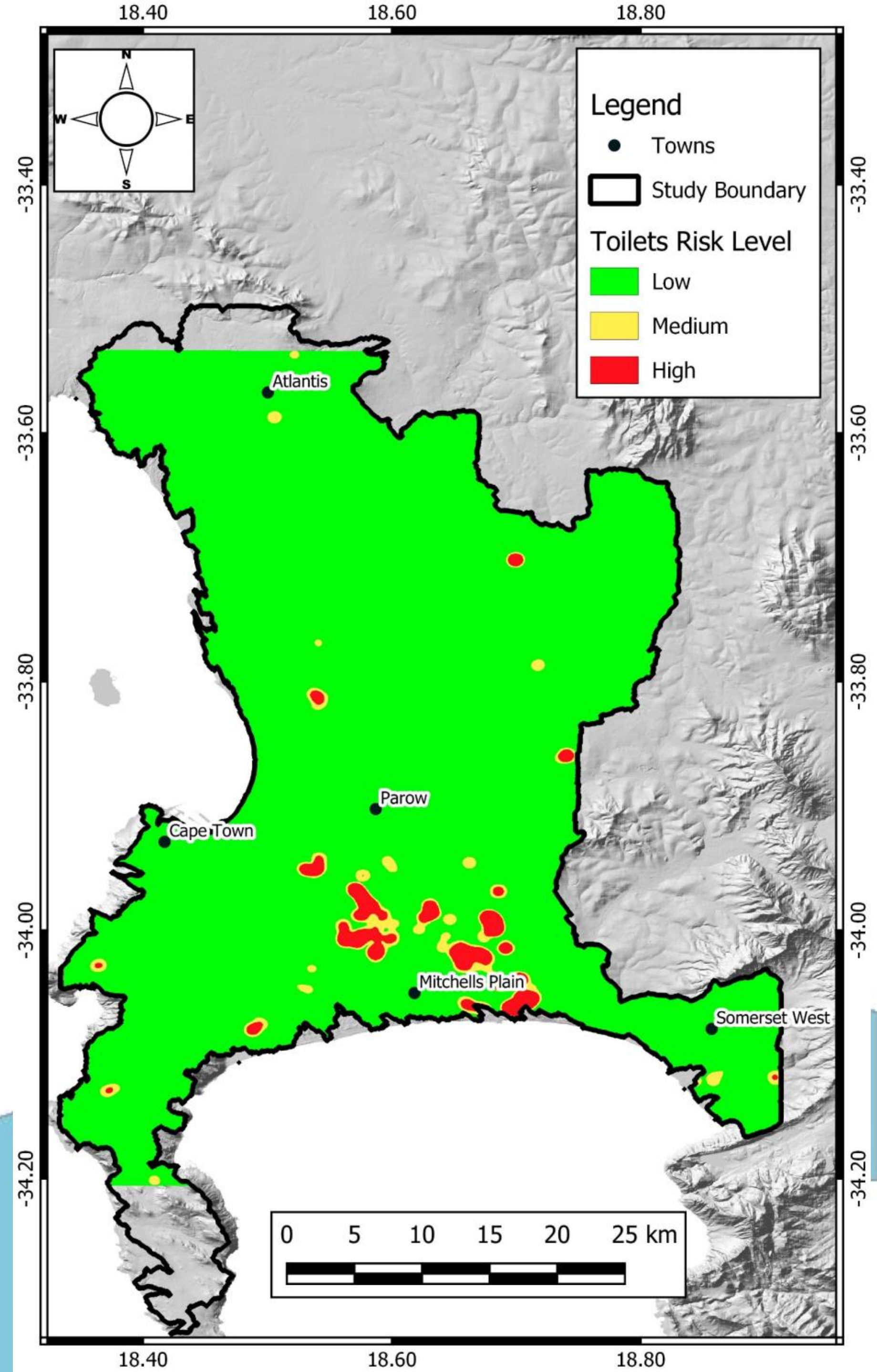
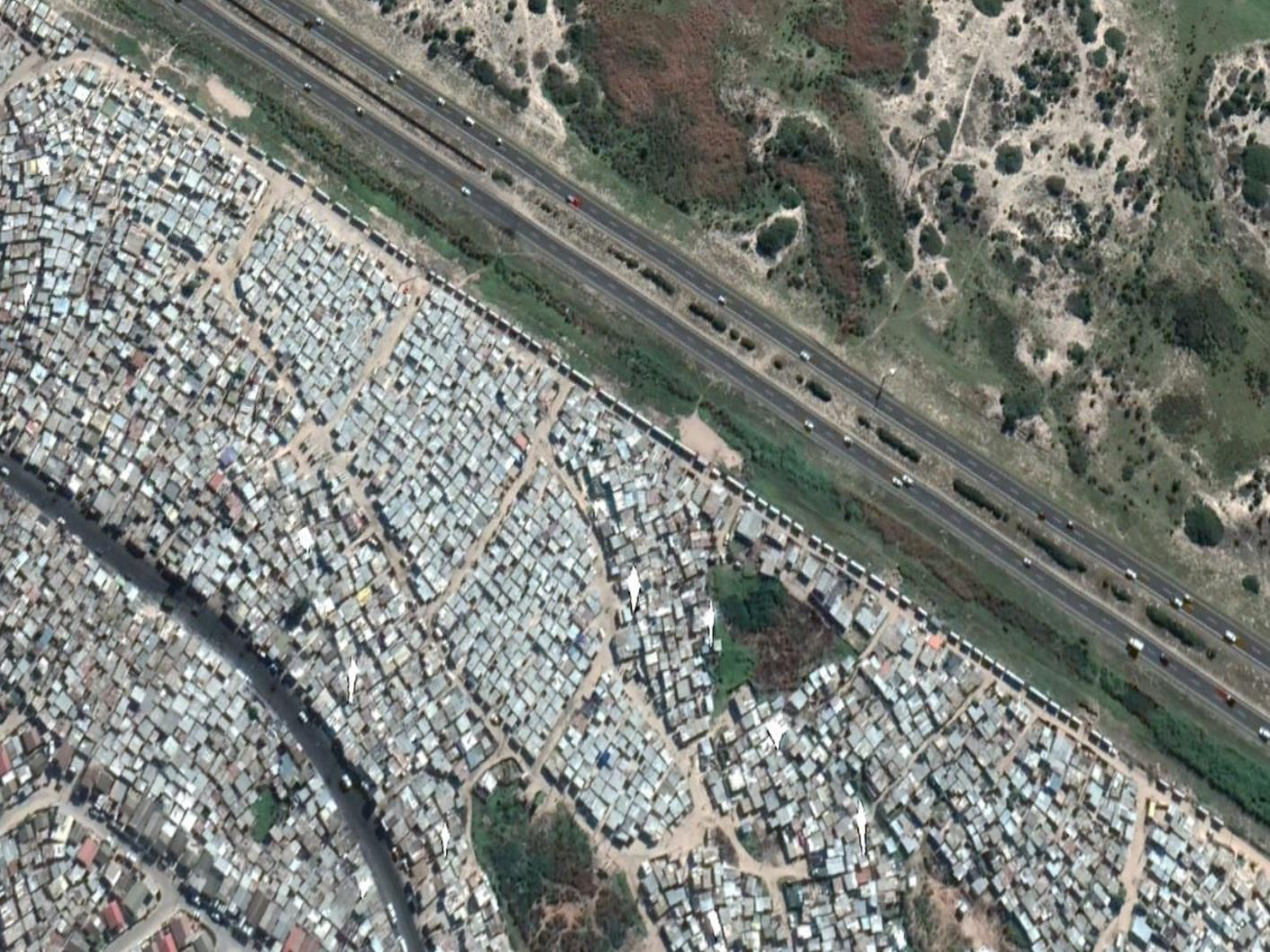
Dataset 8: Toilets In Informal Settlements

- Public toilets in informal settlements in the Metro
- Create a raster layer using the Kernel Density Function
- Symbolize using Jenks and reclass



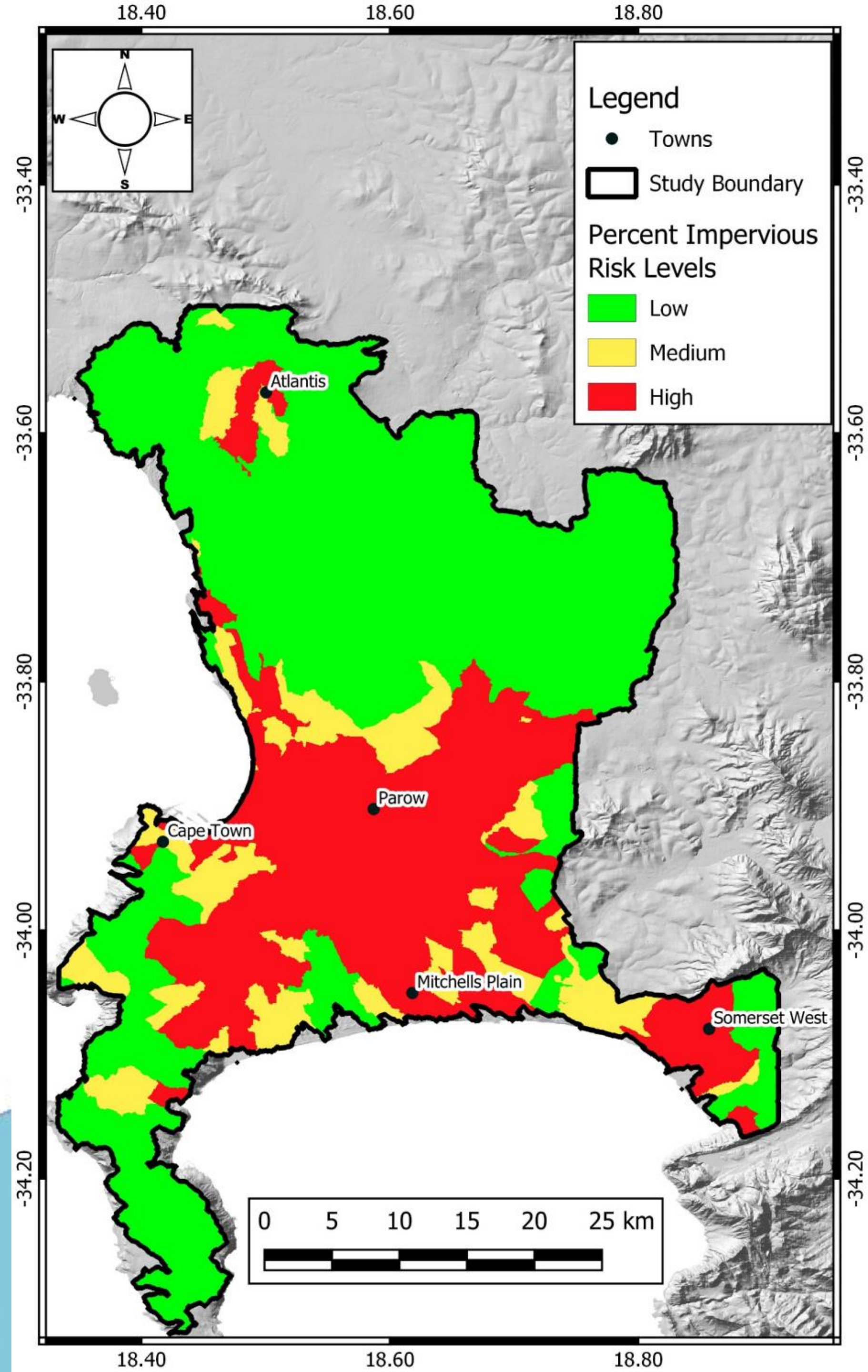




West Beach 3 informal settlement community leader, Xoliswa Mbetheni says at night residents have to relieve themselves in plastic bags and buckets, which they empty in stormwater drains. They then rinse their buckets at a communal standpipe the next day. (Peter Luhanga, GroundUp)

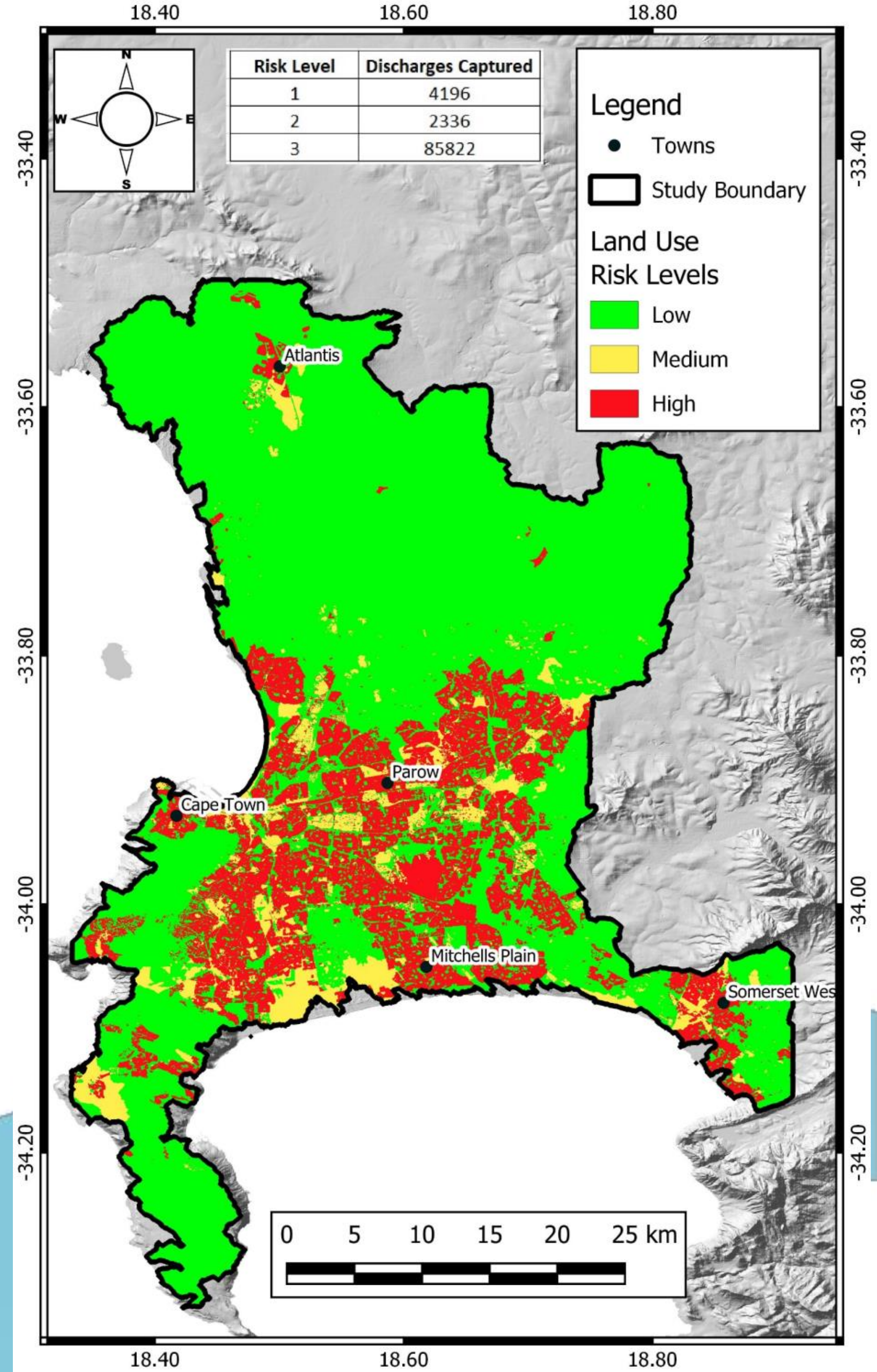
Dataset 9: Percent Impervious

- Convert the impervious file to raster
- Zonal stats with sub-drainage areas (to get total area of impervious per catchment)
- Get percentage covered (sum/area of sub catch)
- Symbolize using Jenks and reclass



Dataset 10: Land-Use

- 2013-14 NLC used and reclassed to 6 classes [Commercial (3), Residential (3), Industrial (3), Recreational (2), Instituitional (2) and Agric (1)]



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Past Discharge Records

- Point file of all discharges reported to the City (only up to 2012)
- Checked for statistical significance using a 2x2 matrix (http://vassarstats.net/odds2x2.html)

RISK FACTORS	PDCR : Wastewater	PDCR: Water	PDCR: Greywater	PDCR: Solid Waste	PDCR: All
Records in Cluster	**70120**	**1009**	**1124**	**6313**	**97419**
Population Density	33	49	29	24	29
Development Age	46	17	34	37	44
Outfall Density	11	4	10	5	11
Aging Sanitary Infrastructure	36	14	16	26	32
Drainage Density	14	7	12	9	14
Generating Site Density	25	40	22	24	24
Infrastructure Access Density	28	10	33	25	28
Toilets	6	39	13	6	6
Percent Impervious	82	44	80	86	79
Land Use	93	82	82	91	90

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AHP Process

- MCE used to analyse a series of alternatives or objectives with a view of ranking them from high priority to least priority using a structured approach.
- The Analytical Hierarchy Process using the Pairwise Comparison Method was chosen for this study. The basic steps for AHP are as follows
  - Develop a pairwise comparison matrix
  - Normalize the resulting matrix
  - Obtaining weights by averaging cells in each row

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The Saaty Table (1980)

Intensity of Importance	Definition	Explanation	*(Range or) Difference between risk factors' capture rates (%)
1	Equal Importance	Two factors contribute equally to the objective	0-4
2	Weak or Slight Importance		5-10
3	Moderate Importance	Experience and judgement slightly favour one over the other	11-20
4	Moderate Plus Importance		21-30
5	Strong Importance	Experience and judgement strongly favour one over the other	31-40
6	Strong Plus Importance		41-50
7	Very Strong Importance	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice	51-60
8	Very Very Strong Importance		61-80
9	Extreme Importance	The evidence favouring one over the other is of the highest possible validity	81-100

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The Pairwise Comparison Method (Water)

j

i	Ppln Density	Dev Age (Storm)	Outfall Density	Aging San Infra	Drainage Density	Generating Site Density	Infra Access Density	Aging Septic Tanks (Toilets)	Land Cover	Percent Impervious	Land Use
Ppln Density	1	4	4	4	4	3	4	3	1/5	1	1/7
Dev Age (Storm)	1/4	1	2	2	2	1	1	1/2	1/7	1/4	1/8
Outfall Density	1/4	1/2	1	1	1	1/2	1/2	1/3	1/8	1/5	1/9
Aging San Infra	1/4	1/2	1	1	1	1/2	1/2	1/3	1/8	1/5	1/9
Drainage Density	1/4	1/2	1	1	1	1/2	1/2	1/3	1/8	1/5	1/9
Generating Site Density	1/3	1	2	2	2	1	2	1	1/7	1/4	1/8
Infra Access Density	1/4	1	2	2	2	0,5	1	1/2	1/7	1/4	1/8
Aging Septic Tanks (Toilets)	1/3	2	3	3	3	1	2	1	1/6	1/3	1/8
Land Cover	5	7	8	8	8	7	7	6	1	4	1/4
Percent Impervious	1	4	5	5	5	4	4	3	1/4	1	1/7
Land Use	7	8	9	9	9	8	8	8	4	7	1
sums	15,91666667	29,5	38	38	38	27	30,5	24	6,420238095	14,68333333	2,369048

	Ppln Density	Dev Age (Storm)	Outfall Density	Aging San Infra	Drainage Density	Generating Site Density	Infra Access Density	Aging Septic Tanks (Toilets)	Land Cover	Percent Impervious	Land Use	Sum	Score (sum/11)
Ppln Density	0,062827225	0,13559322	0,105263158	0,105263158	0,105263	0,111111111	0,131147541	0,125	0,031151493	0,068104427	0,060302	1,041026	**0,094639**
Dev Age (Storm)	0,015706806	0,033898305	0,052631579	0,052631579	0,052632	0,037037037	0,032786885	0,020833333	0,022251066	0,017026107	0,052764	0,390198	**0,035473**
Outfall Density	0,015706806	0,016949153	0,026315789	0,026315789	0,026316	0,018518519	0,016393443	0,013888889	0,019469683	0,013620885	0,046901	0,240396	**0,021854**
Aging San Infra	0,015706806	0,016949153	0,026315789	0,026315789	0,026316	0,018518519	0,016393443	0,013888889	0,019469683	0,013620885	0,046901	0,240396	**0,021854**
Drainage Density	0,015706806	0,016949153	0,026315789	0,026315789	0,026316	0,018518519	0,016393443	0,013888889	0,019469683	0,013620885	0,046901	0,240396	**0,021854**
Generating Site Density	0,020942408	0,033898305	0,052631579	0,052631579	0,052632	0,037037037	0,06557377	0,041666667	0,022251066	0,017026107	0,052764	0,449054	**0,040823**
Infra Access Density	0,015706806	0,033898305	0,052631579	0,052631579	0,052632	0,018518519	0,032786885	0,020833333	0,022251066	0,017026107	0,052764	0,37168	**0,033789**
Aging Septic Tanks (Toilets)	0,020942408	0,06779661	0,078947368	0,078947368	0,078947	0,037037037	0,06557377	0,041666667	0,025959577	0,022701476	0,052764	0,571283	**0,051935**
Land Cover	0,314136126	0,237288136	0,210526316	0,210526316	0,210526	0,259259259	0,229508197	0,25	0,155757463	0,272417707	0,105528	2,455473	**0,223225**
Percent Impervious	0,062827225	0,13559322	0,131578947	0,131578947	0,131579	0,148148148	0,131147541	0,125	0,038939366	0,068104427	0,060302	1,164798	**0,105891**
Land Use	0,439790576	0,271186441	0,236842105	0,236842105	0,236842	0,296296296	0,262295082	0,333333333	0,623029854	0,476730988	0,422111	3,835299	**0,348664**
													1

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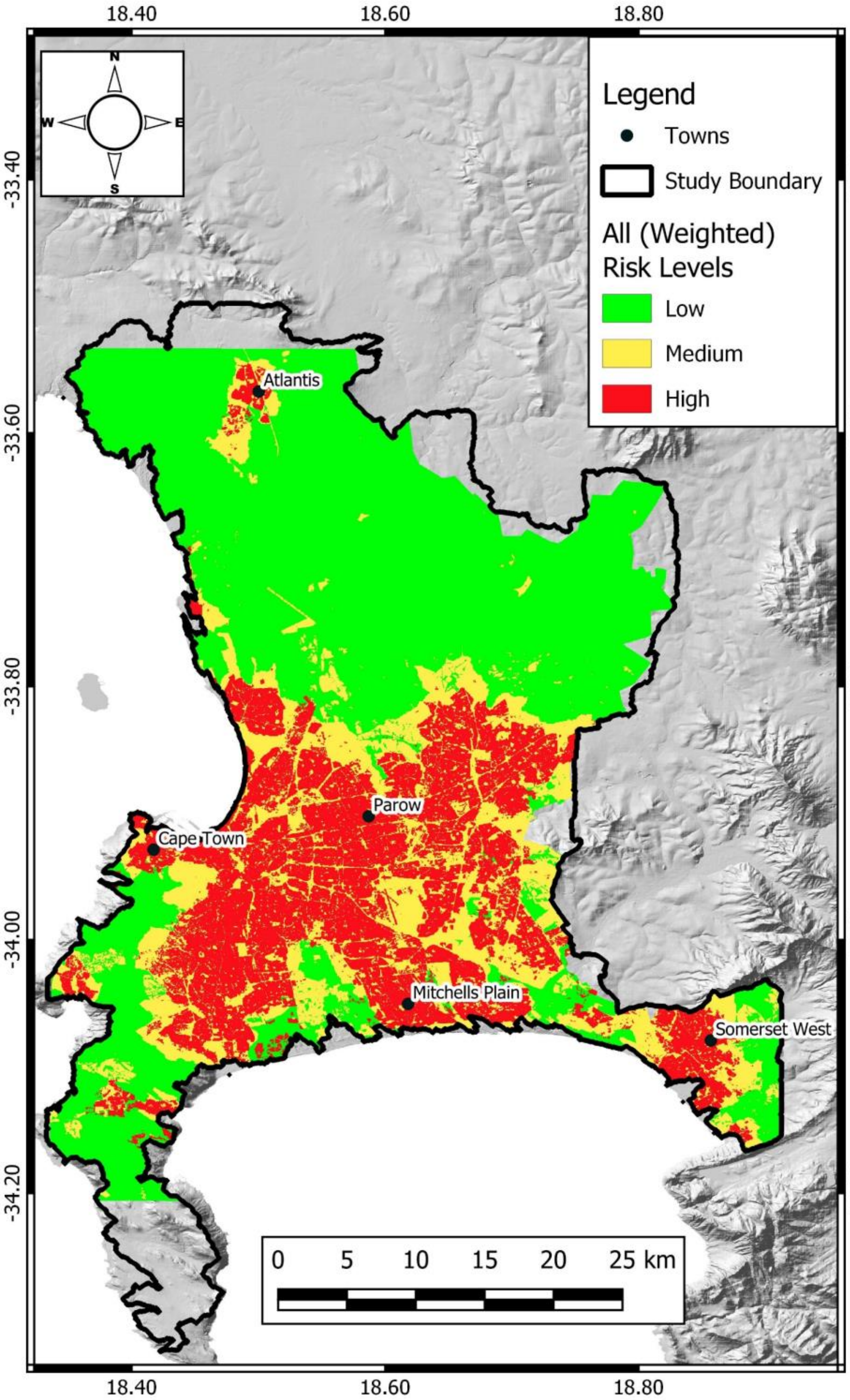
Final Weights

	Final Weights (Water)	Final Weights (Greywater)	Final Weights (Waste Water)	Final Weights (Solid Waste)	Final Weights (All)
Ppln Density	0.154	0.070	0.062	0.051	0.056
Dev Age (Storm)	0.041	0.083	0.100	0.104	0.109
Outfall Density	0.022	0.025	0.030	0.022	0.022
Aging San Infra	0.035	0.031	0.083	0.054	0.063
Drainage Density	0.025	0.028	0.024	0.023	0.026
Generating Site Density	0.108	0.059	0.038	0.051	0.047
Infra Access Density	0.031	0.078	0.051	0.051	0.055
Aging Septic Tanks (Toilets)	0.105	0.028	0.019	0.022	0.020
Percent Impervious	0.120	0.297	0.248	0.304	0.260
Land Use	0.359	0.301	0.345	0.317	0.341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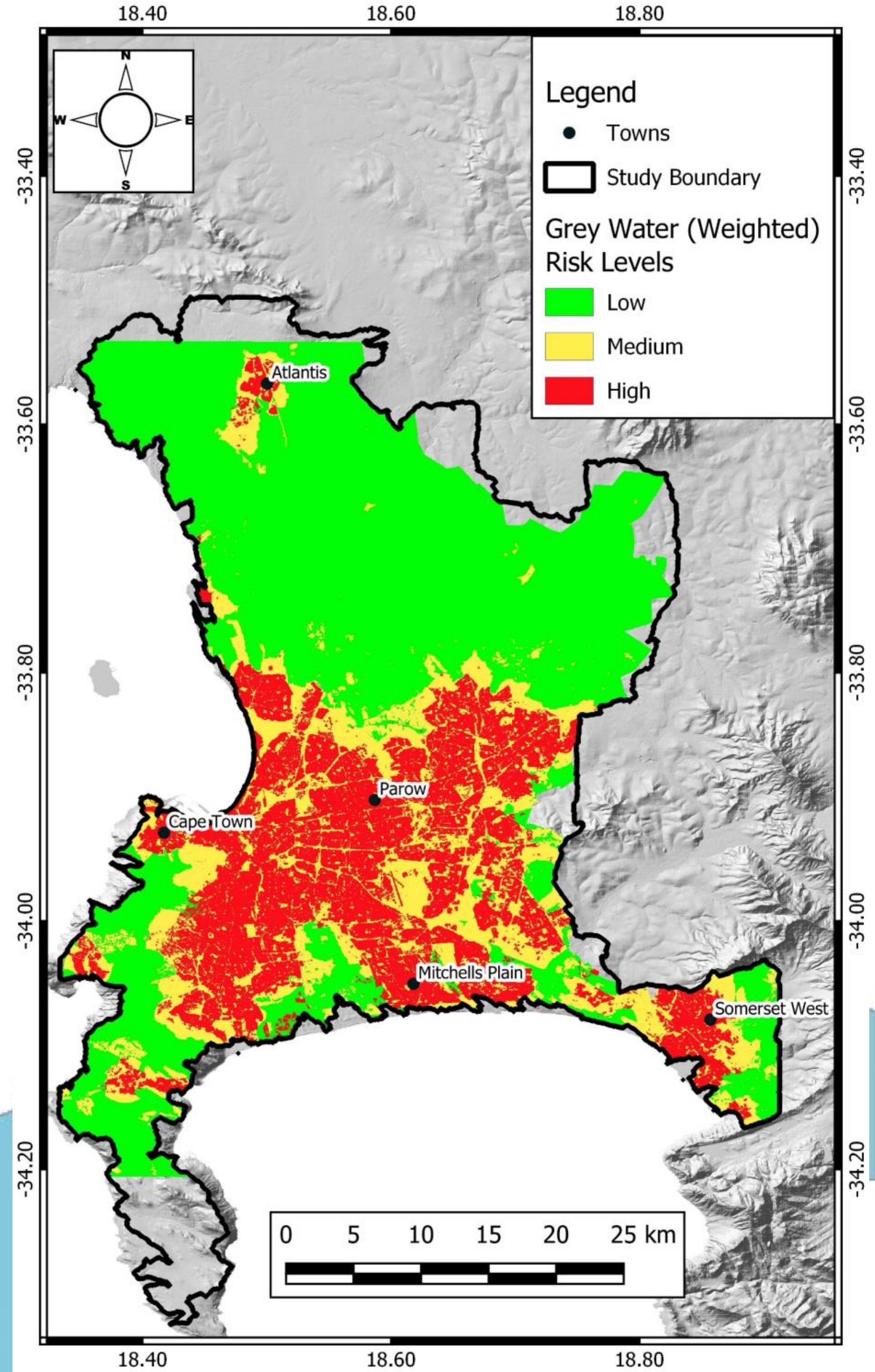
Legend
Towns
Study Boundary
All (Weighted) Risk Levels
Low
Medium
High
Atlantis
Parow
Cape Town
Mitchells Plain
Somerset West
0 5 10 15 20 25 km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Grey Water (Weighted) Risk Levels
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Somerset West
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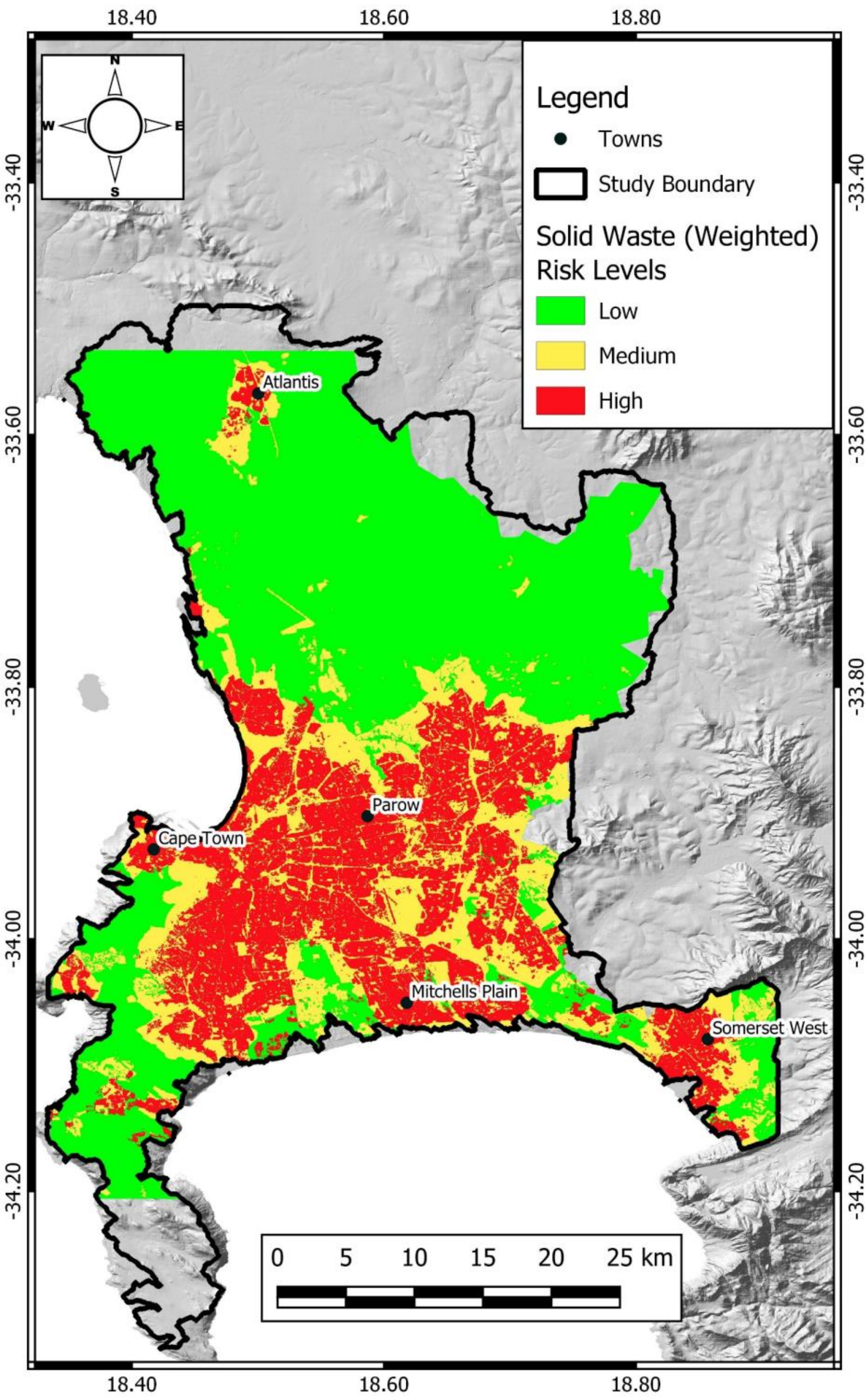

Legend
Towns
Study Boundary
Solid Waste (Weighted) Risk Levels
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Atlantis
Parow
Cape Town
Mitchells Plain
Somerset West
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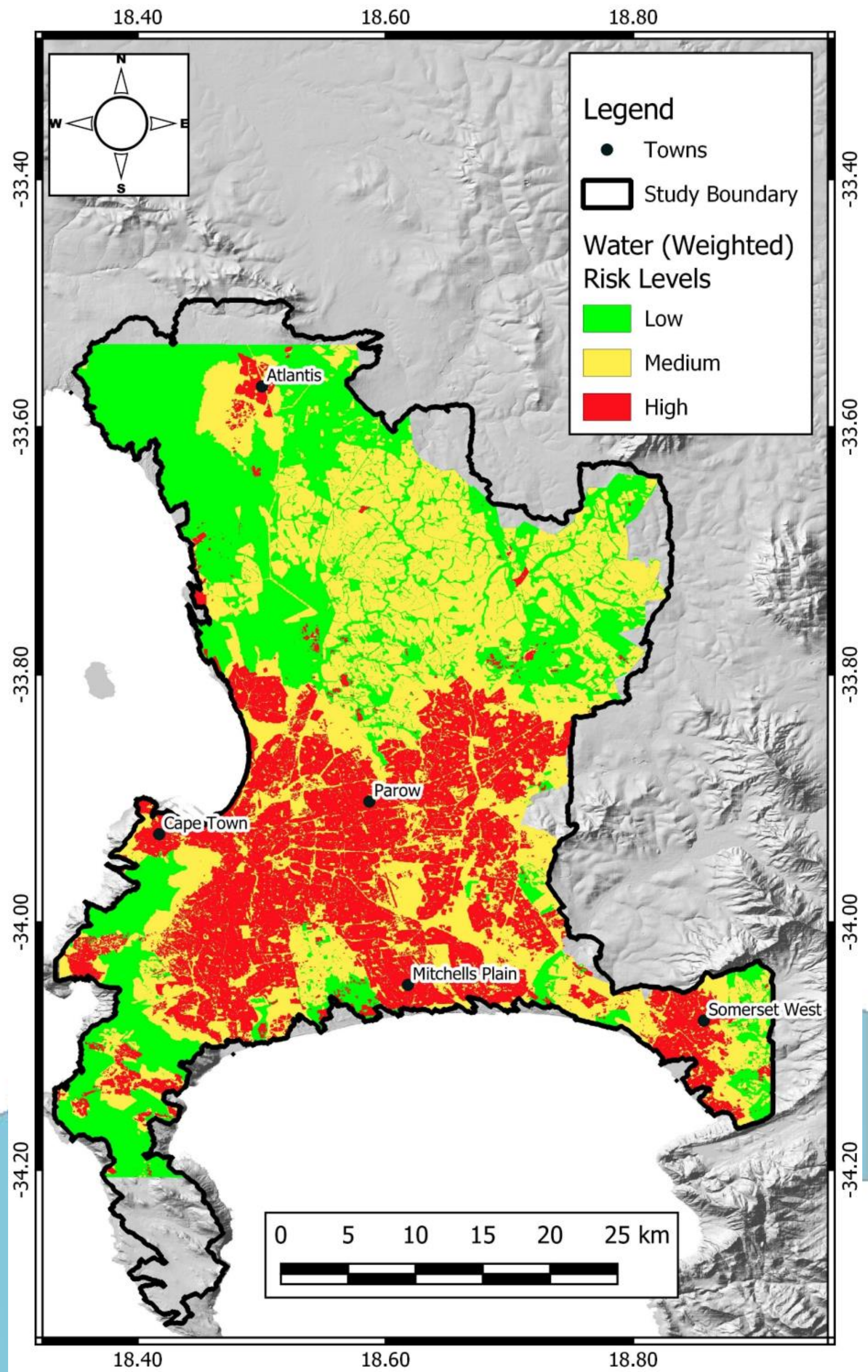

Legend
Towns
Study Boundary
Water (Weighted) Risk Levels
Low
Medium
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Atlantis
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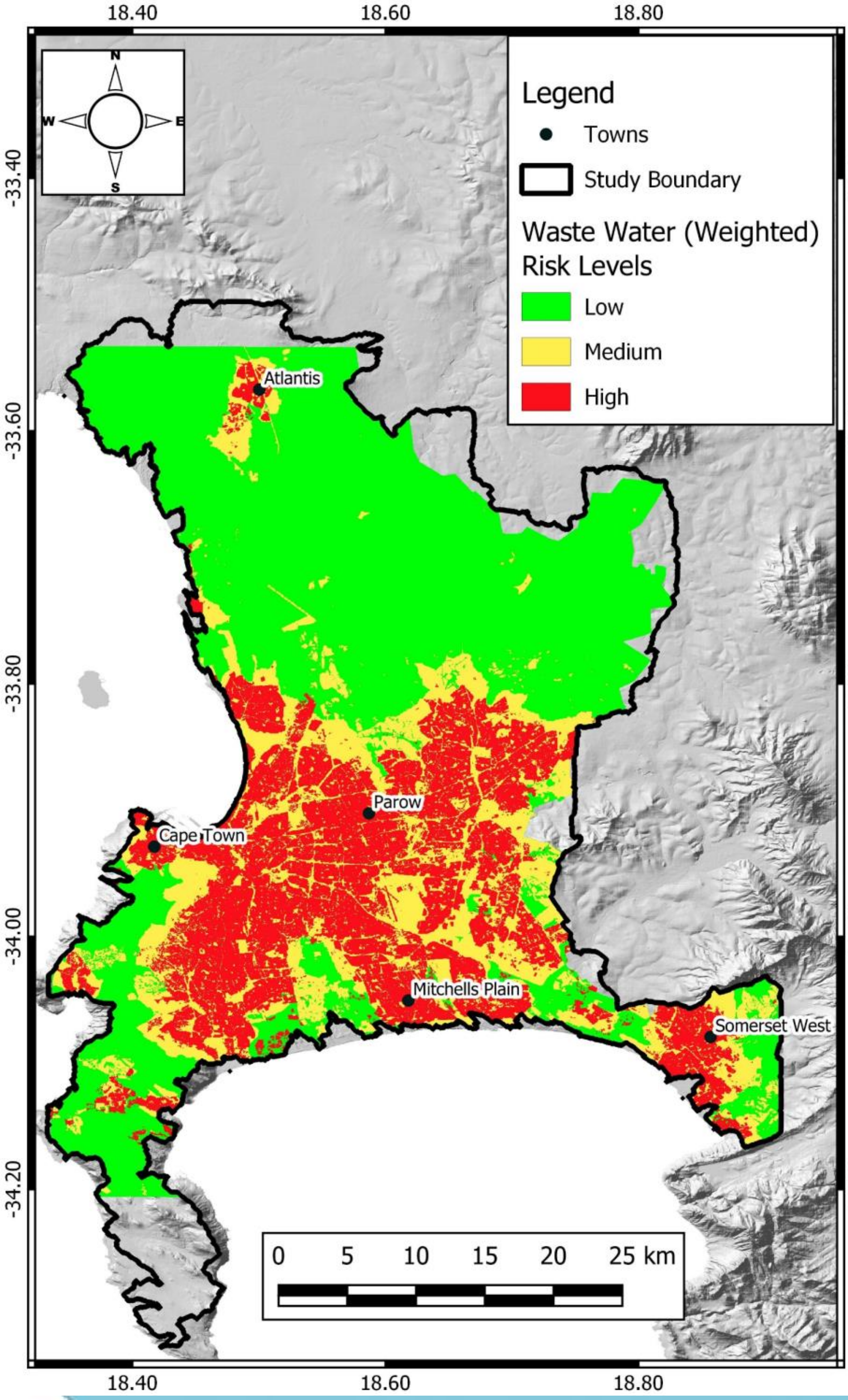
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Somerset West
0
5
10
15
20
25 km

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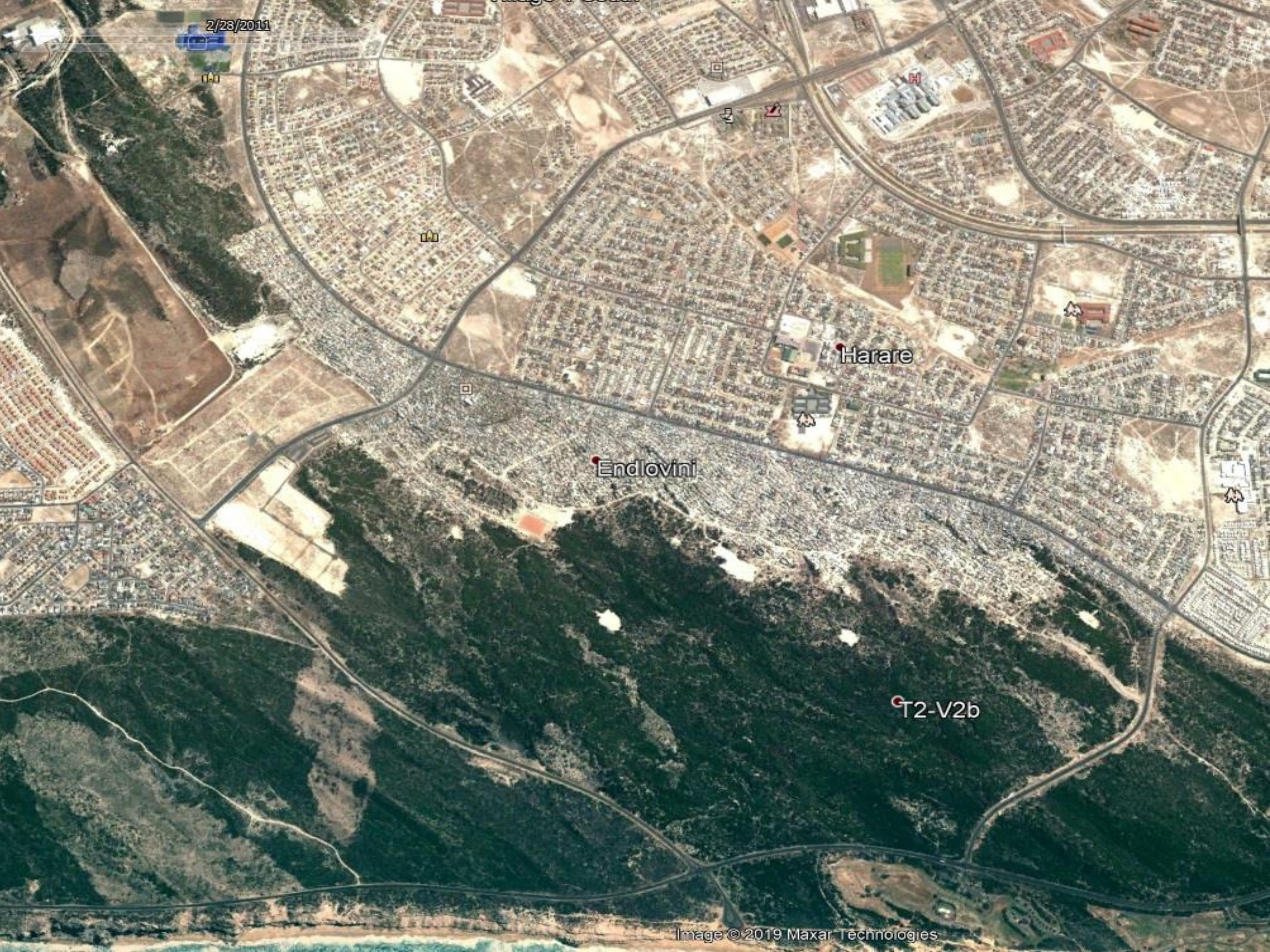
Results and Recommendations

- Some areas captured as high risk repeatedly. These are areas of concern and possible reasons are
  - Industrial areas (linked to land use, percent impervious) as these factors appear to be the most dominant
  - Informal areas with lack of service delivery, etc
- Old datasets used and results could be improved by using up-to-date data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Thank you for listening!