

Improvements of population estimate using remote sensing techniques for urban and rural areas (POPSATER)

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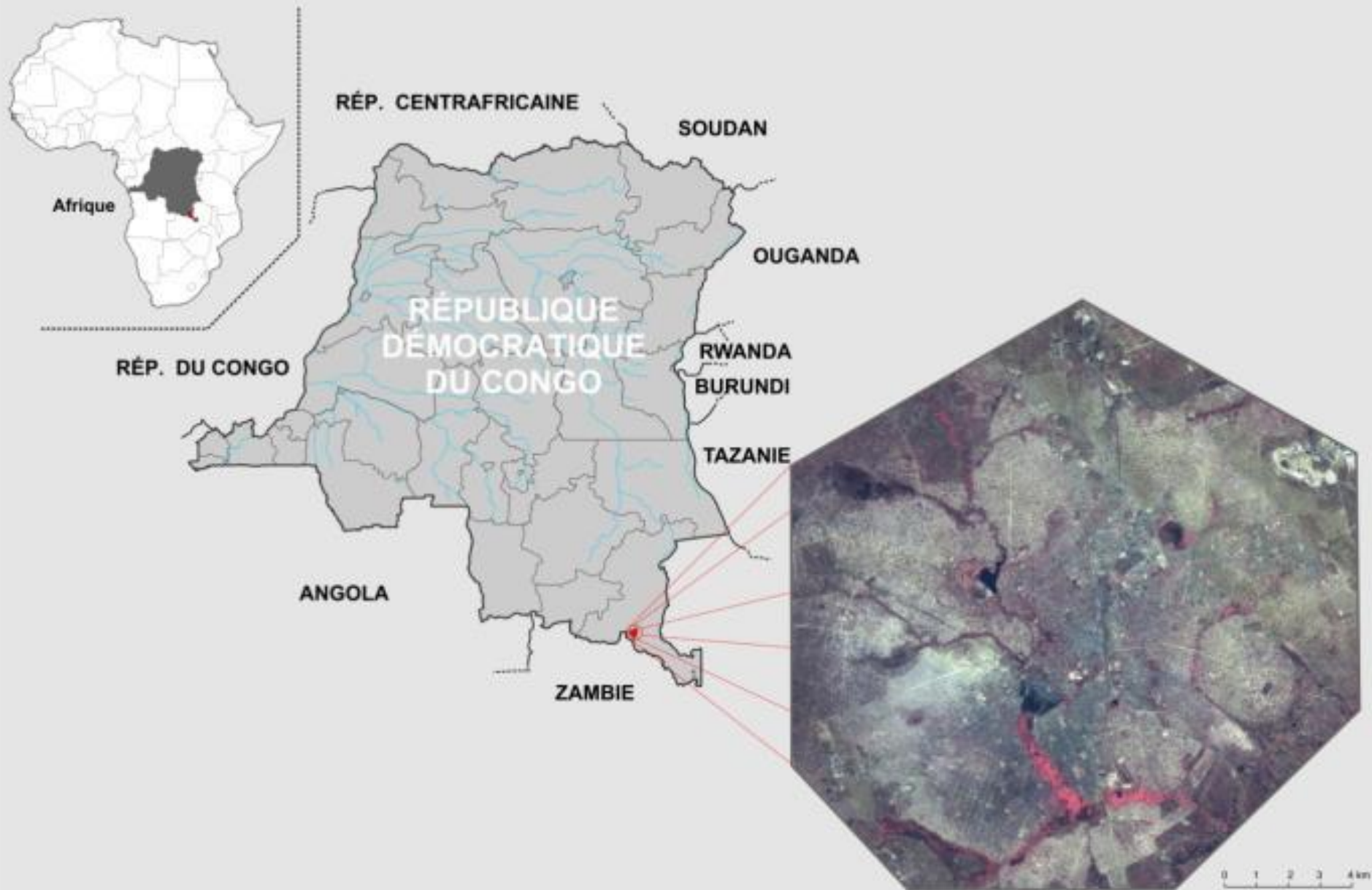


Introduction

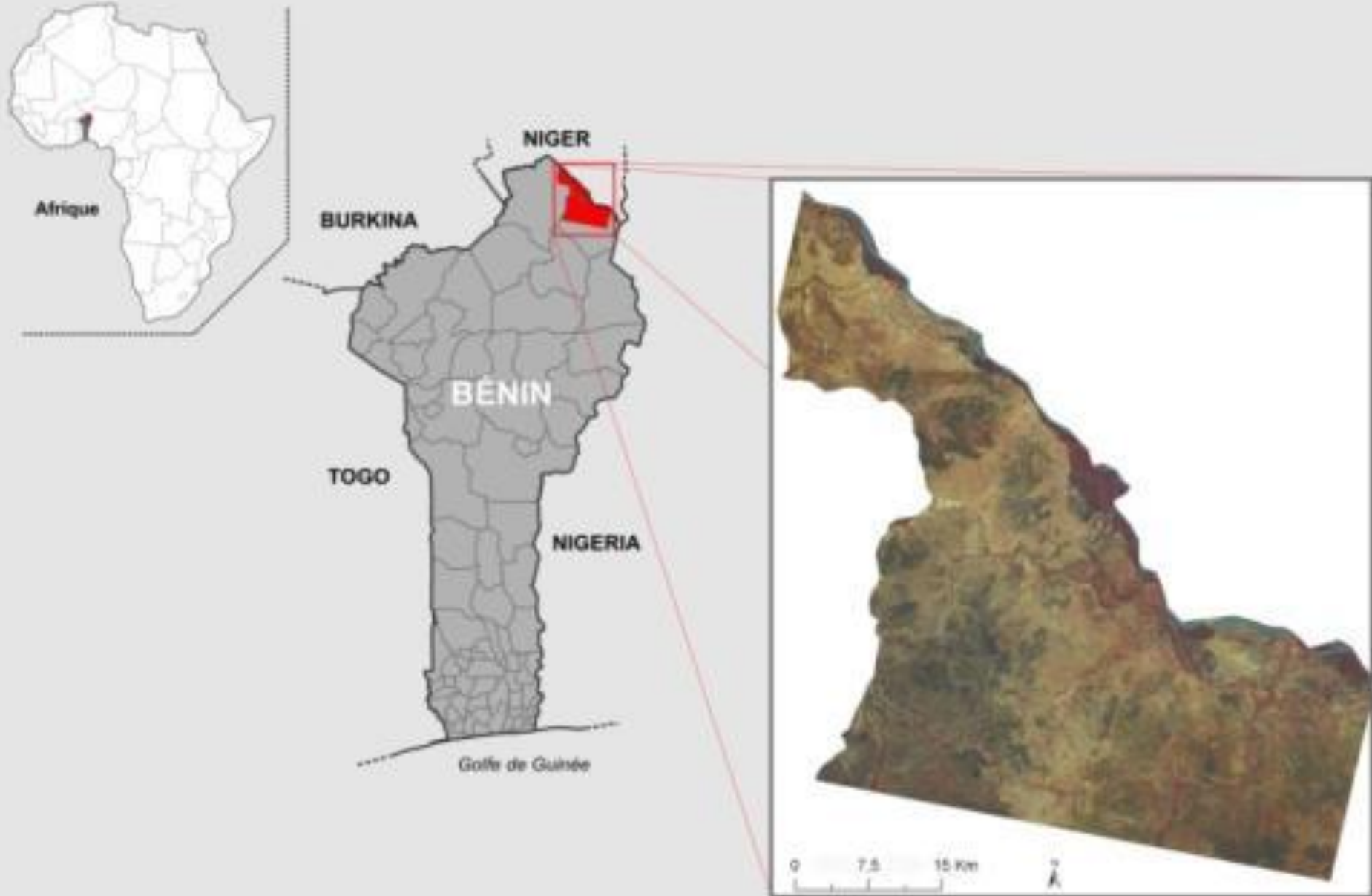
- Quantifying the population is mandatory to plan the infrastructures and manage the land
- Population census and survey are at high costs; their existence is no more ensured
- Use of remote sensing and GIS to diminish the costs and improve the accuracy of such estimate
- To lighten the field survey of the demographer in absence of detailed and recent maps
- 2 cases studies



Urban : Lubumbashi (DRC)



Rural : North Benin



Outline

- Sampling
- Field survey
- Extrapolation
- Cross-validation



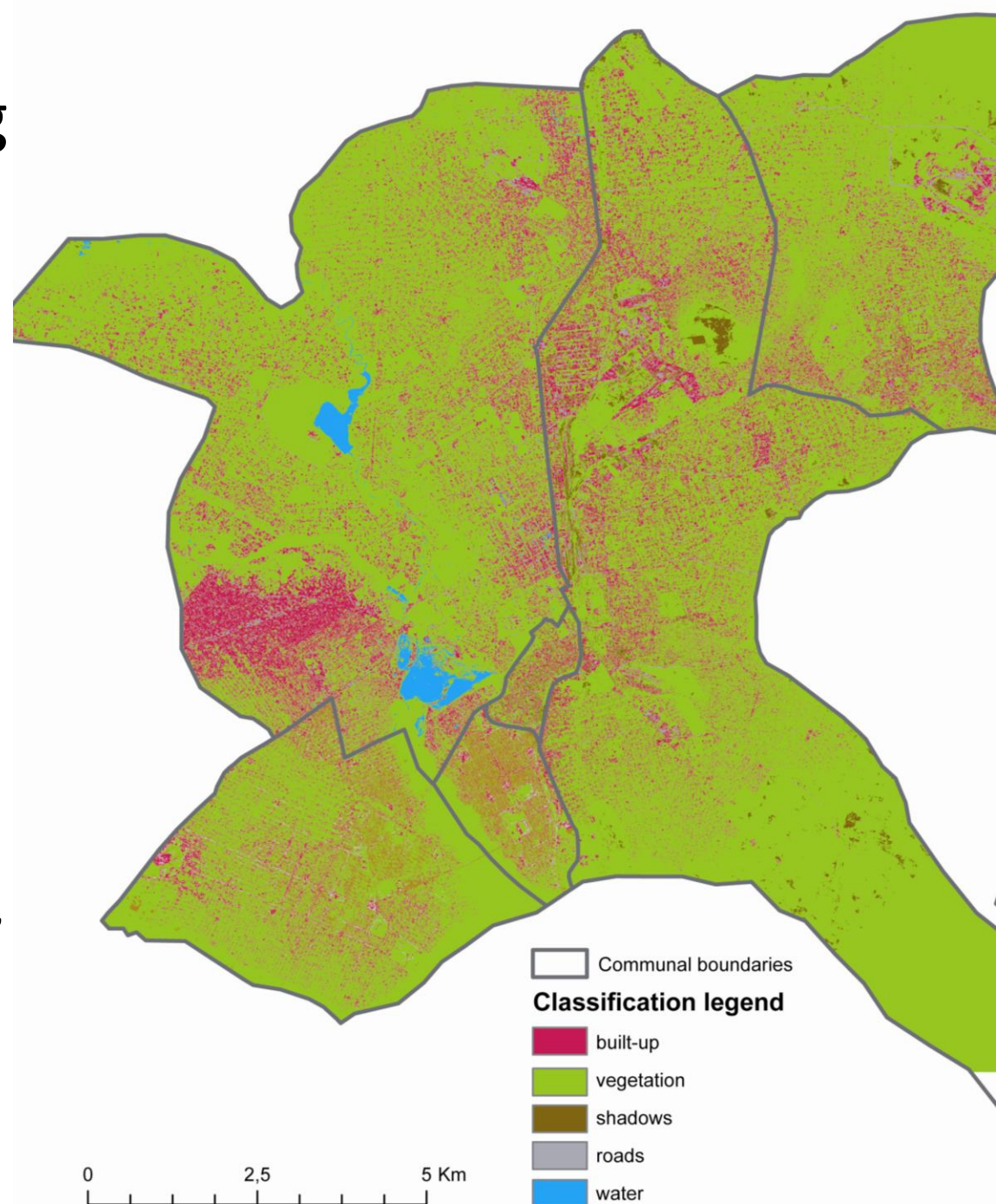
Classical sampling

- Use of any kind of spatial info to get a proxy of the size of the area to survey
 - In RDC and Benin, no updated population register, no recent census to to define population to be surveyed
 - Delineation and numbering of blocks/villages and populated plots by foot, if possible with GPS
- ➔ Very heavy



Improved sampling

- Sampling in populated areas
- OBIA classification of dwellings on VHR images
- Lubumbashi :
 - Size of the image
 - confusions between dwellings, roads and bare soil
 - Eastern pollution by Gecamine



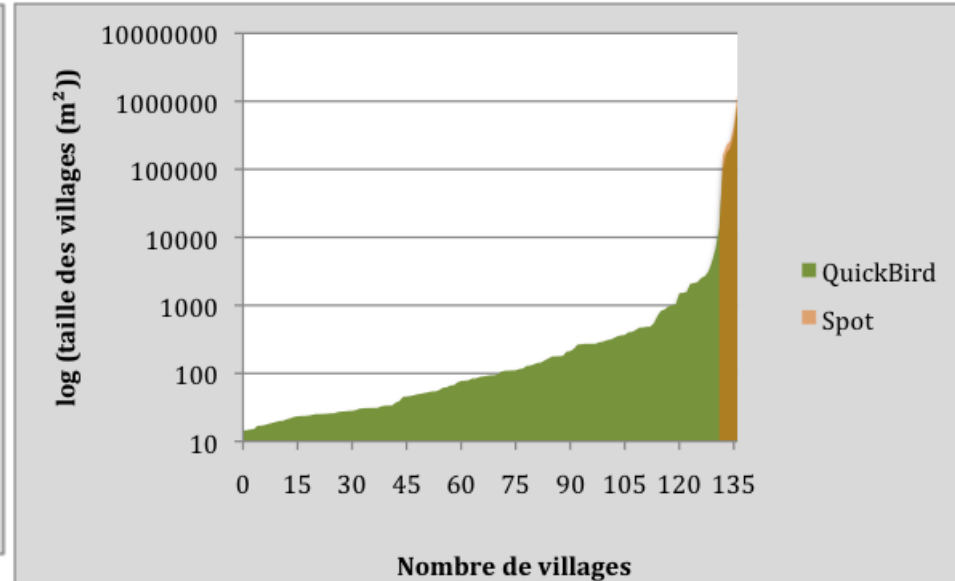
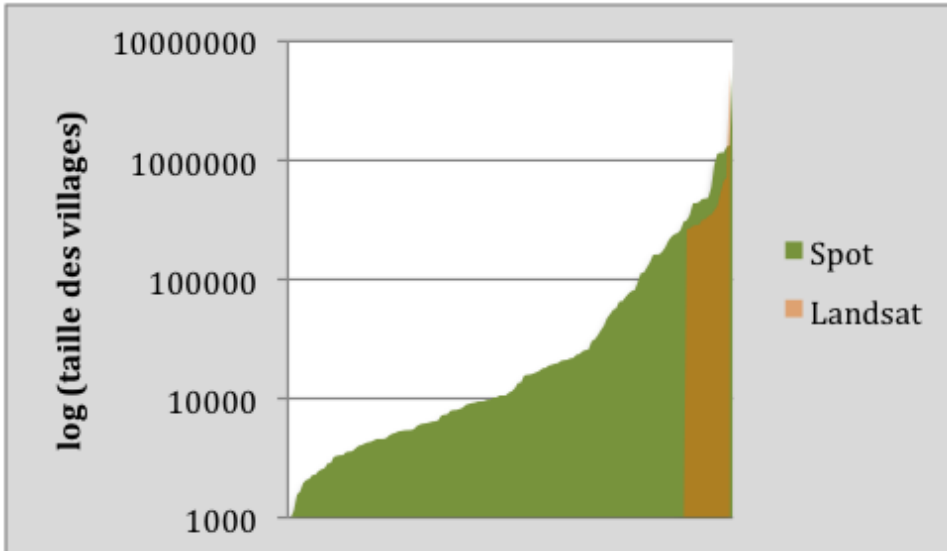
Improved sampling

- North Benin :
 - Very good detection of sheet metal roof, but
 - Dwellings are very diverse, small, covered by natural materials, very similar to granaries
 - Very poor results (Kappa of 39%)



Improved sampling

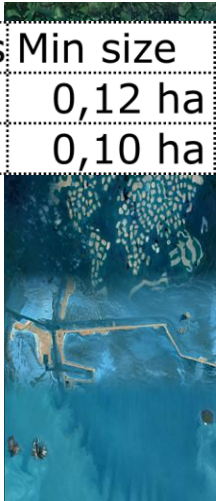
- Which spatial resolution for visual interpretation of the village ?



	Resolution	N villages	Min size
LANDSAT TM	15 m	15	26,00 ha
SPOT 5	5 m	144	0,12 ha

	Resolution	N villages	Min size
SPOT 5	2,5 m	6	0,12 ha
QuickBird	0,6 m	137	0,10 ha

- SPOT 5 fused image at 5m seems a good compromise according to price/sqkm

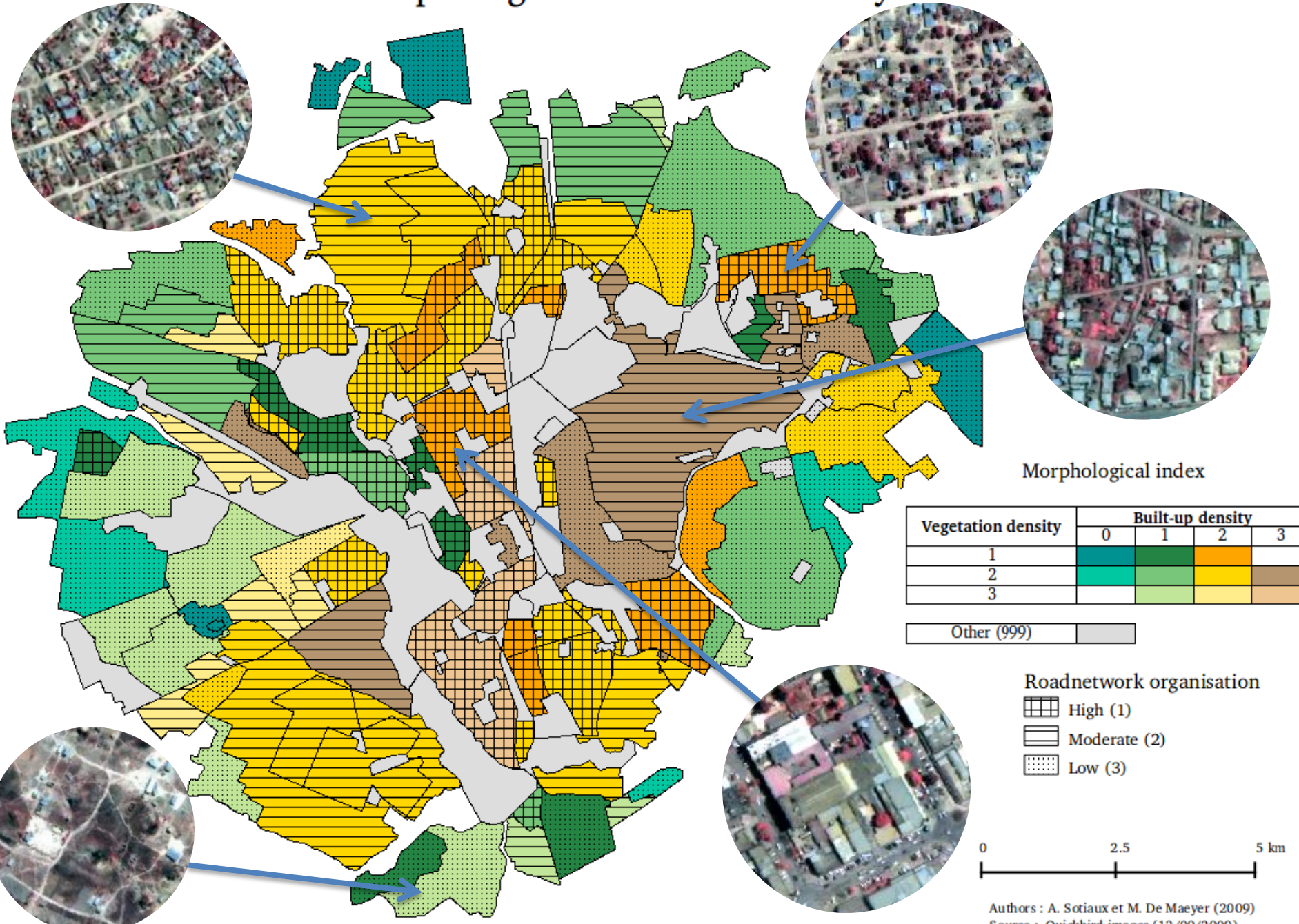


Improved sampling

- Stratification according to
 - Administrative units
 - Define by legal texts
 - Evolution of the limits may be unknown
 - Paper or digital maps difficult to get
 - Homogeneous areas visually interpreted on remote sensing data



Distribution of morphological classes for the city of Lubumbashi



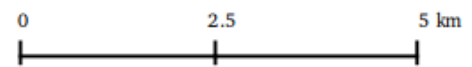
Morphological index

Vegetation density	Built-up density			
	0	1	2	3
1	Teal	Dark Green	Orange	
2	Light Green	Light Green	Yellow	Brown
3		Light Green	Yellow	Brown

Other (999) [Grey Box]

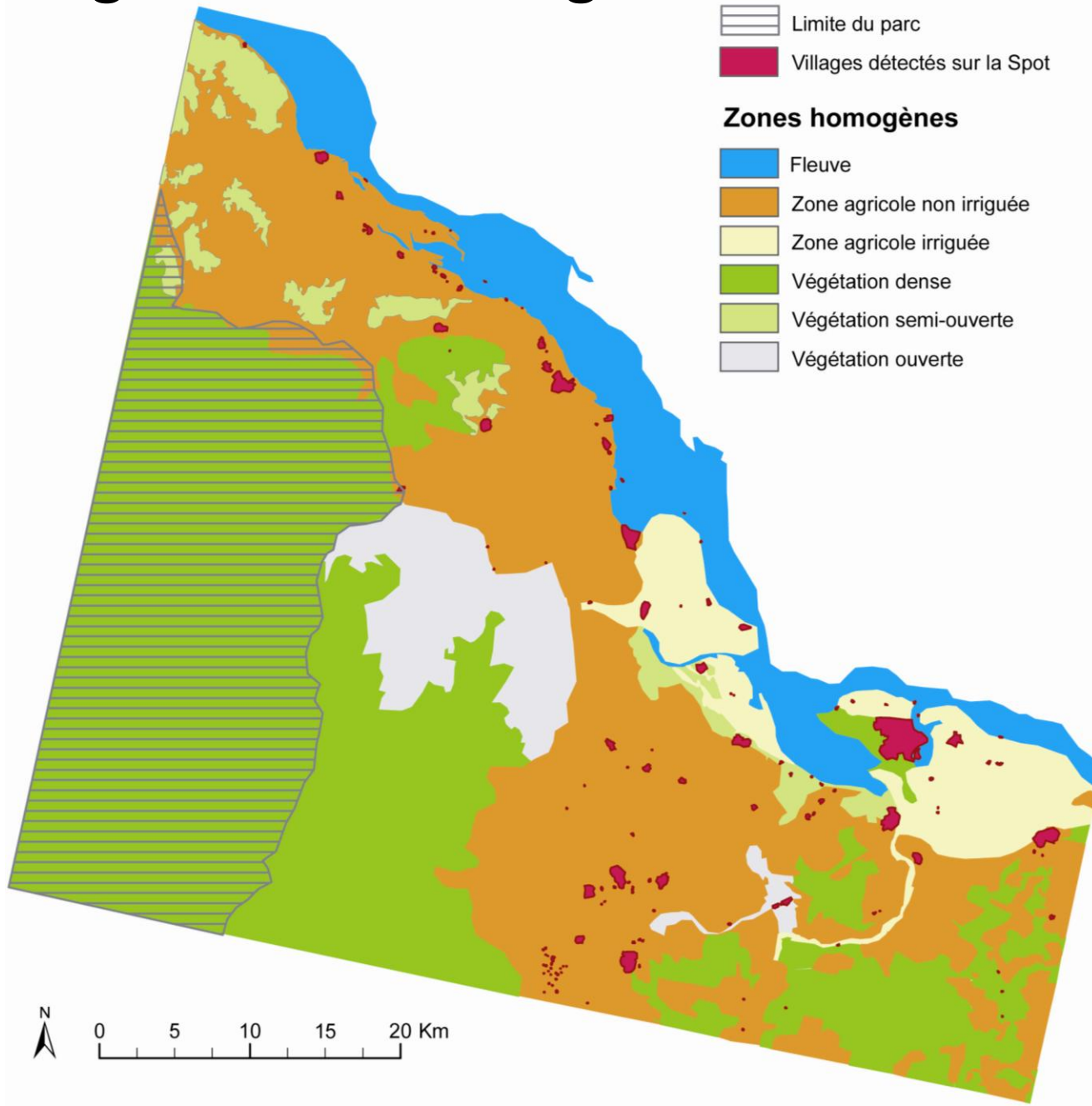
Roadnetwork organisation

- [Grid Pattern] High (1)
- [Horizontal Lines] Moderate (2)
- [Dotted Pattern] Low (3)



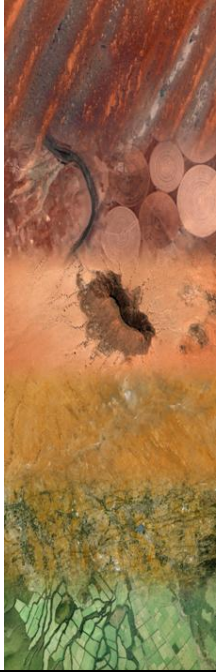
Authors : A. Sotiaux et M. De Maeyer (2009)
 Source : Quickbird images (12/09/2009)

Sampling : 1st level : villages in North Benin



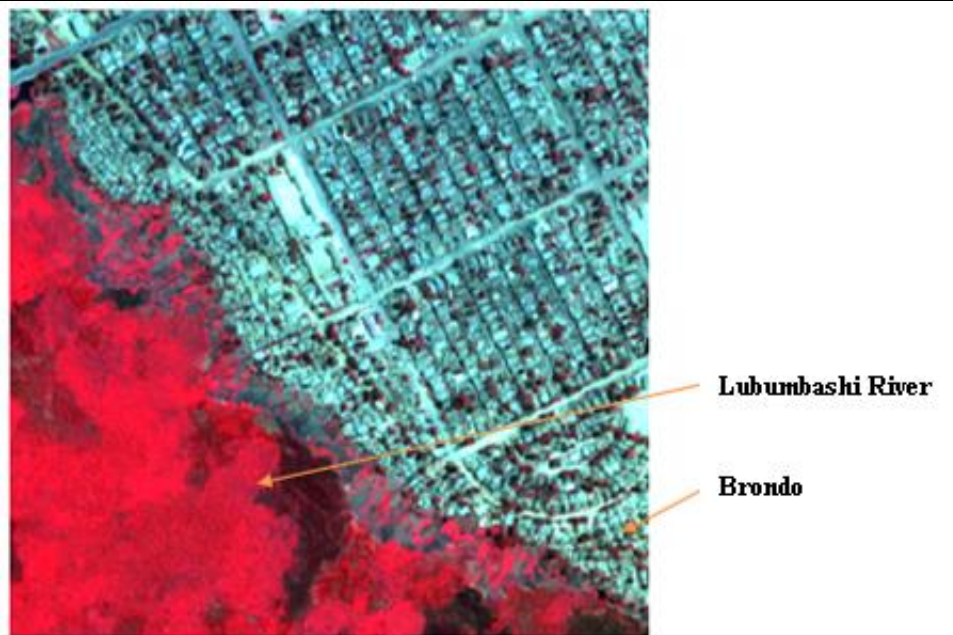
Sampling : 1st level : Lubumbashi

- For 90% of the city, blocks are easy to identify by visual interpretation on a VHR space-map using roads, tracks, rivers, clear land cover areas, power lines, ...
- Only 5 randomly selected blocks defined on the field with GPS in less structured areas



Brondo (Kenya commune)

Annex commune



Sampling : 2d level : plots in Lubumbashi

- For plots numbering
- 2 BW space-maps
 - General overview
 - On sampled block
 - With main reference locations

➔ Remote sensing allows to avoid double counting and omissions



Sampling

- North Benin :
 - Sampling : 1st level : 48 blocks spread in 2 communes and 5 arrondissements, 8 villages, 2 small cities
 - Sampling 2d level : counting of 2 844 dwellings



Sampled block	Surface area	Enclos	Buildings of which		Dwelling Units	inhabited	Empty but habitable	stock	Private Facilities	Shops and workshops	Public facilities	Empty and not habitable	Buildings partially inhabited	inhabitants	
			Huts	Houses											
1111 Malanville Wouroyessou	16.729,70	23	82	18	64	149	106	18	8	9	5	3	0	9	395
1112 Malanville Wolo (block A)	12.846,40	20	48	16	32	64	51	12	0	0	0	1	0	5	162
1113 Malanville Wolo (block B)	17.580,80	24	65	11	54	92	73	10	4	1	1	3	0	5	262
1114 Malanville Wolo (block C)	17.229,00	12	31	23	8	33	25	6	0	1	0	1	0	0	104
1115 Malanville (section 5)	7.865,50	15	33	3	30	65	50	9	2	3	0	1	0	8	185
1116 Malanville (section 3)	8.984,00	14	45	8	37	87	53	12	7	6	8	1	0	8	190
1121 Bodjécali centre - block 1	2.734,56	5	9	0	9	15	11	1	2	0	0	1	0	3	27
1122 Bodjécali centre - block 2	9.261,05	6	12	2	10	20	17	0	1	0	0	0	2	1	50
1123 Bodjécali centre - block 3	5.635,42	11	18	2	16	30	19	5	5	0	1	0	0	3	67
1124 Bodjécali centre - block 4	1.376,43	12	31	2	29	60	38	13	4	2	3	0	0	8	132
1125 Bodjécali centre - block 5	1.314,25	29	65	3	62	102	66	11	11	3	6	1	4	10	230
1211 Saïtounga	13.721,30	27	49	19	30	71	52	6	12	0	0	1	0	7	183
1212 Bagaotounga	14.102,80	15	71	34	37	84	61	5	16	0	1	1	0	1	185
1213 Courétounga	10.487,50	19	36	10	26	60	44	0	14	0	0	2	0	3	155
1214 Sabongari	58.214,40	41	121	99	22	131	70	11	46	0	1	1	2	2	316
1311 Koaratedji periphery - block 1	12.407,90	9	27	5	22	39	21	3	13	0	1	1	0	6	78
1312 Koaratedji periphery - block 2	6.391,00	3	6	1	5	10	5	3	1	0	0	1	0	1	19
1313 Koaratedji centre - block 1	7.933,90	12	46	4	42	75	45	4	21	0	4	1	0	15	154

Field survey : population survey

- Rapid population counting during plots delineation
- In depth demographic and socio-economic survey

➔ VHR remote sensing contributions, use of space-maps :

➔ to find sampled plot

➔ To control field surveyors



Extrapolation : spatial basis ?

- For Lubumbashi :
 - statistical analysis by segmentation showed that the communes are the most relevant stratification layer

Commune	S com (ha)	S built- up/com (ha)	Pop. Est.	Gross dens. (pers/ha)	Net dens. (pers/ha)
Lubumbashi	5.026	3.629	211.599	42,10	58,31
Kenya	352	243	64.352	182,62	265,00
Katuba	1.611	1.263	214.023	132,84	169,47
Kamalondo	128	101	35.641	278,22	351,71
Ruashi	1.987	984	94.435	47,52	95,95
Kampemba	5.242	2.685	250.042	47,70	93,12
Annexe	64.579	4.320	232.896	3,61	53,91
Totals	78.926	13.225	1.102.989	13,97	83,40

- But their delineation received from the town authorities does not match the ones defined by law in 1970



Extrapolation : North Benin

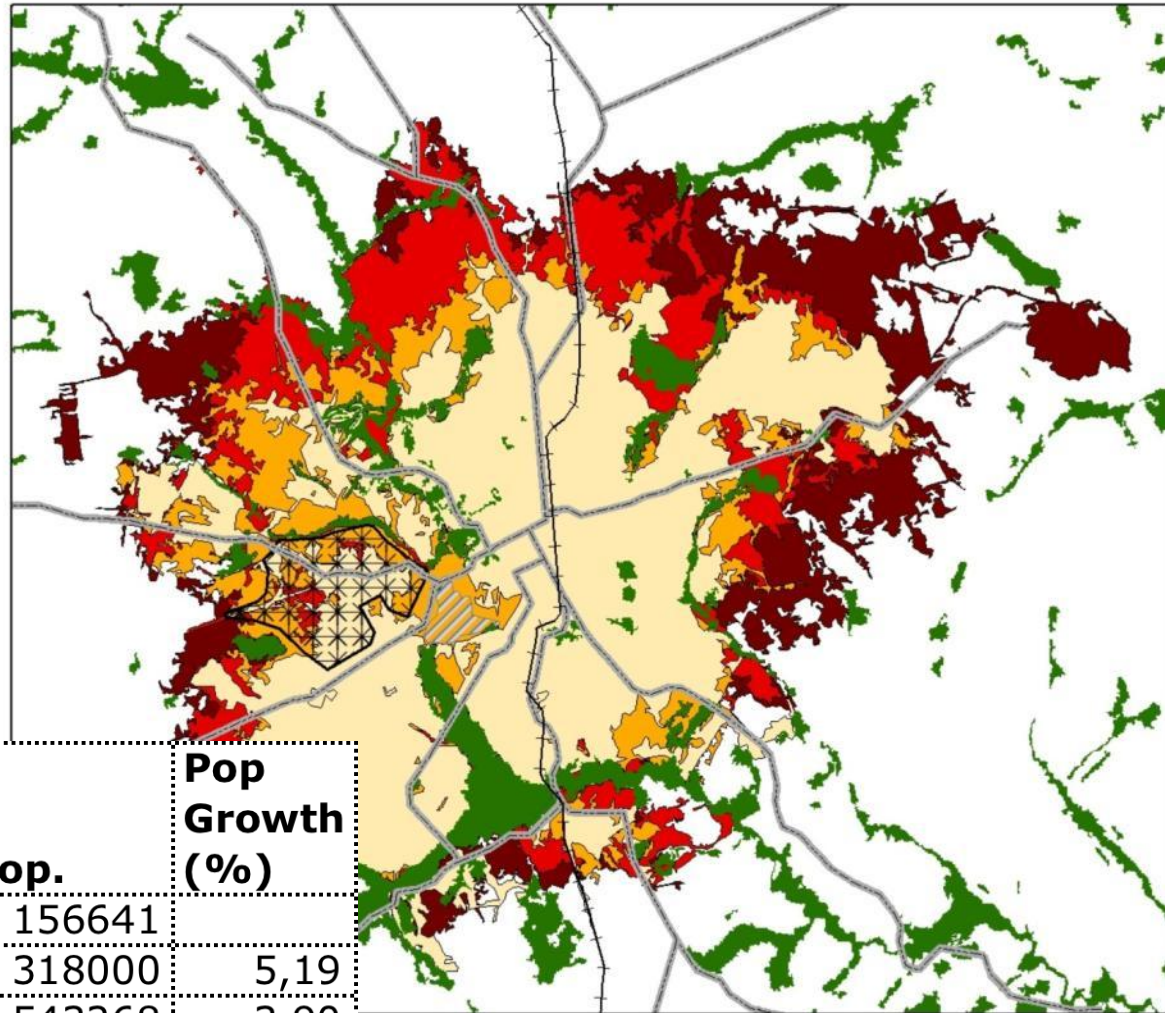
VILLAGE	Proportion of inhabited units	Total surface area	estimated population	Density	Population in 2.002	Growth from 2002
111 Malanville	73,1%	4.819.335,60	77.005	159,8	31.856	11,0%
112 Bodjécali	66,5%	796.519,00	19.833	249,0	4.200	19,4%
121 Dégué-Dégué	65,6%	96.526,00	839	86,9	—	—
131 Koaratedji	53,4%	405.048,95	4.418	109,1	2.934	5,1%
132 Kantro	55,8%	544.610,15	3.304	60,7	2.757	2,3%
133 Guéné	63,4%	509.300,00	9.362	183,8	5.862	5,9%
134 Yakamata (Férékéré)	66,2%	25.298,47	180	71,2	—	—
211 Mamassy-Peulh	74,3%	153.108,50	2.225	145,3	1.565	4,4%
212 Karimama	71,0%	880.415,00	17.516	199,0	4.007	18,4%
2131 Goroubéri	68,1%	171.827,60	3.091	179,9	2.203	4,2%
2211 Mamassy-Gourma	62,8%	333.448,50	4.020	120,6	2.645	5,2%

- In blue : no extrapolation for 2 villages (lack of representativity)
- In red : weighted estimates
- Cross validation with 2002 census
 - Rates of growth very high but plausible because of very dynamic population and many migrations
 - Rates of growth too high for urban areas (probable inclusion of administrative compounds, schools, markets, police quarters, ...)

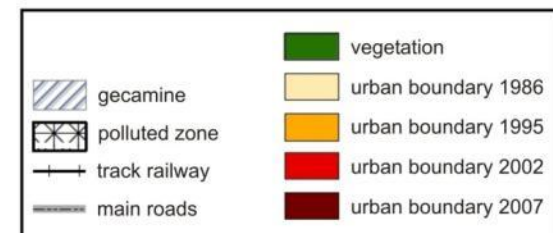


Cross validation

- By remote sensing, H_o : the population grows at the same pace than its extension
- Urban growth mapped with HR time serie
- $Diff \approx 20\%$



Years	S built-up (sqkm)	Built-up Growth (%)	Pop.	Pop Growth (%)
1956 *			156641	
1970 *			318000	5,19
1984 *			543268	3,90
1986	71,9		586463	3,90
1995	88,3	2,31	720232	2,31
2001	118	4,95	962485	4,95
2007	144,3	3,41	1177005	3,41
2011			1345948	3,41

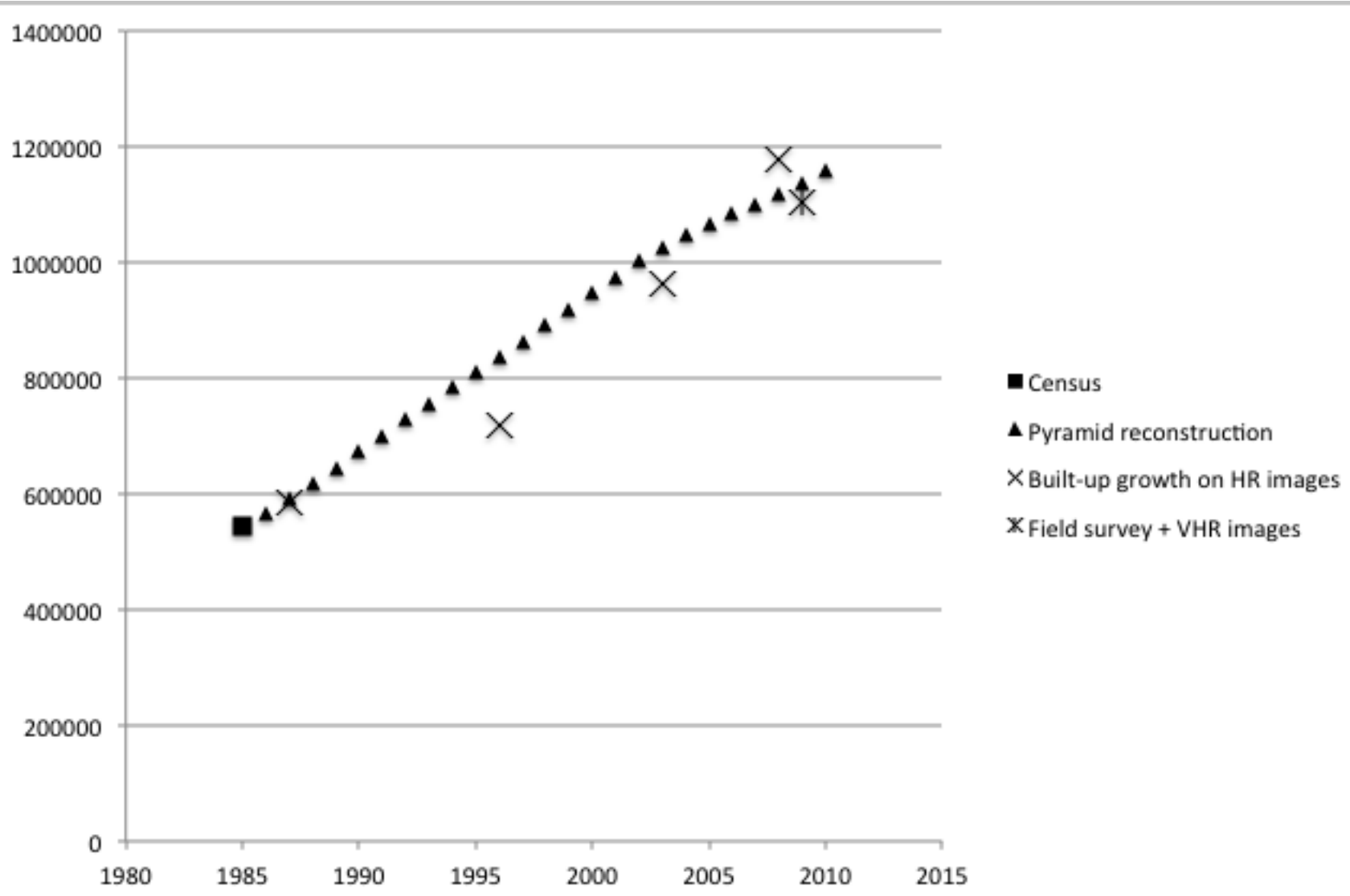


Cross validation

- Second cross-validation, age pyramid reconstruction using population data :
 - Sex and age from the last census (1984)
 - Sex, age, movements from the administrative population register of 2001
 - Sex and age from the voting enrolment decount (2005)
 - Sex and age from the project field survey in 2009



Comparison of the population estimates



Conclusions : use of remote sensing

- To improve sampling by:
 - Excluding unpopulated areas by classification in urban context and visual interpretation in rural areas,
 - Stratifying visually the area,
 - Delineating the sampled blocks and 90% of the plots in urban context
- To ease the field survey by
 - Counting the dwellings in rural context
 - localising the sampled units on BW space-maps to support field surveyors and their control
- To extrapolate the field data by
 - Using the built-up area instead of the total area
- Data :
 - Fused VHR QuickBird (0,6m) in urban context
 - Fused SPOT 5 (5m) in rural context
- Methods :
 - Identification of populated areas are difficult by OBIA (small dwellings, use of natural material on the roof, pollution, rusted corrugated sheet roof, ...)
 - Visual interpretation operational

