Center for International Earth Science Information Network
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Validation of OpenStreetMap road data for integration into the gROADS v1

- Bogdan-Mihai Cirlugea -

Master's project in Environmental sciences and engineering *(01.09.2015 – 19.02.2016)*

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  - Versioning as trust parameter
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Context

gROADS v1

- Global dataset - best available open access road data by country
- Low positional accuracy *(RMSE > 900m)* + Low completeness

OpenStreetMap

- Successful Volunteered Geographic Information product *(> 2 million active users)*
- Best source of data to improve gROADS v1

Problematic

- OSM has no systematic quality control
- OSM's quality is highly variable

Objective

- Develop diagnostics that can give a sense about overall quality of OSM
- Decide if OSM country data should be ingested into gROADS

OSM

OSM Background

Gathering: Classical crowdsourcing | Mapping party | Bulk upload

HOT Humanitarian OpenStreetMap Team

difference in quality expected!!!

Offline use:

- **OSM current data:** *.osm (XML) -> ArcGIS, Qgis – edits necessary*
- **OSM historic data:** *.osh (XML) -> No tools built for common GIS*

Ingestion into gROADS would increase ease of use!!!

OSM

Quality components

- **Positional accuracy** – Accuracy of coordinate values *(horizontal and vertical)*
- **Attribute accuracy** - Accuracy of quantitative attributes, the correctness of non-qualitative ones and the correctness of classification.
- **Completeness** – A measure of the absence of data and the presence of excess data
- **Lineage** - Traceability of geographic data - capacity to describe the origin and evolution

OSM

Previous validation work

- **Comparison against reference datasets**

Completeness

Positional accuracy

Attribute accuracy

- **Historic assessment**

Evolution of road length

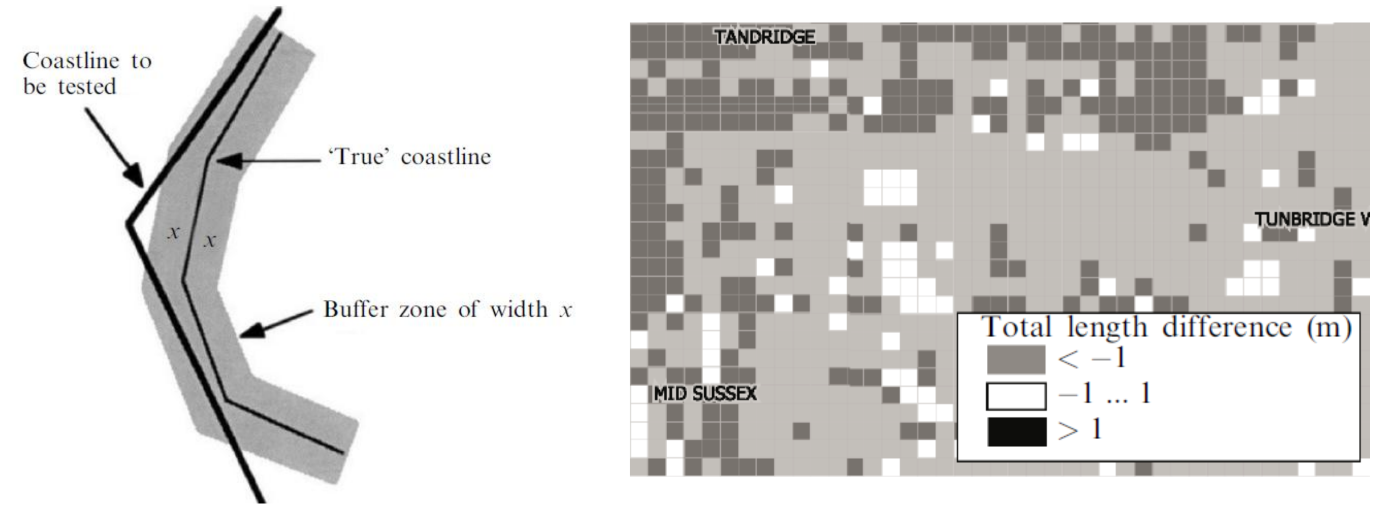
Evolution of position

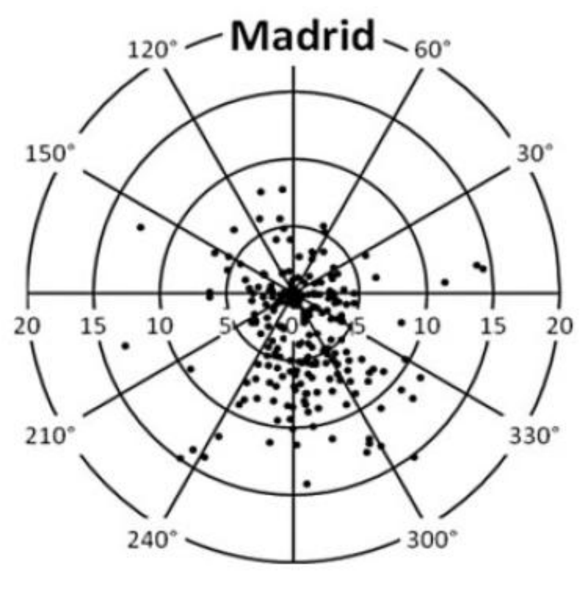
Attribute evolution

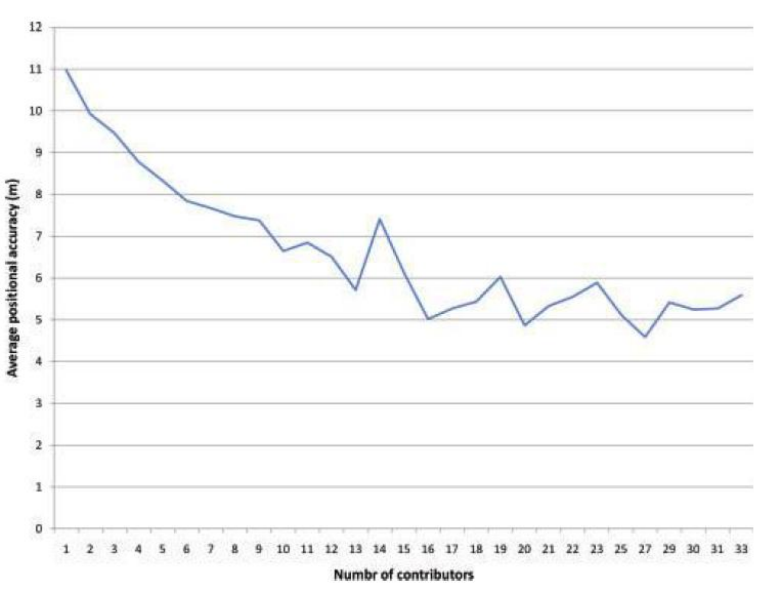
- **Trust parameters**

Number of contributors

Number of versions







OSM

Objective

- Develop diagnostics that can give a sense about overall quality of OSM
- Decide if OSM country data should be ingested into gROADS

Assessments:

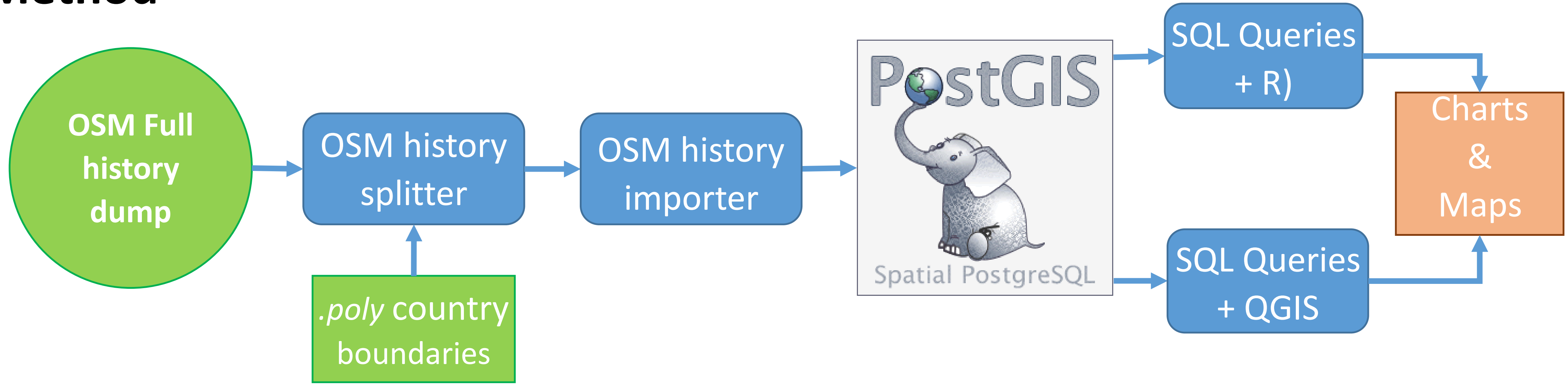
- Length evolution *(Historic assessment)*
- Attribute structure *(Intrinsic quality)*
- Completeness *(Use of complementary datasets)* **New approach!**
- Positional accuracy *(Comparison against reference dataset)*
- Versioning *(Trust parameter)*

Case study: Liberia, Guinea, Ghana, Senegal

Analysis Platform : R, ArcGIS, PostGIS

Historic assessment

Method



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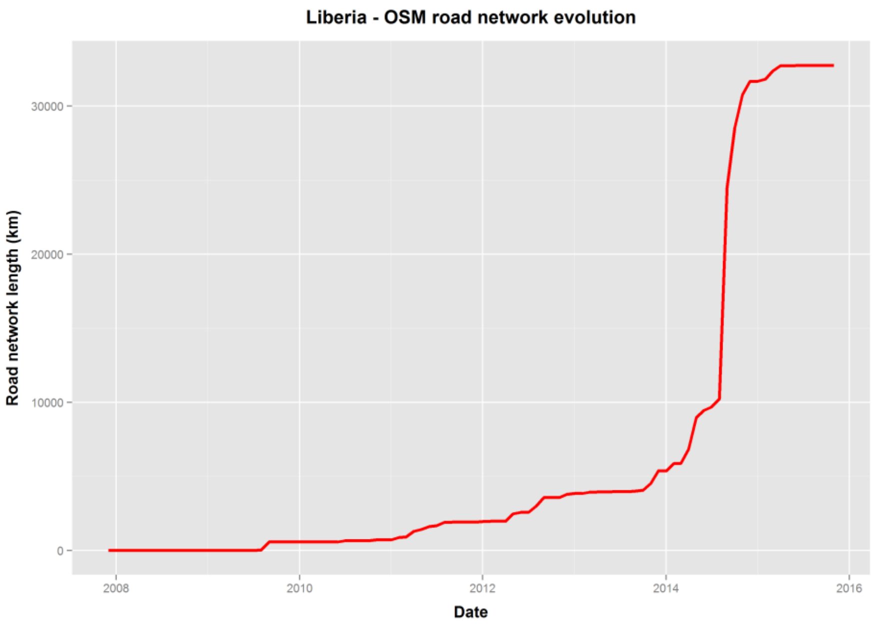
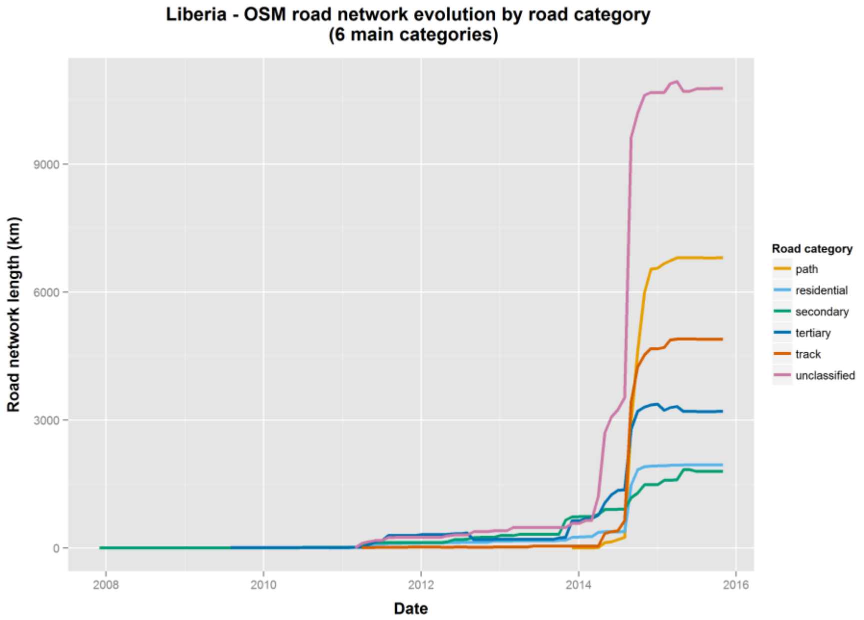
Historic assessment

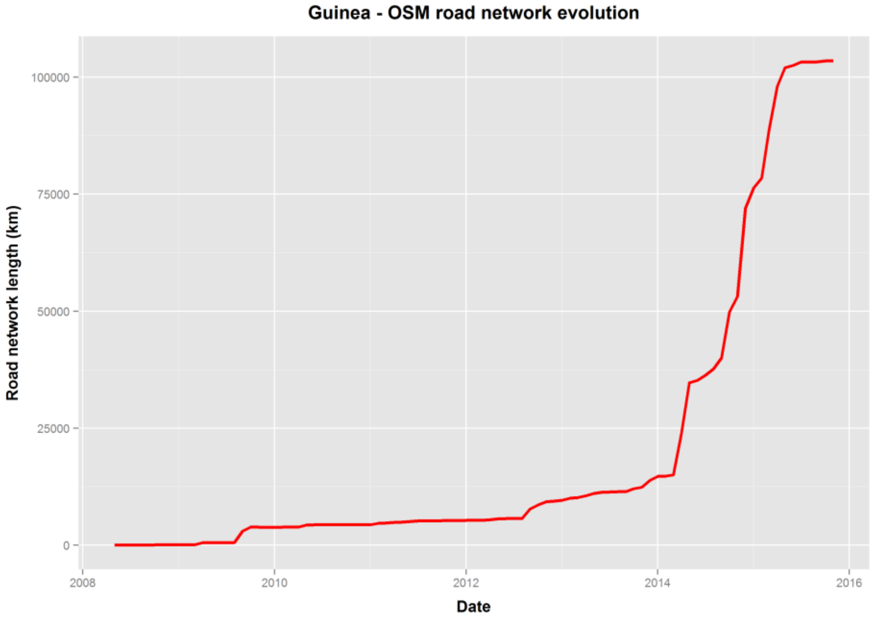
Results

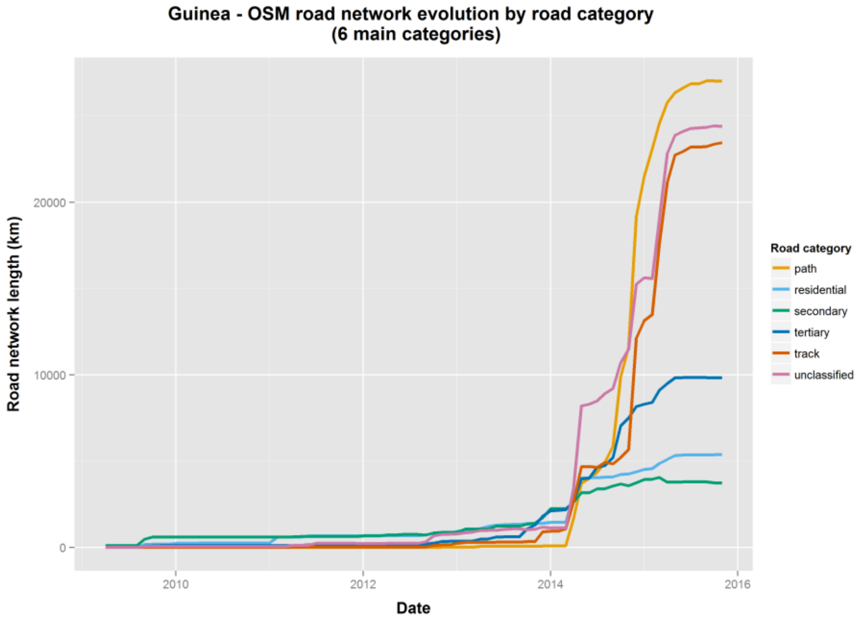
Liberia & Guinea

- Mapping intensified during Ebola crisis
- Contribution stagnates in the present







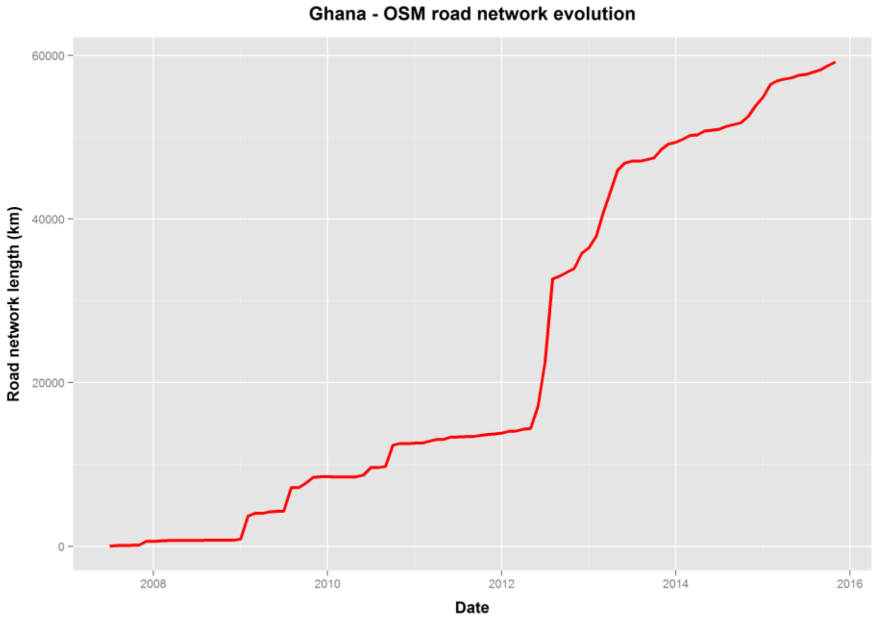


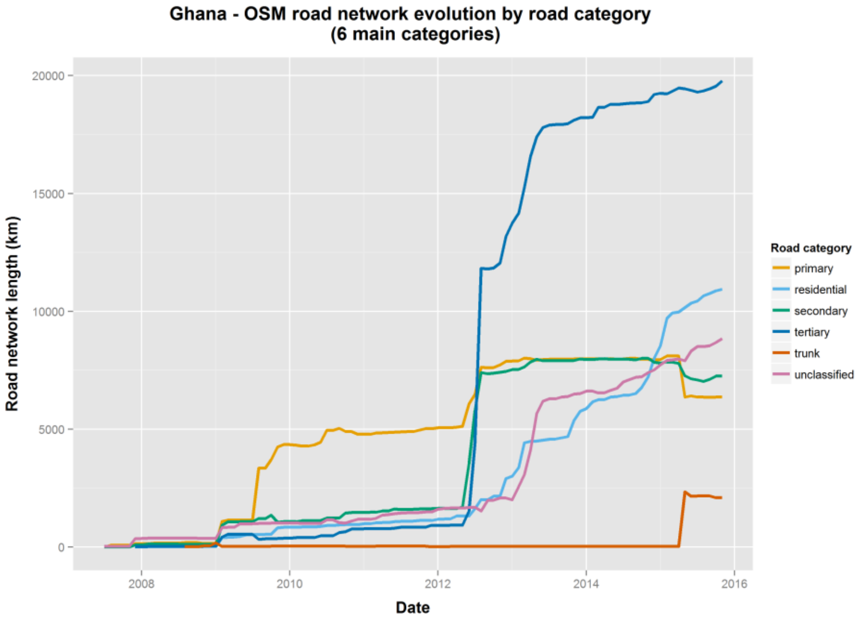
Historic assessment

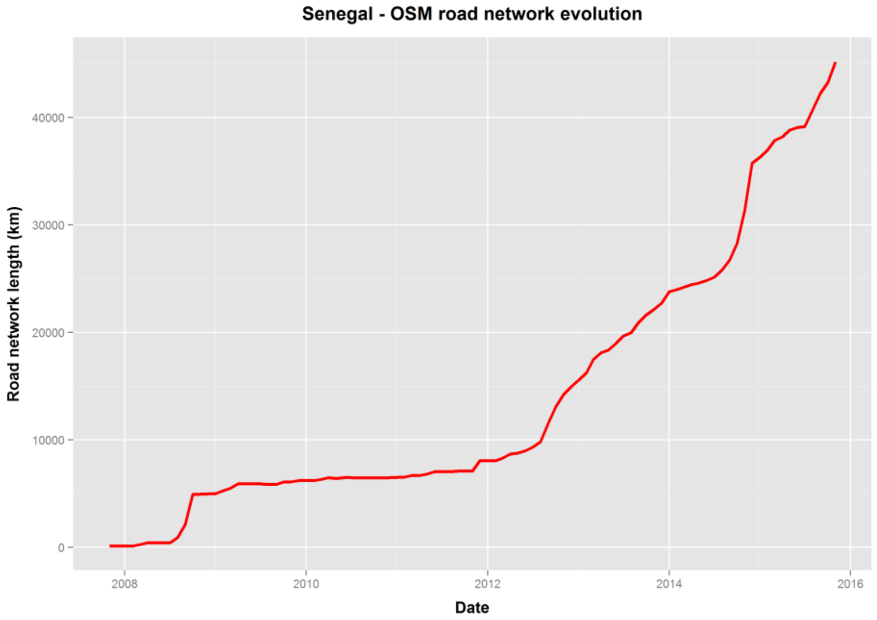
Results

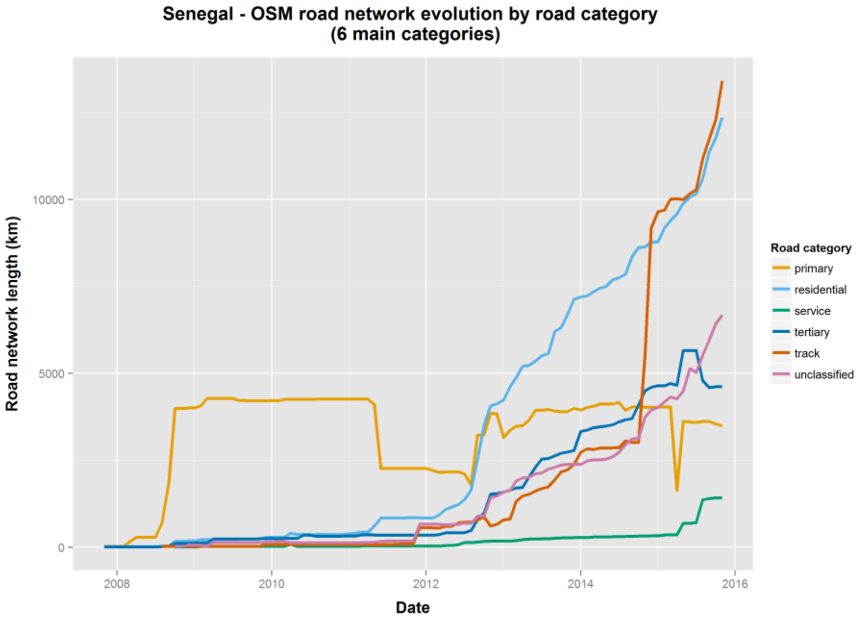
Ghana & Senegal

- More steady evolution
- Reclassifications
- Strong contribution in the present
- No pattern for road types









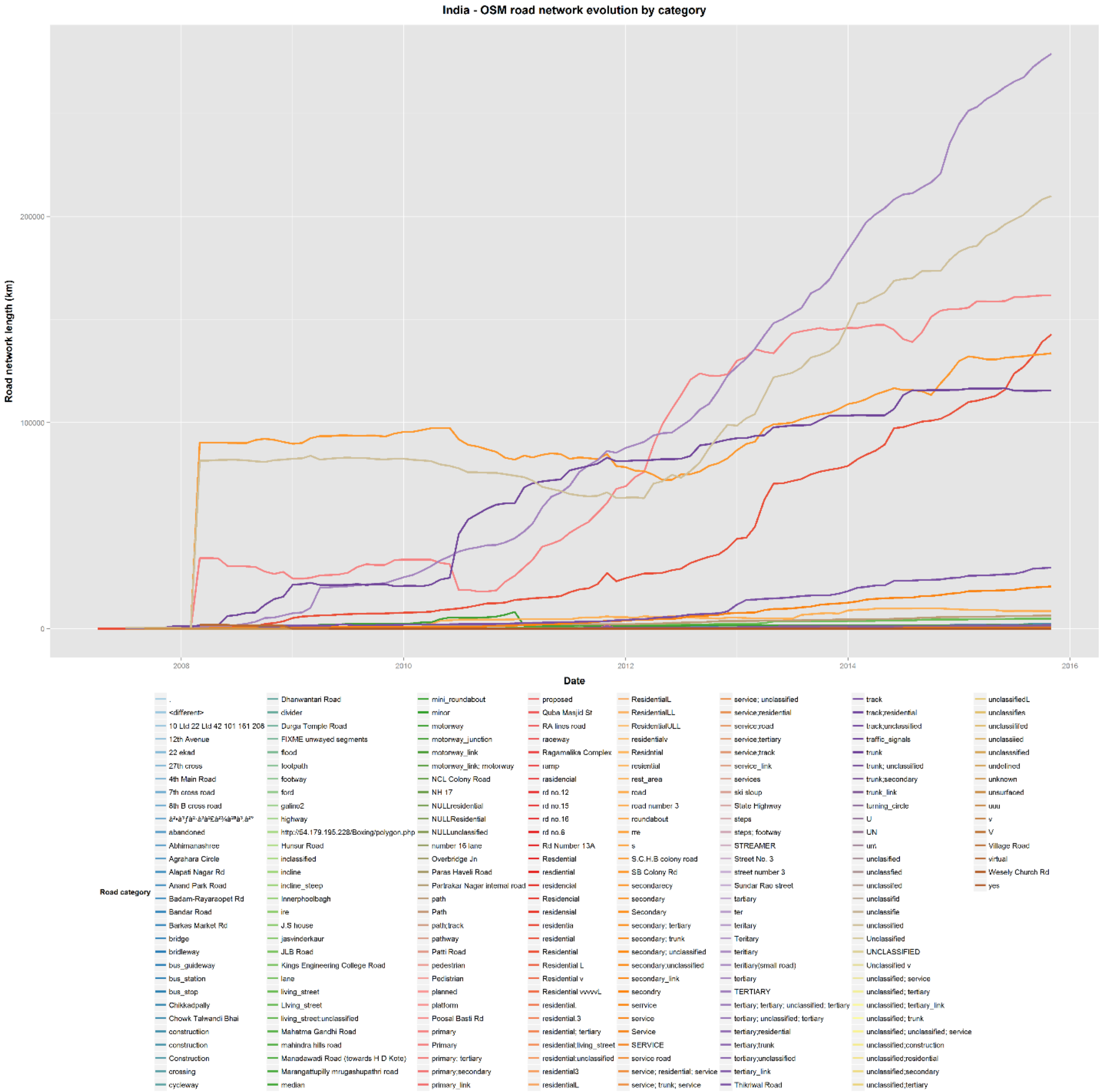
Attribute structure

Assessments:

- Proportion of ‘misclassified’ features
- Proportion of unclassified features

Metrics

- Number of unclassified / ’misclassified’ features out of total number of features *(%)*
- Length of unclassified / ’misclassified’ features out of total length of the road network *(%)*



Attribute structure(2/2)

Results

Countries	Unclassified roads		Misclassified roads	
	Count (%)	Length (%)	Count (%)	Length (%)
Liberia	13.39	32.89	0.01	> 0.01
Guinea	10.72	23.57	> 0.01	0.01
Ghana	7.57	14.94	0	0
Senegal	3.44	14.80	> 0.01	> 0.01

- ‘Misclassified’ roads not a problem
- Length (%) a better metric → Longer segments are unclassified

Completeness assessment

Assumption

Presence/absence of roads is influenced by 3 quantifiable variables:
Population, **Wealth**, **Terrain Variability**

IF TRUE → The 3 variables can be used to predict regions with missing roads in OSM

Workflow

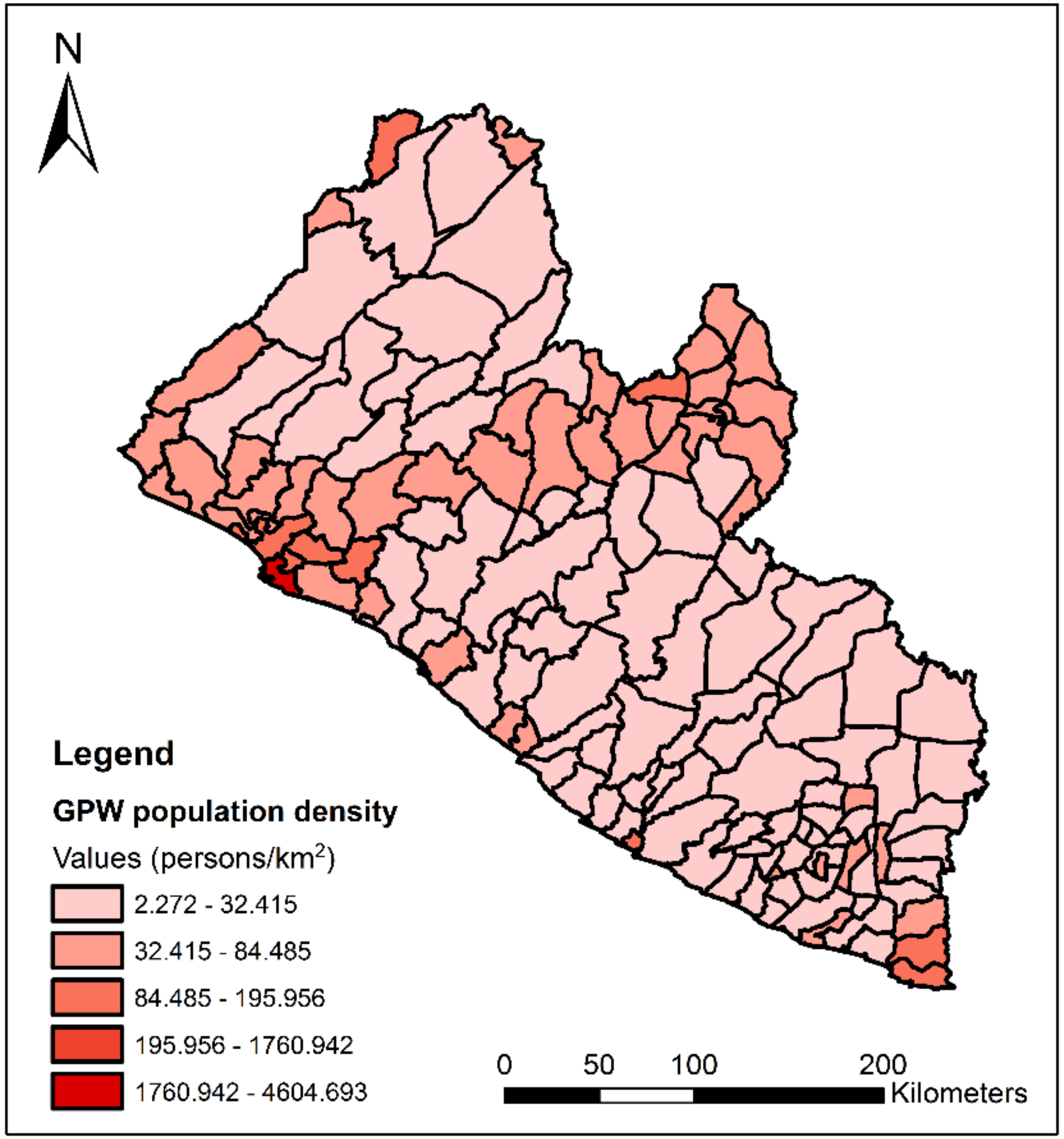
- **Identify suitable datasets:** GPW, DSH survey, STRM-1 Arc Second Global
- **Aggregate datasets:** Subnational admin units 2
- **Asses data correlation**
- **Develop prediction methods:** Discrete classification & Regression model
- **Verify prediction accuracy**

Completeness assessment

GPW 4

No transformation needed

Population density
(pers./km2)

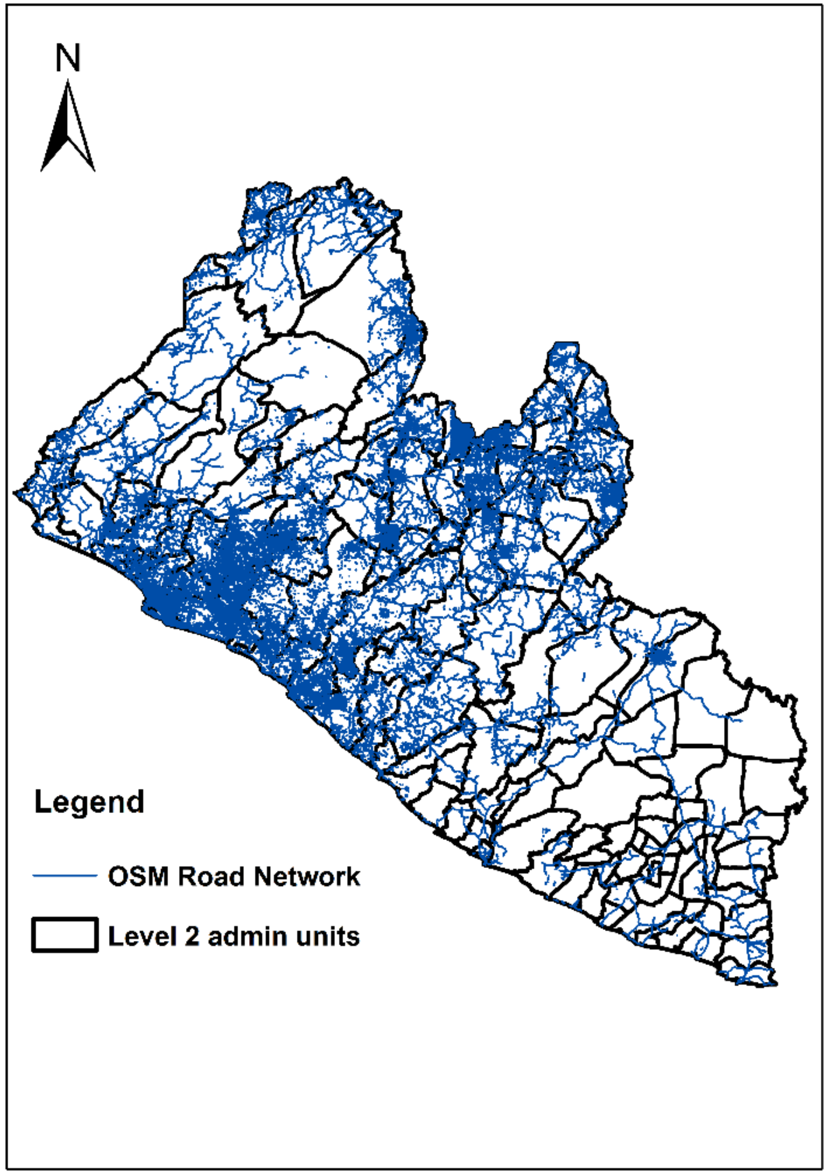


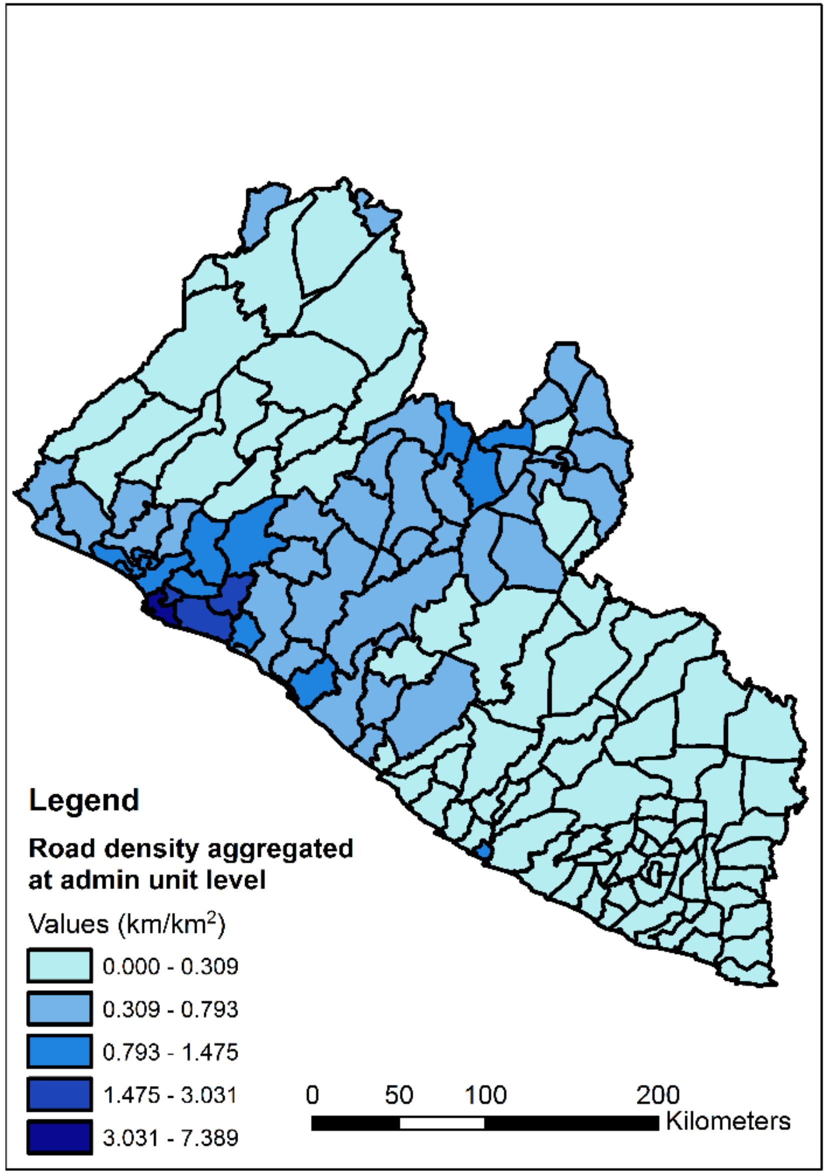
Completeness assessment

OSM road network

↓

Road density
(km/km^2)





Completeness assessment

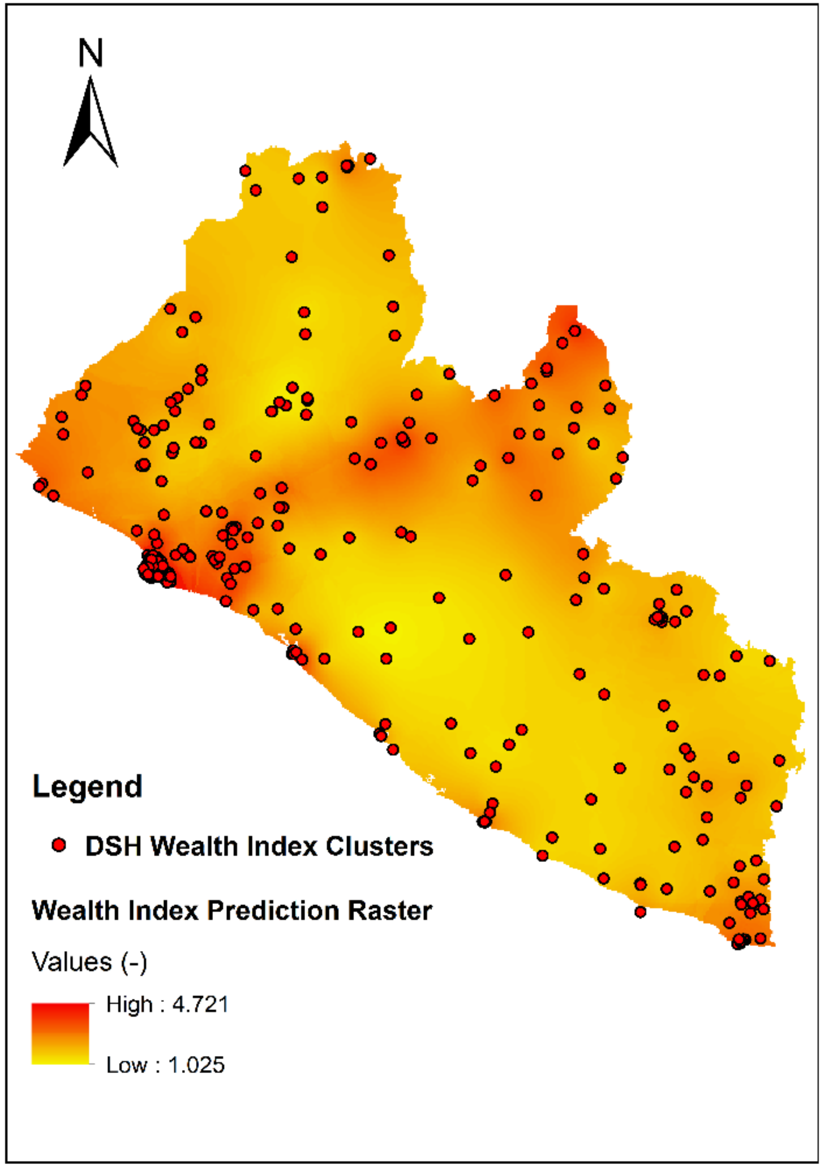
DSH Survey

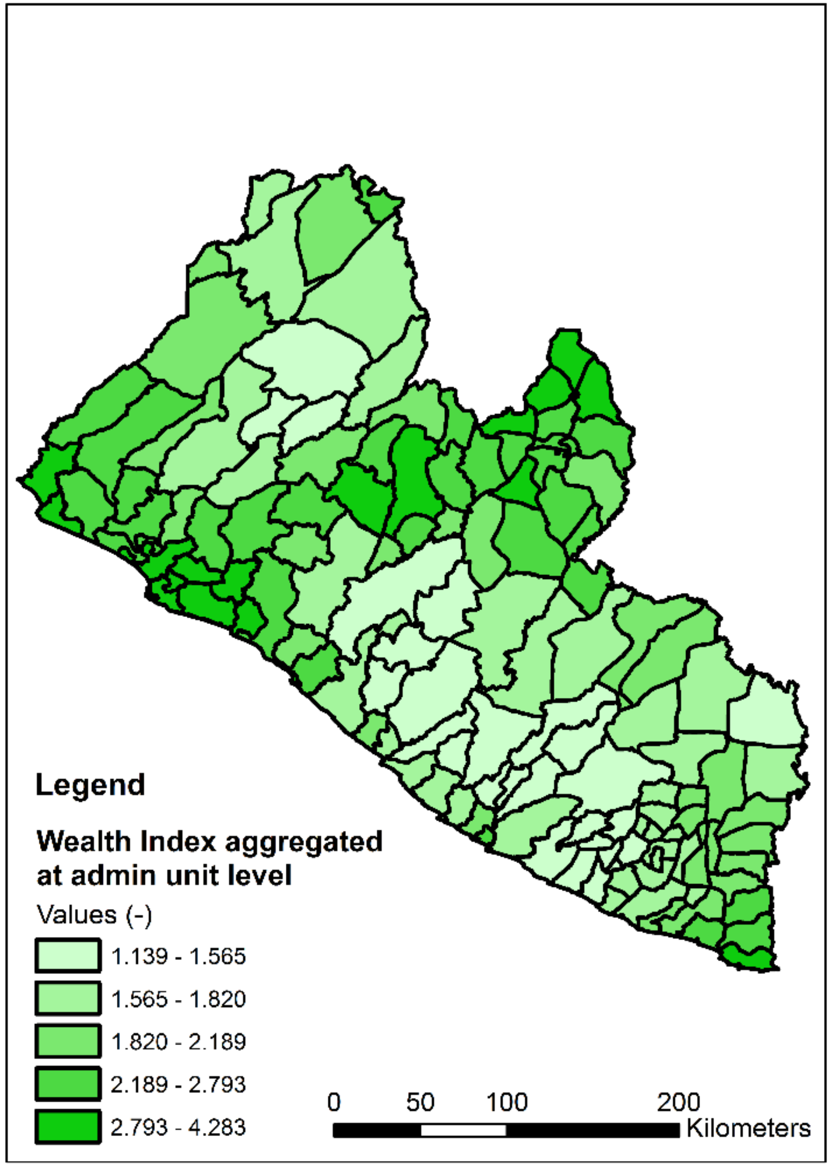
↓

Prediction raster

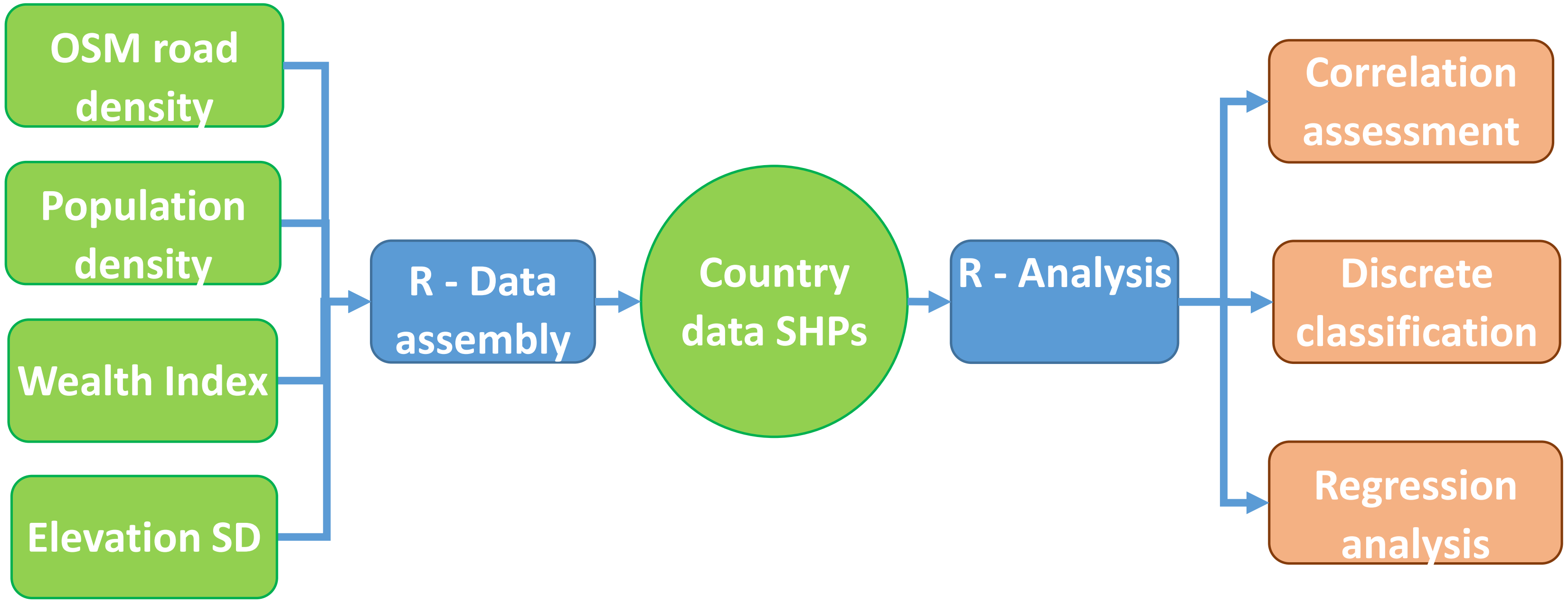
↓

Aggregated Wealth Index *(relative value 1 - 5)*





Completeness assessment



Correlation results

	Road density	Pop. density	Wealth	Elevation SD	Slope AVG
Road density	1.00	0.86	0.68	-0.18	-0.35
Pop. density	0.86	1.00	0.45	-0.16	-0.25
Wealth	0.69	0.45	1.00	-0.07	-0.29
Elevation SD	-0.18	-0.17	-0.07	1.00	0.67
Slope Avg	-0.35	-0.25	-0.29	0.67	1.00

Conclusions

- Road Dens. correlates with Pop. Dens. & Wealth
- No correlation with terrain variables
- Interrelation between Pop. Dens. & Wealth

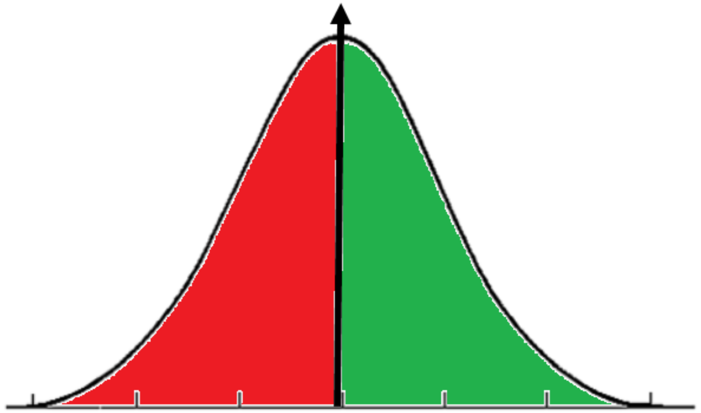
Completeness assessment

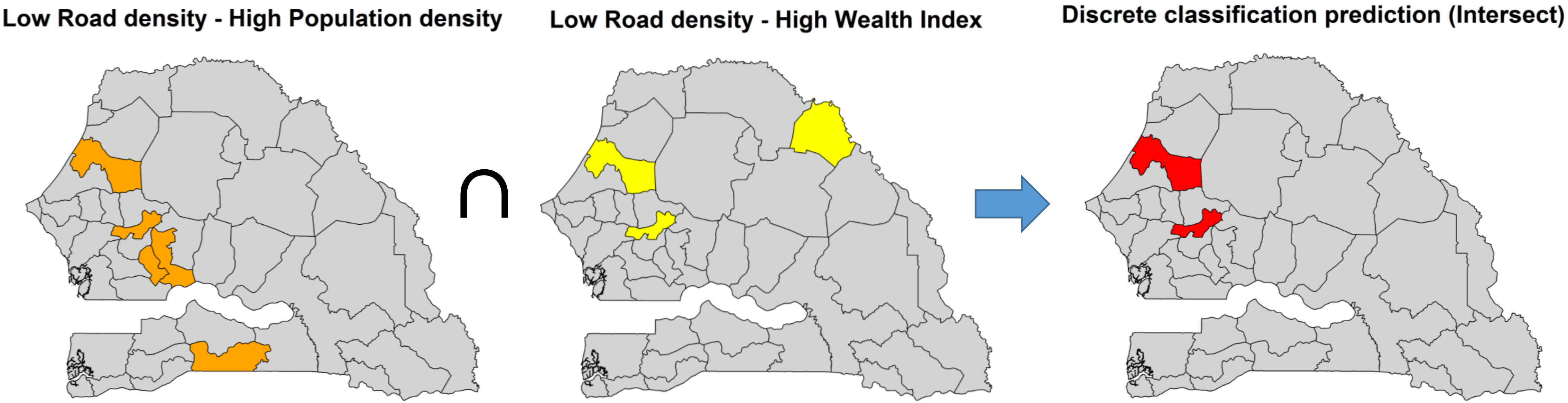
Method 1: Discrete classification prediction

Determine: **Low**-**High** Road density, **Low**-**High** Population density, **Low**-**High** Wealth

Use: Median

Tag: Regions with **Low** Road Density but **High** Pop. Denisty & **High** Wealth





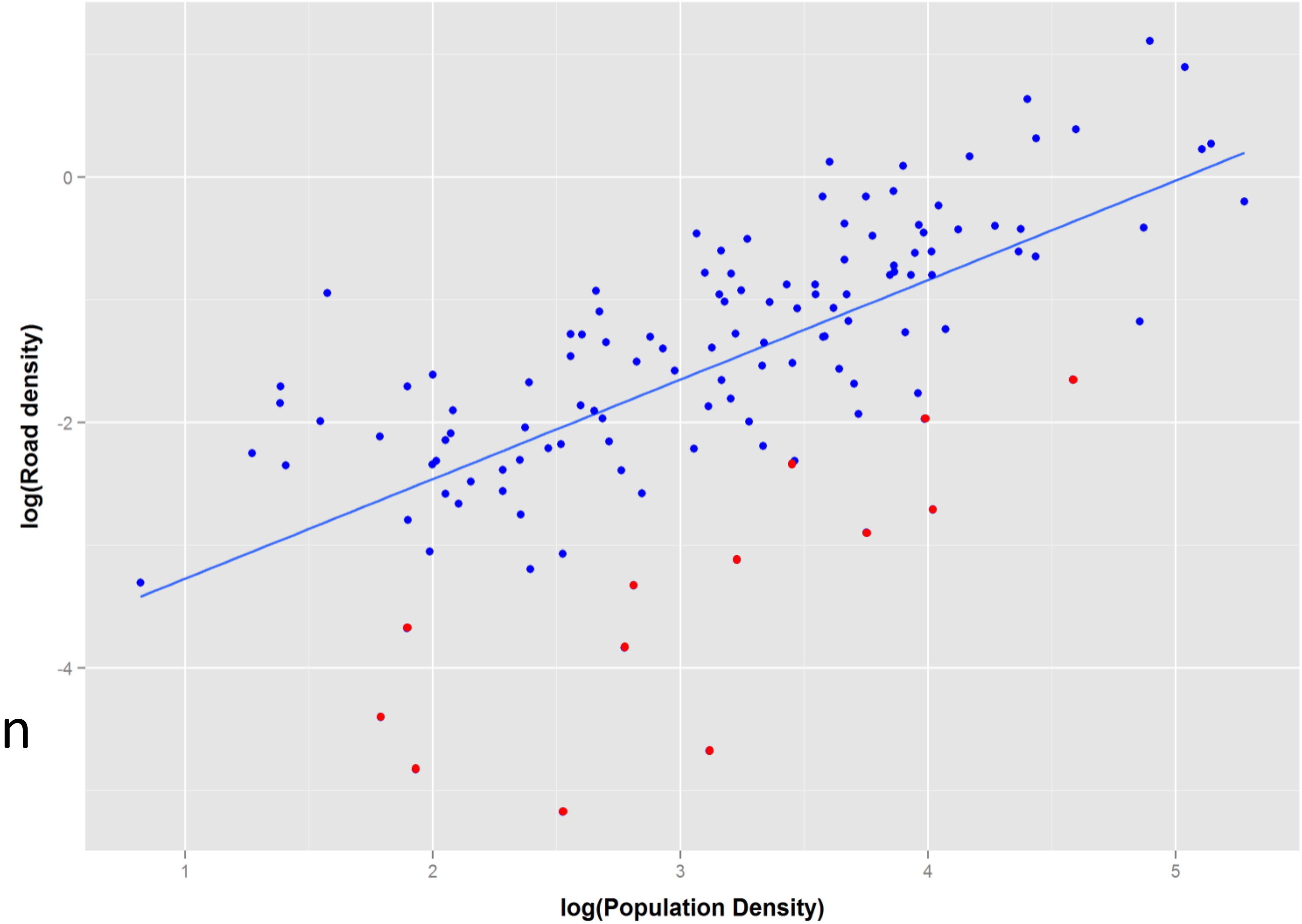
Completeness assessment

Method 2: Spatial regression prediction

- Predict Road density with Population density & Wealth
- Tag regions with extreme negative residuals
- Extreme residuals: lower quartile of negative residuals *(<25%)*

Regression model: Spatial Durbin

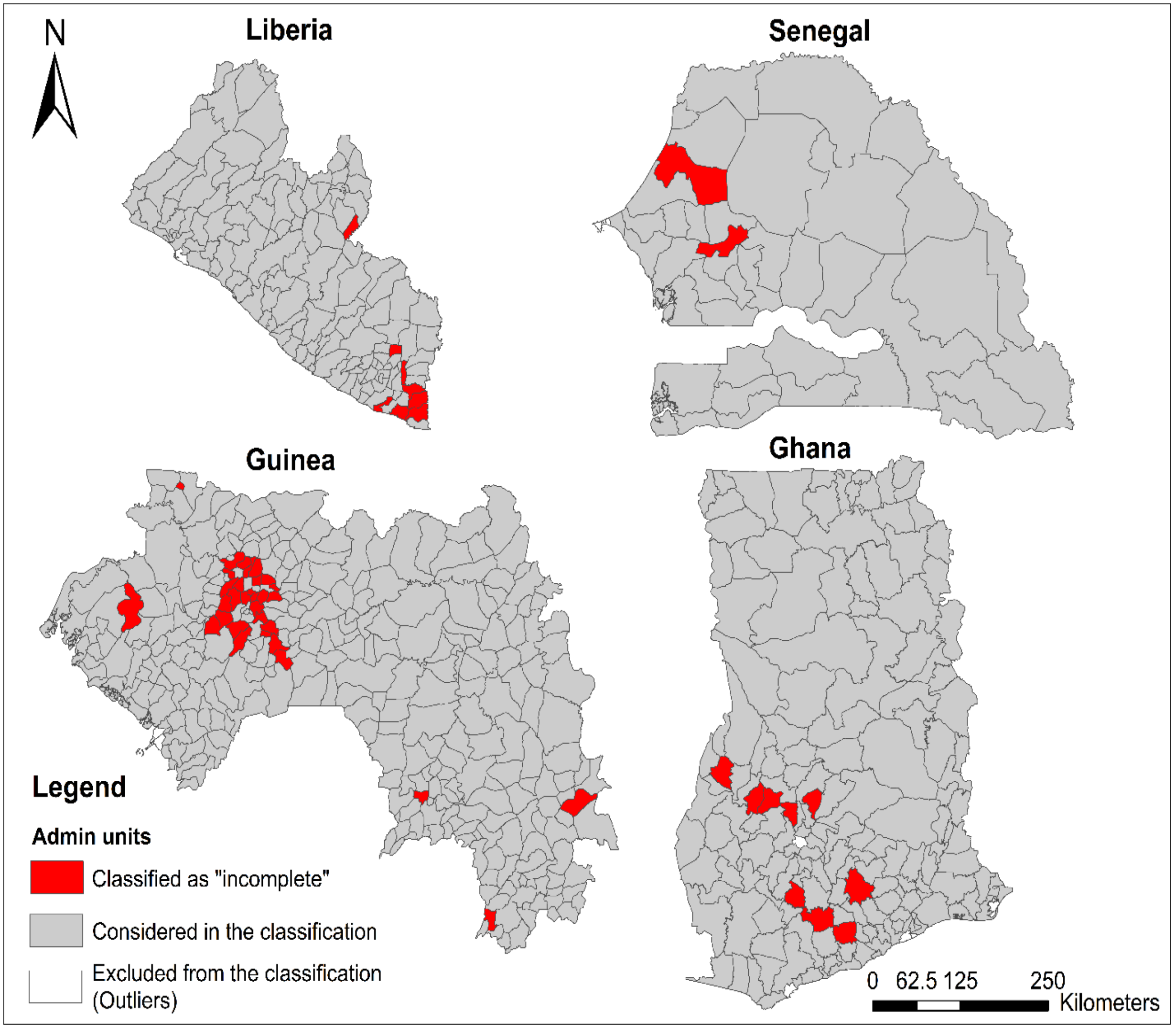
Weighting scheme: Queen 1 contiguity



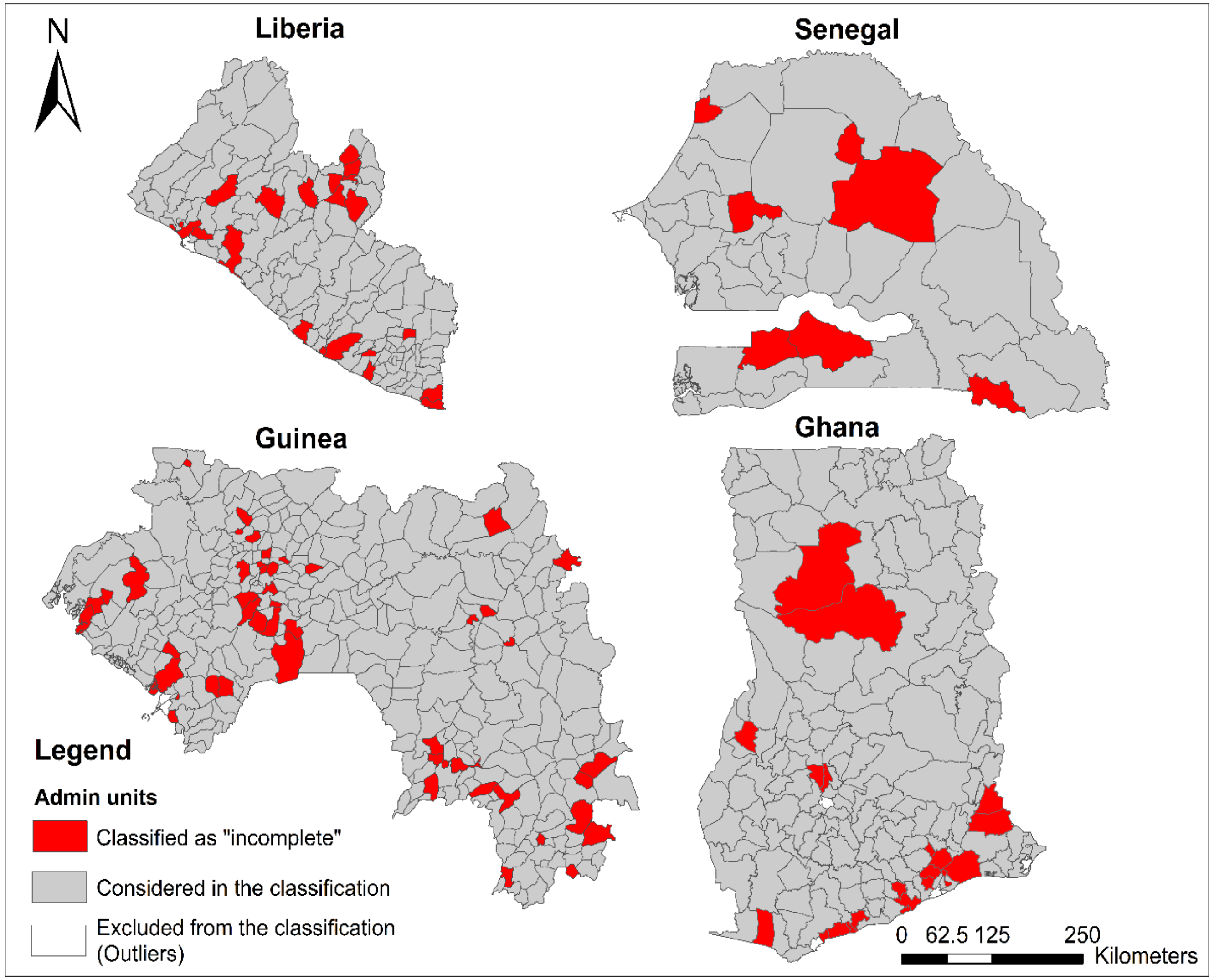
Simplification !

Completeness assessment

Discrete classification



Regression model



Completeness assessment

Conclusions

- Some patterns can be spotted
- Generally different predictions!
- Big number of erroneous predictions!
- Methods suitable for exploration *(complementarily)*

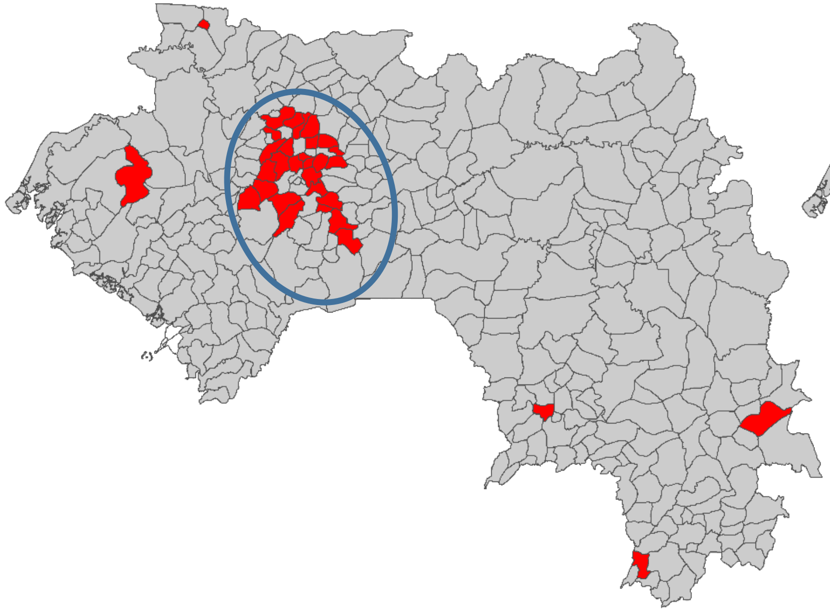
Country	Incorrect classifications	
	Discrete classification (%)	Regression models (%)
Liberia	21%	31%
Guinea	0%	11%
Ghana	22%	23%
Senegal	0%	0%

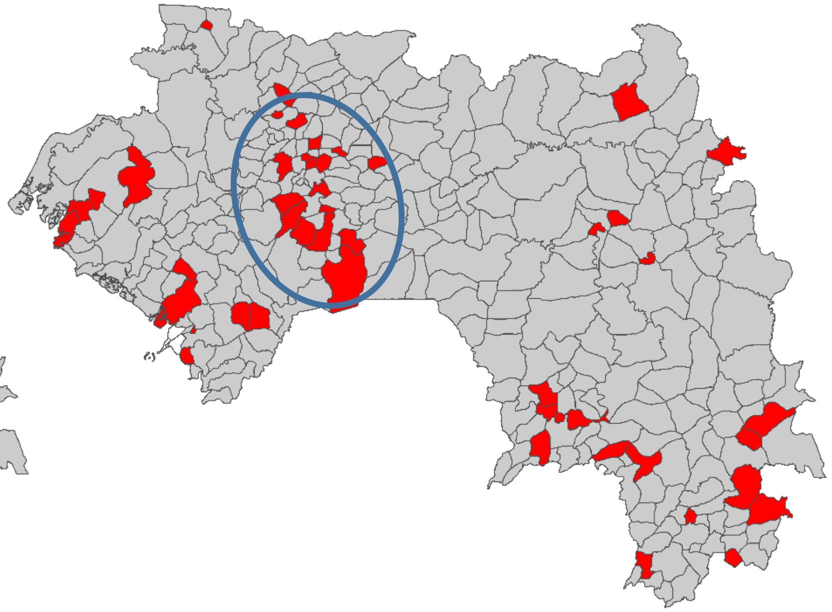
?!

Limitations

- Modifiable area unit
- Quality of input datasets
- Cut-off values

\+ Others





Positional accuracy

Method

Compare position of OSM road intersections with the position of road intersections digitized on imagery *(ground truth).* Provide one RMSE value for each country.

Issue

Which source of imagery? How to sample? How big of a sample?

Preliminary tests

- 2 imagery sources: Google Earth, Esri
- 3 sampling schemes
- 2 countries: Liberia, Guinea

Conclusions

- Imagery: Google Earth
- Sample size: 100
- Sampling scheme: 10 random admin units (urban + rural) & 10 random intersections in each

Positional accuracy

Results

- RMSE < 50m
- Urban RMSE < Rural RMSE
- Classical gathering < Mapping party

Limitation

- Relative value of accuracy
- Digitization process and imagery induce systematic errors
- Digitization is time consuming

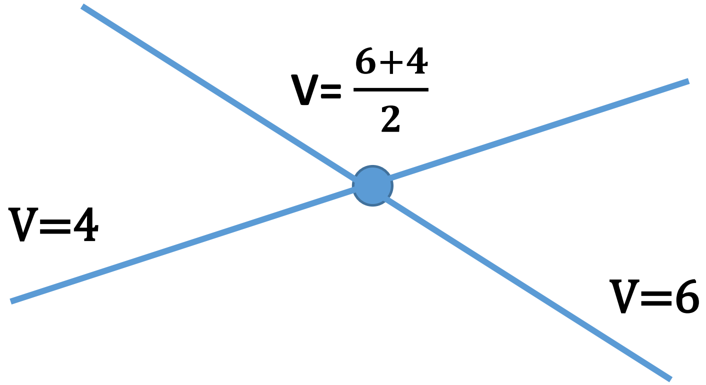
Country	Total RMSE (m)	Urban RMSE (m)	Rural RMSE (m)	Regional RMSE SD (m)
Liberia	31.57	7.97	43.93	26.68
Guinea	11.50	8.06	13.30	5.17
Senegal	7.46	4.10	8.99	3.66
Ghana	9.47	9.90	9.03	3.46

Versioning as trust parameter

Assumption

Positional accuracy & Segment complexity increases as Number of versions increases

IF TRUE → *'version'* attribute – trust parameter



Methods

Positional accuracy

- Use the road intersection of known RMSE already samples
- Transfer them a the version of the parent segments

Study correlation

Segment complexity

- Segment complexity = number of nodes / segment length
- Use directly *'version'* attribute

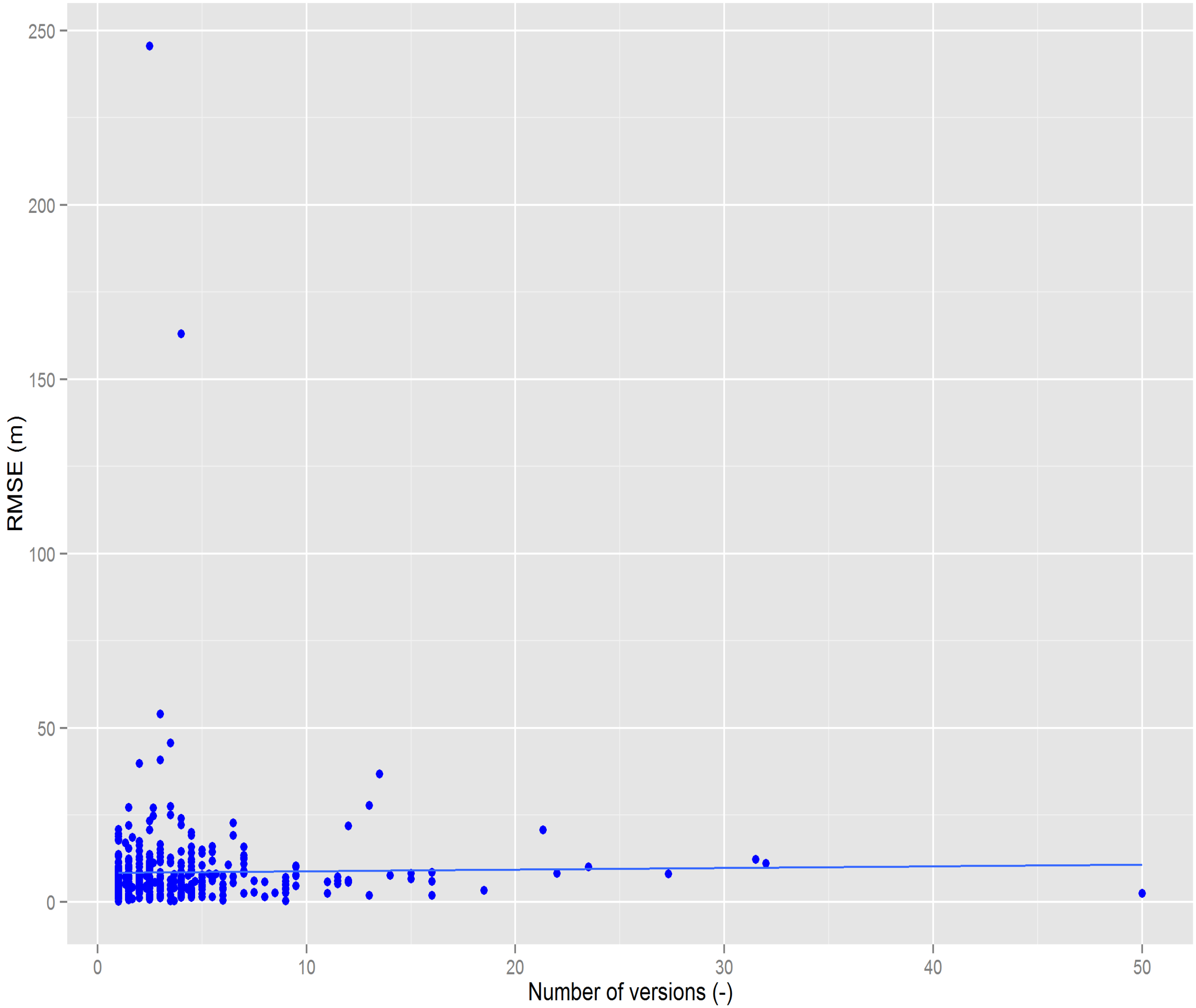
Study correlation

Versioning as trust parameter

Results

- No significant correlation noticed
- Numbers improve when excluding 1-3 versions
- Small number of points for the assessment

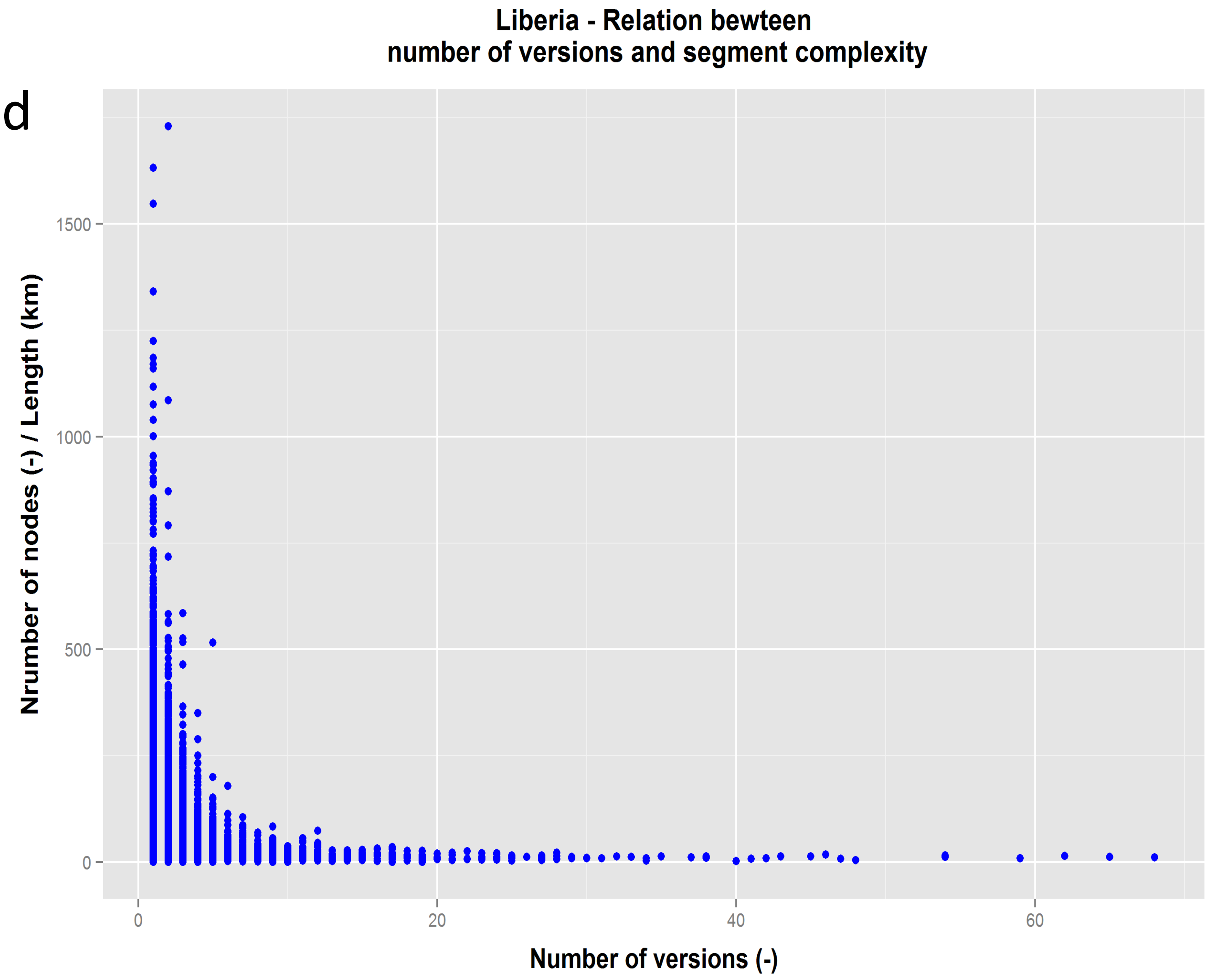
Countries	Correlation coefficient / Nr. of points		Correlation coefficient *(subset)* / Nr. of points	
Liberia	-0.0357	100	-0.0661	58
Guinea	0.1069	100	-0.0089	40
Ghana	-0.0008	100	-0.0221	54
Senegal	0.0426	99	0.2119	31
All samples	0.0142	399	-0.0189	183



Versioning as trust parameter

Results

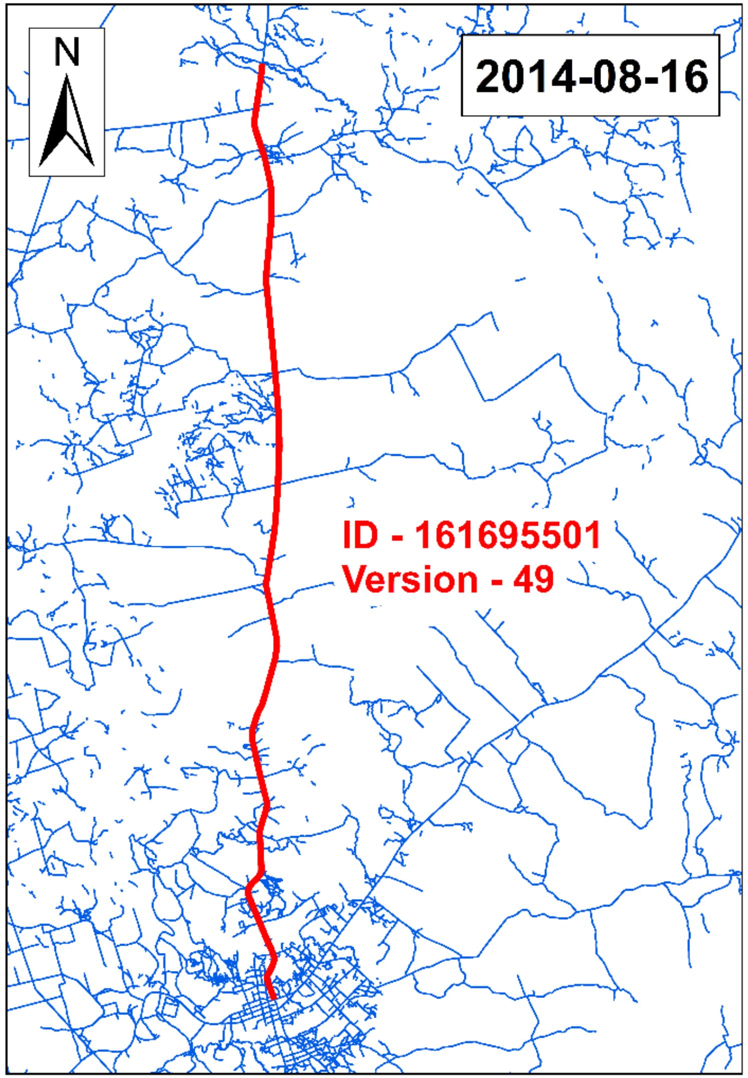
- Opposite results than expected
- Consistent in all cases
- Number of nodes & Segment length individually follow the same trend with increase in version

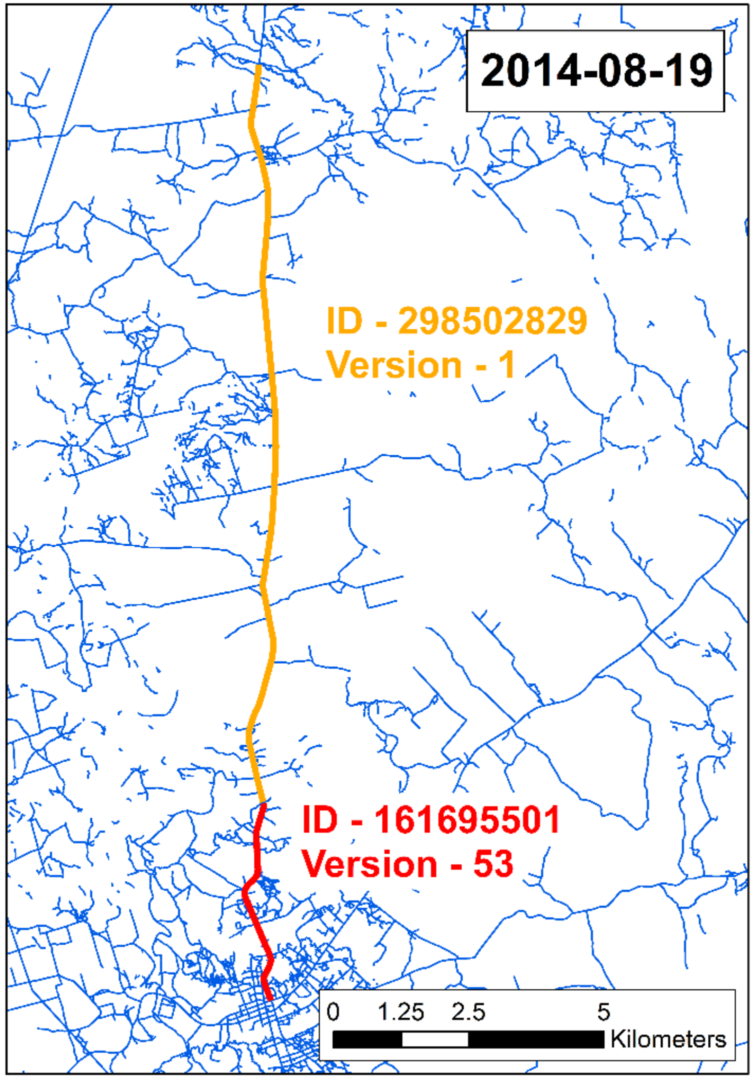


Versioning as trust parameter

Results

- Road fragmentation
- Data lineage error
- Magnitude of problem hard to assess
- Use of 'version' as trust parameter not recommended in case of roads !!!





Ingestion decision

Great! But...

How could we use the methods to make an ingestion decision???

A comparative approach!

- Compare OSM data with gROADS for each criteria
- If OSM is an improvement over gROADS → OK for that criteria
- Weight results for each country and make final decision

Country	Criteria			Ingestion decision
	Completeness	Positional Accuracy	Attribute structure	
Liberia				
Guinea				
Ghana				
Senegal				

Ingestion decision

Attribute structure

- Results compared based on % of Length
- gROADS generally present a smaller proportion of unclassified roads

Country	Criteria			Ingestion decision
	Completeness	Positional Accuracy	Attribute structure	
			Improvement	
Liberia			NO	
Guinea			NO	
Ghana			YES	
Senegal			NO	

Countries	Unclassified roads	
	gROADS(%)	OSM(%)
Liberia	20.98	32.89
Guinea	9.58	23.57
Ghana	98.37	14.94
Senegal	9.18	14.80

Ingestion decision

Positional accuracy

- gROADS has a 50m RMSE requirement
- Experience with gROADS indicates RMSE values as superior

Country	Criteria			Ingestion decision
	Completeness	Positional Accuracy	Attribute structure	
		RMSE < 50m	Improvement	
Liberia		YES	NO	
Guinea		YES	NO	
Ghana		YES	YES	
Senegal		YES	NO	

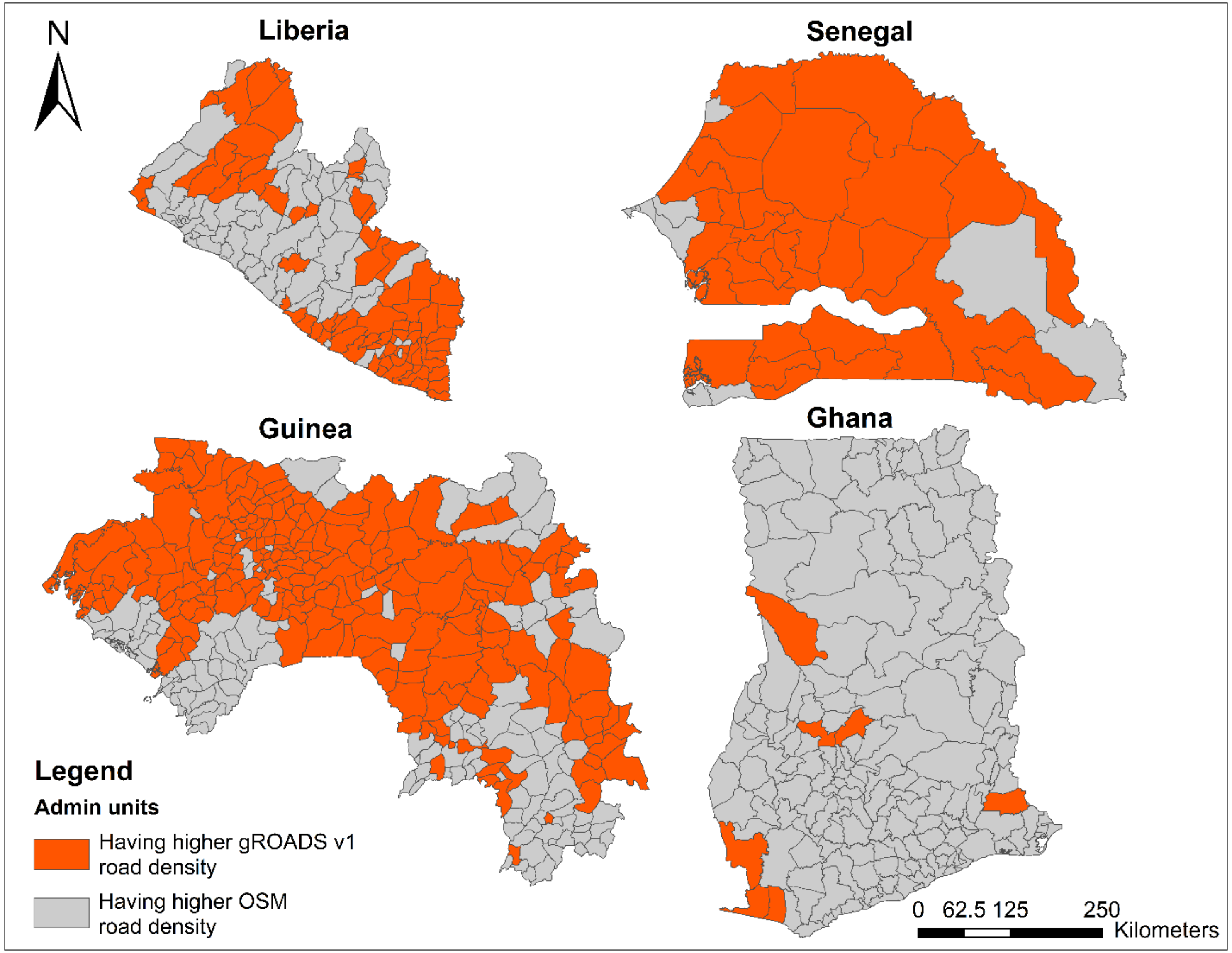
Country	Total RMSE (m)
Liberia	31.57
Guinea	11.50
Senegal	7.46
Ghana	9.47

Ingestion decision

Completeness comparison

- OSM mapping is concentrated in urban areas
- Only Ghana seems to be a significant improvement
- Qualitative inspection needed → use the prediction models!

Country	OSM road network length (km)	gROADS v1 road network length (km)
Liberia	32’457	25’205
Guinea	101’733	100’401
Ghana	57’613	22’752
Senegal	41’622	71’375



Ingestion decision

Conclusion

- Decision **cannot** be taken only base on quantitative aspects
- Data inspections also needed
- Only one country seems to be a clear improvement over gROADS

Country	Criteria			Ingestion decision
	Completeness	**Positional Accuracy**	**Attribute structure**	
	Improvement	**RMSE < 50m**	**Improvement**	
Liberia	NO	YES	NO	NO
Guinea	NO	YES	NO	NO
Ghana	YES	YES	YES	YES
Senegal	NO	YES	NO	NO

Questions

- How should criteria be weighed?
- Can we add other diagnostics?

Conclusion

OSM is not always superior to gROADS v1 for low income countries

- Validation process is necessary
- Implications for datasets derived from OSM: WorldPop...

Ingestion decision based on comparison between datasets

- Easy techniques are very revealing
- Decision is harder to take for countries with similar level of quality for OSM - gROADS

Completeness assessment - combination of the 2 methods useful for exploration

- Improvements are necessary
- Other datasets? Different aggregation units? New models?

Conclusion

OSM is not always superior to gROADS v1 for low income countries

- Validation process is necessary
- Implications for datasets derived from OSM: WorldPop...

Ingestion decision based on comparison between datasets

- Easy techniques are very revealing
- Decision is harder to take for countries with similar level of quality for OSM – gROADS

Completeness assessment - combination of the 2 methods useful for exploration

- Improvements are necessary
- Other datasets? Different aggregation units? New models?

Thank you!

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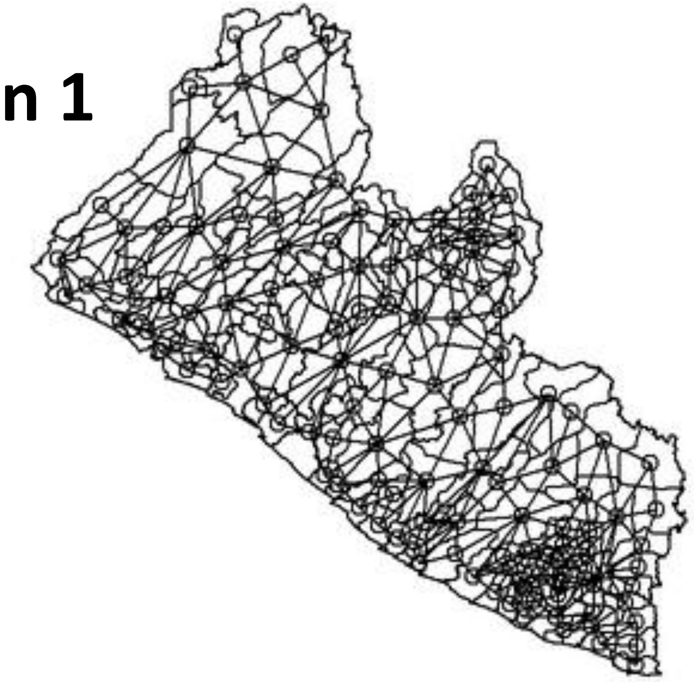
Spatial Durbin – Backup

Durbin model: $y = x\beta + Wx\theta + \varepsilon$

Queen 1



$\boldsymbol{y}$ - dependent variable

$\boldsymbol{x}$ - set of independent variables

$\boldsymbol{Wx}$ - spatially lagged independent variables

$\boldsymbol{\theta}$ - spatial coefficient,

$\boldsymbol{\varepsilon}$ - vector of error terms.

AIC results

Countries	Lag	Error	Durbin	GWR
Liberia	32.46	32.46	14.91	-97.83
Guinea	503.64	503.64	498.84	416.91
Ghana	167.26	167.26	148.21	156.04
Senegal	-73.48	-73.48	-70.52	-104.74

Moran I

Countries	OLS		Durbin	
	MI	p-value	MI	p-value
Liberia	0.36	3.87e-13	-0.001	0.44
Guinea	0.39	6.67e-35	0.02	0.23
Ghana	-0.05	8.81e-01	0.02	0.27
Senegal	0.12	6.05e-02	0.01	0.34

Positional accuracy - Backup

		Reference Imagery	
		Esri Imagery RMSE (m)	Google Earth RMSE (m)
Liberia	Multi-stage sampling	10.48	14.52
	Multi-stage stratified sampling	31.50	31.57
	Clustered sampling	17.36	22.98
Guinea	Multi-stage sampling	10.11	12.08
	Multi-stage stratified sampling	10.98	11.50
	Clustered sampling	34.27	4.85