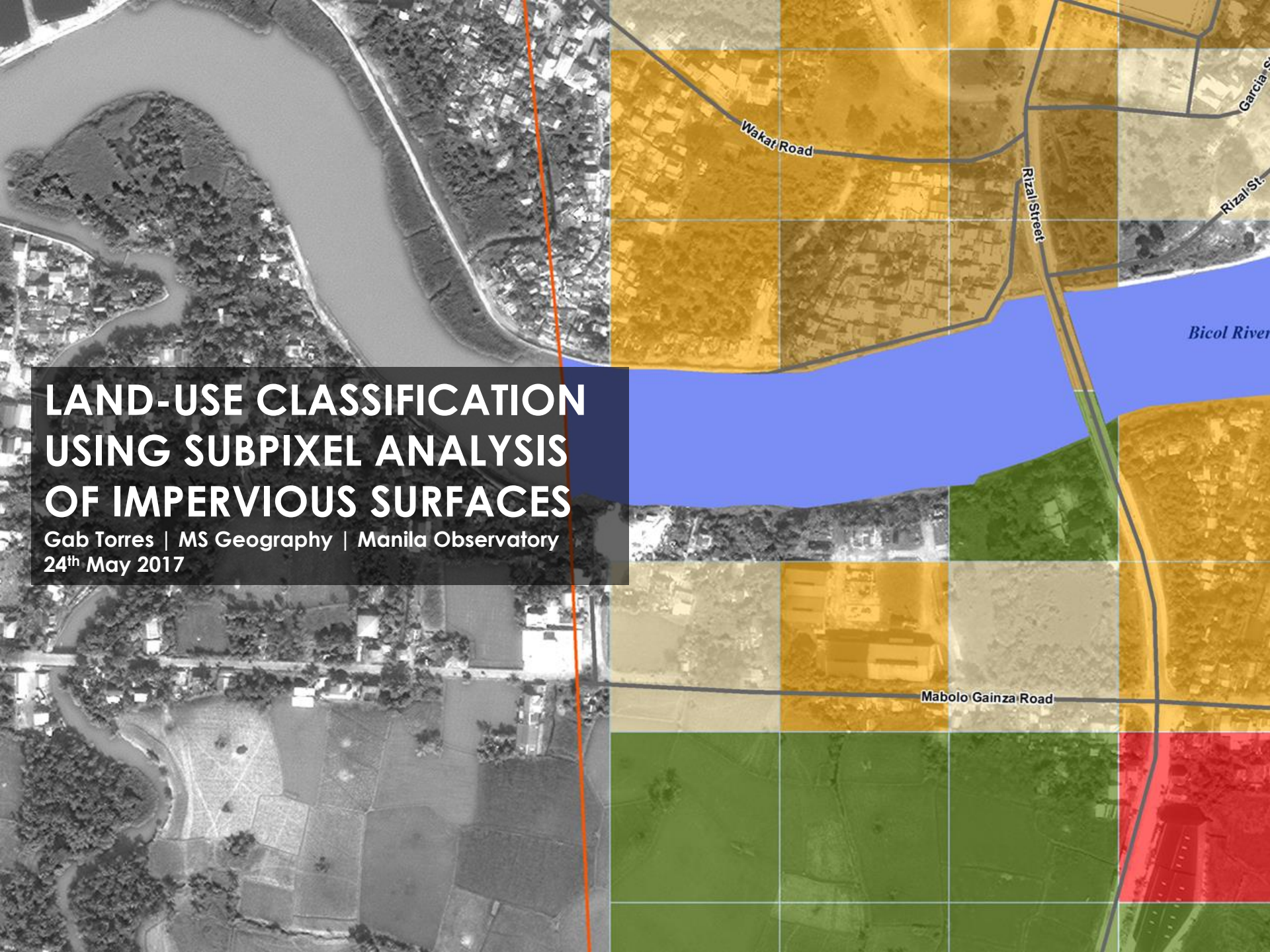


LAND-USE CLASSIFICATION USING SUBPIXEL ANALYSIS OF IMPERVIOUS SURFACES

Gab Torres | MS Geography | Manila Observatory

24th May 2017

Motivation and Research Question

Lack of research on the link between land-cover and land-use

What is land-cover? What is land-use?

How can we map land-use from land-cover?

Study Area

Naga City is primarily an agricultural city in terms of land-use.

Undergoing rapid population growth (26.9% from 2000-2010) and urbanization.

Urban barangays (classified by the LGU) as priority for mapping because of proximity to sources of flooding: Naga River and Bicol River.

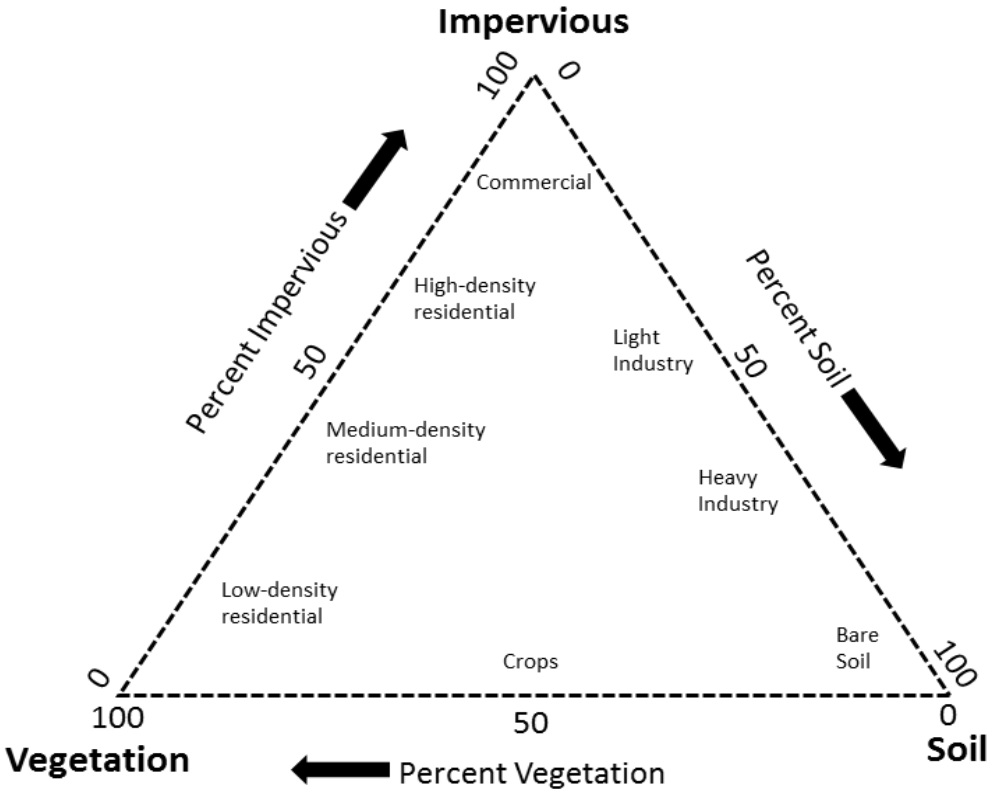
Definitions

Land-Cover	Land-use
The composition of the features of the earth's surface.	Type of human activity taking place at or near the earth's surface.
Material that we see and which directly interacts with electromagnetic radiation observed from a satellite.	Determined by many factors – natural, economic, institutional, cultural, and legal…

Cihlar, J., & Jansen, L. (2001). From Land Cover to Land Use: A Methodology for Efficient Land Use Mapping over Large Areas. *The Professional Geographer*, *53*(2), 275–289.

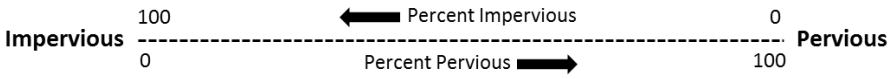
Fisher, P. F., & Unwin, D. (David J. (2005). *Re-presenting GIS*. *Representing GIS Wiley Sons London*.

Vegetation-Impervious surface-Soil (VIS) model



Ridd, M. K. (1995). Exploring a V-I-S (vegetation-impervious surface-soil) model for urban ecosystem analysis through remote sensing: comparative anatomy for cities†. *International Journal of Remote Sensing*. https://doi.org/10.1080/01431169508954549

Simplified Impervious-Pervious surface model



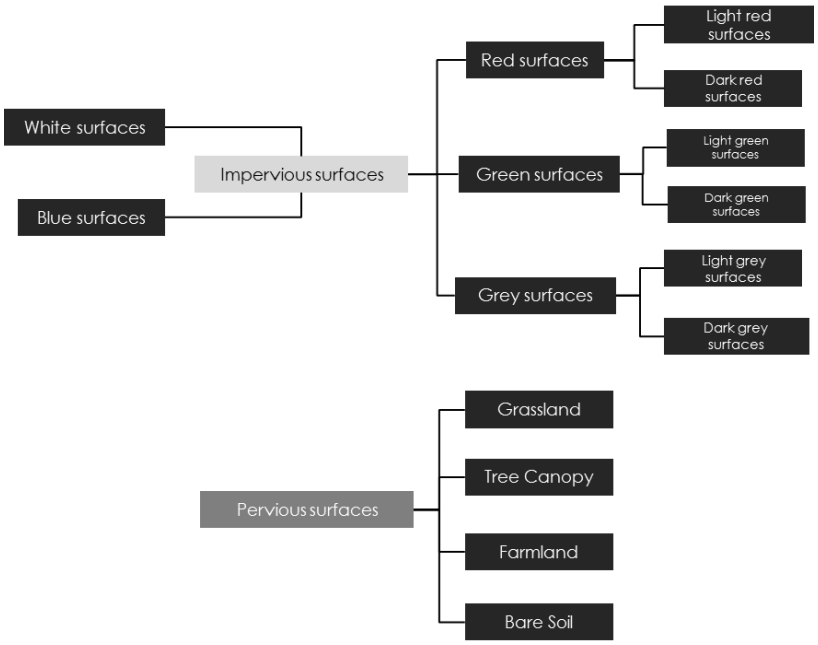
Definitions of impervious surface

Definition	Source
"...are anthropogenic features through which water cannot infiltrate the soil, including roads, driveways, sidewalks, parking lots, rooftops, and so on."	Lu, D., & Weng, Q. (2006). Use of impervious surface in urban land-use classification. Remote Sensing of Environment, 102(1–2), 146–160.
"...is generally recognized as an anthropogenic feature through which water cannot infiltrate into the soil. This includes roads, rooftops,, and other features in close contact with human activities and habitation."	Lu, D., & Weng, Q. (2009). Extraction of urban impervious surfaces from an IKONOS image. International Journal of Remote Sensing, 30(5), 1297–1311.
"…impervious surfaces can be defined as any material that prevents the infiltration of water into the soil."	Arnold, C. L., & Gibbons, C. J. (1996). Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. *Journal of the American Planning Association*, 62(2), 243–258.

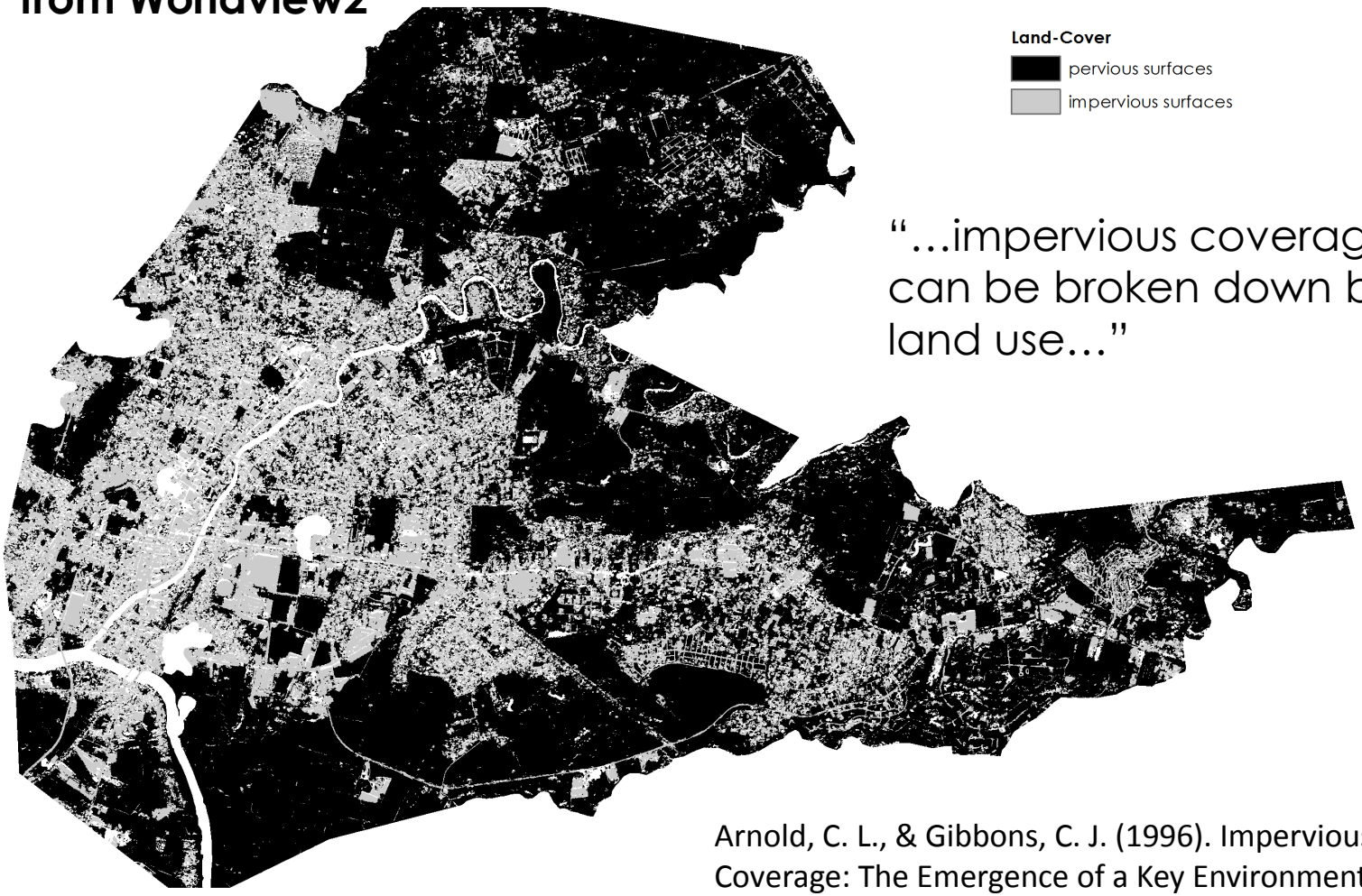
Limitations of impervious-pervious model

Applicable only for small cities such as Naga.

Not for highly urbanized cities such as Metropolitan Manila, Cebu City or Davao City


White surfaces
Blue surfaces
Impervious surfaces
Red surfaces
Light red surfaces
Dark red surfaces
Green surfaces
Light green surfaces
Dark green surfaces
Grey surfaces
Light grey surfaces
Dark grey surfaces
Pervious surfaces
Grassland
Tree Canopy
Farmland
Bare Soil

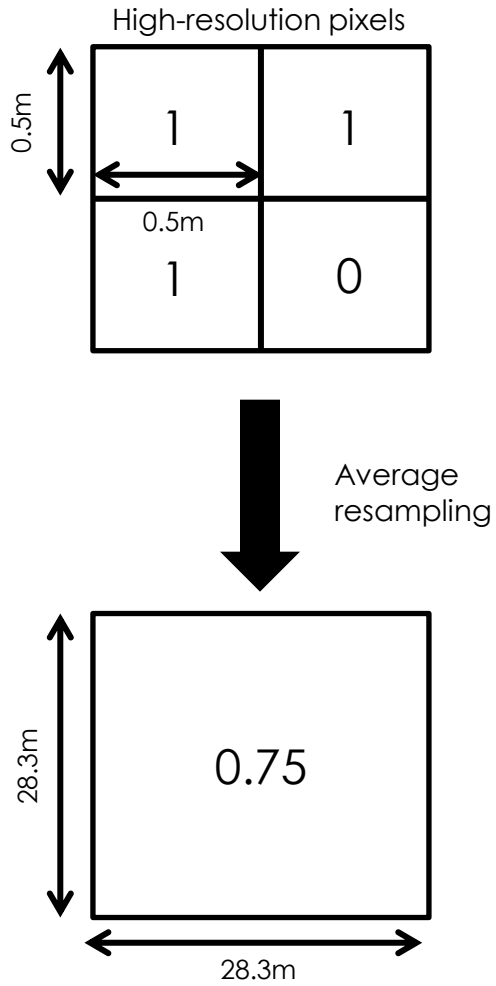
Reclassified land-cover image of Naga City urban barangays from Worldview2



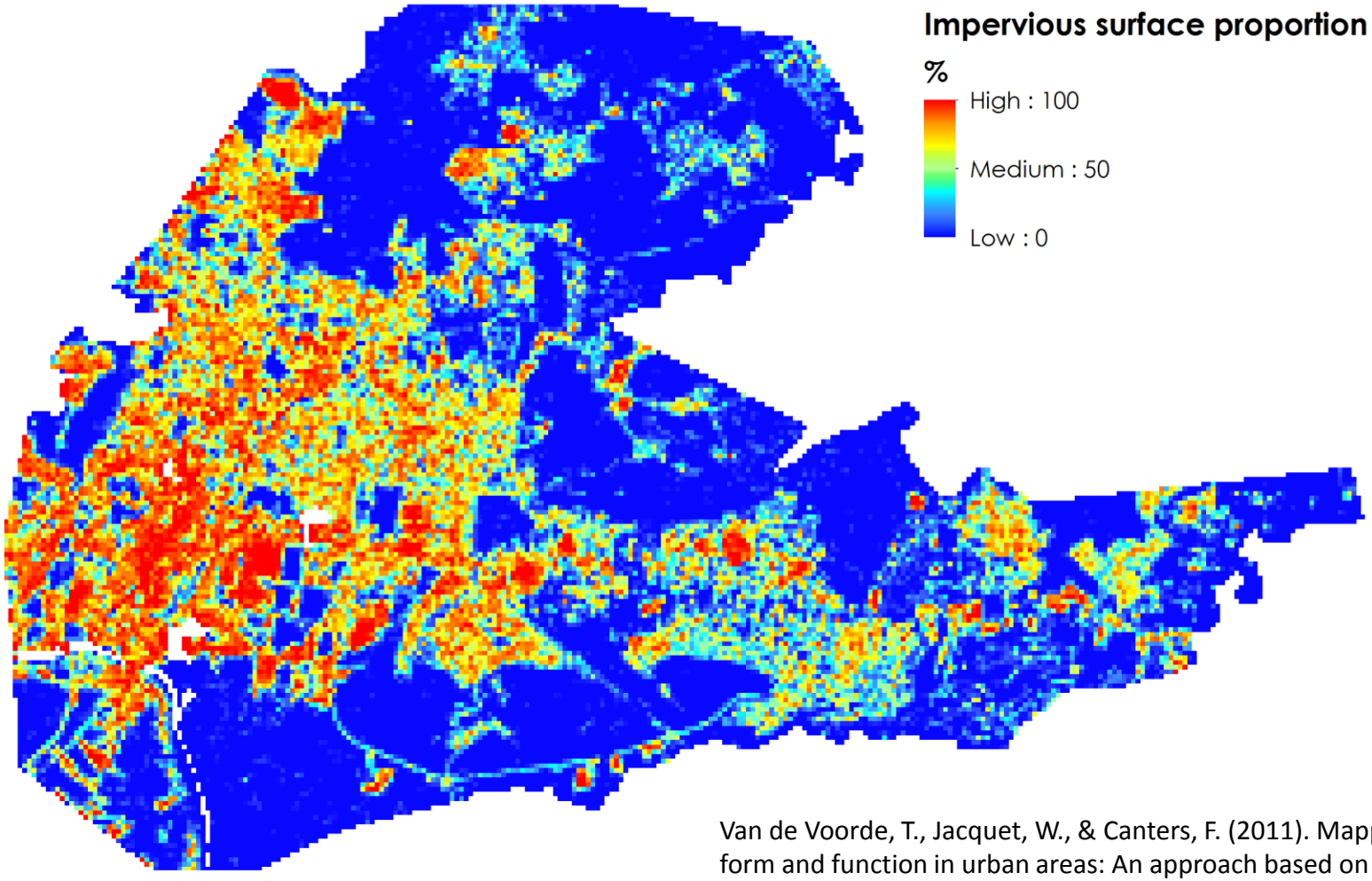
"…impervious coverage can be broken down by land use…"

Arnold, C. L., & Gibbons, C. J. (1996). Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. *Journal of the American Planning Association*, *62*(2), 243–258. https://doi.org/10.1080/01944369608975688

Image average resampling using gdal_warp

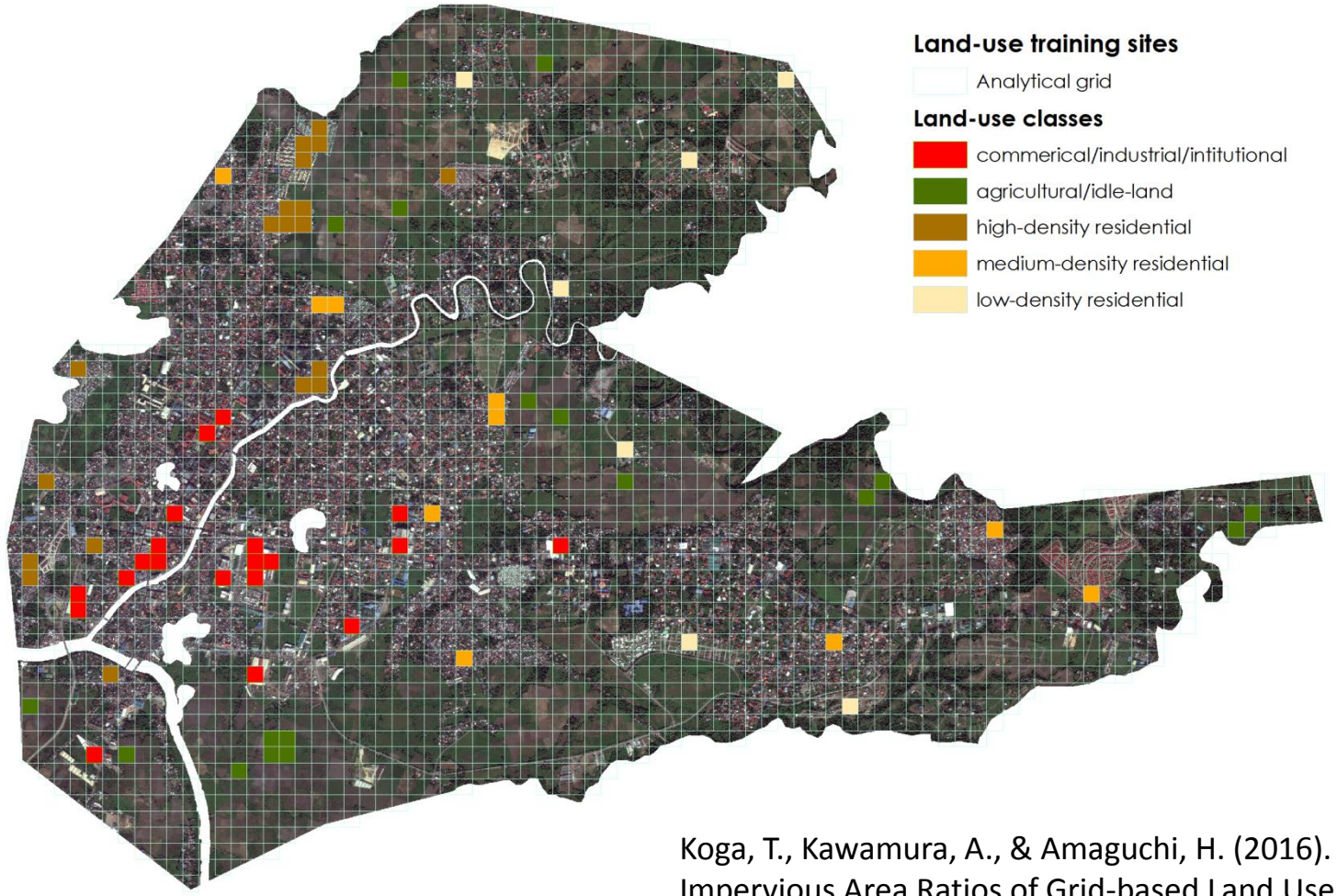


Resampled impervious-pervious land-cover



Van de Voorde, T., Jacquet, W., & Canters, F. (2011). Mapping form and function in urban areas: An approach based on urban metrics and continuous impervious surface data. *Landscape and Urban Planning*, *102*(3), 143–155. https://doi.org/10.1016/j.landurbplan.2011.03.017

Selected training sites for land-use classification



Koga, T., Kawamura, A., & Amaguchi, H. (2016). Assessing Impervious Area Ratios of Grid-based Land Use Classifications on the Example of an Urban Watershed. *Procedia Engineering*, *154*, 609–616. https://doi.org/10.1016/j.proeng.2016.07.559

Impervious land-cover proportion statistics per land-use cell for classification

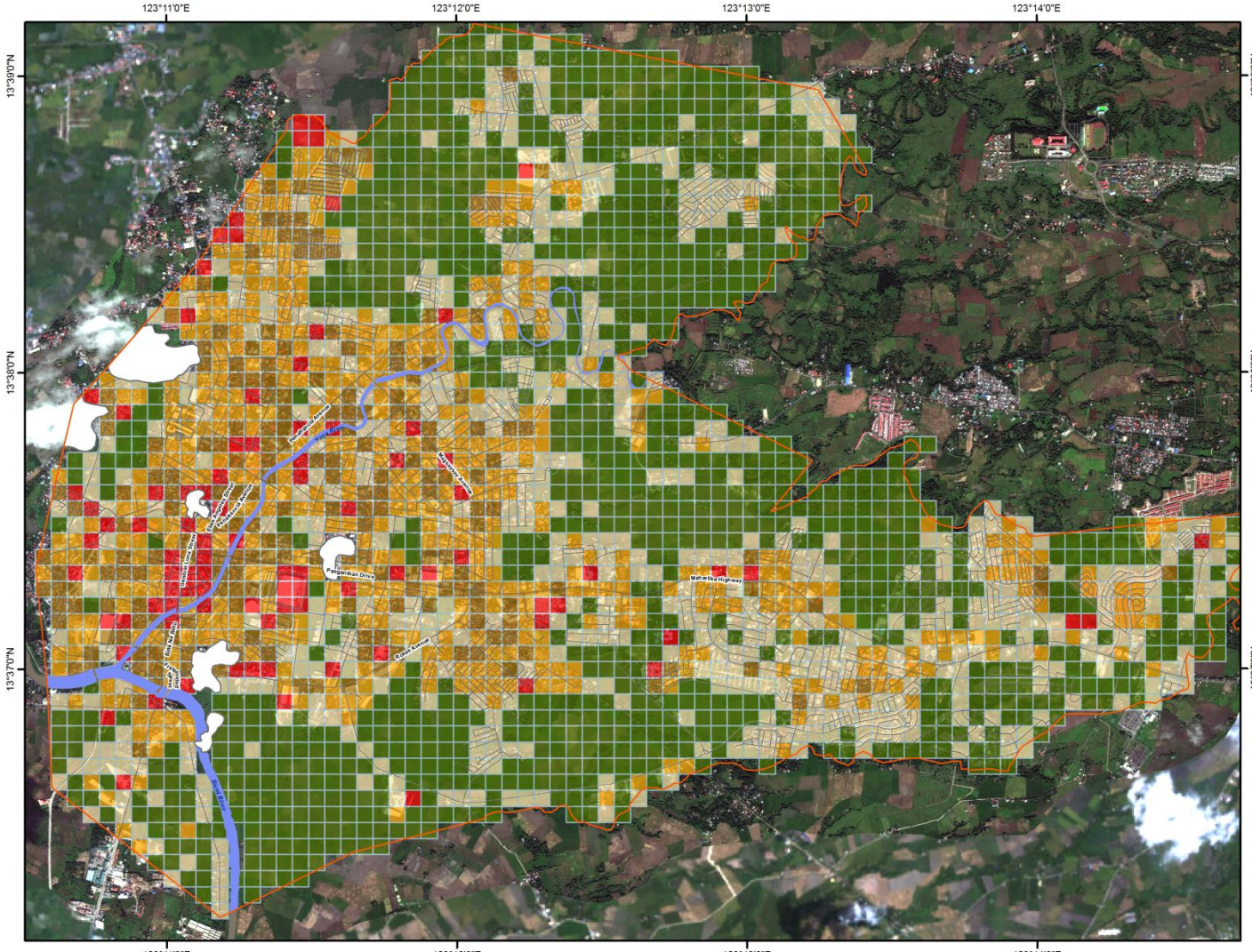
Statistic	Description
Minimum	Describes the lowest value of the sample pixels within a class
Maximum	Describes the largest value of the sample pixels within a class
Mean	Describes the arithmetic mean of the sample pixels within a class
Variance	Describes the spread of the sample pixels from the mean
Kurtosis	Describes the sharpness of the peak of the frequency distribution curve of sample pixels
Skew	Describes the asymmetry of the frequency distribution curve of the sample pixels.

Comparison of accuracy scores of classification algorithms

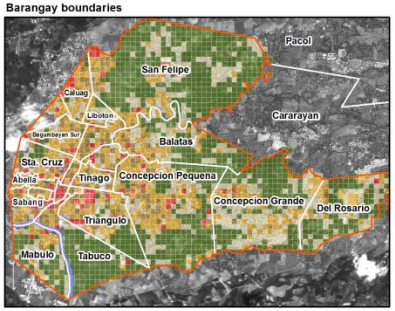
Algorithm	Trial 1 score	Trial 2 score	Trial 3 score	Average
MLP (relu, lbfgs)	0.81	0.53	0.56	0.63
MLP (relu, sgd)	0.56	0.56	0.56	0.56
MLP (logistic,lbfgs)	0.69	0.58	0.61	0.63
MLP (logistic, sgd)	0.36	0.33	0.39	0.36
MLP (tanh, lbfgs)	0.86	0.67	0.64	0.72
MLP (tanh, sgd)	0.50	0.44	0.53	0.49
MLP (identity, lbfgs)	0.72	0.64	0.61	0.66
MLP (identity, sgd)	0.33	0.42	0.53	0.43
Decision Tree	0.69	0.61	0.75	0.69
Random Forest	0.81	0.67	0.64	0.70
Linear SVM	0.64	0.61	0.64	0.63

Confusion matrix of the MLP (tanh, lbfgs)

		Predicted					
True		Agricultural/ Idle	Low-density Residential	Medium-density Residential	High-Density Residential	Commercial/ Industrial/ Institutional	All
	Agricultural/ Idle	9	0	0	0	0	9
	Low-density Residential	0	3	0	0	0	3
	Medium-density Residential	0	0	4	1	0	5
	High-Density Residential	0	0	1	8	0	9
	Commercial/ Industrial/ Institutional	0	0	1	2	7	10
	All	9	3	6	11	7	36



Barangay boundaries



Naga City Urban Land-Use (2015)

Legend

- Urban Barangays Extent
- Clouds
- River
- Roads from OpenStreetMap

Land-Use Classes

- Commercial / Institutional / Industrial
- High-density Residential (R-3)
- Medium-density Residential (R-2)
- Low-density Residential (R-1)
- Agricultural/Idle

Each cell in the land-use grid has an area of 1 hectare.

The map was produced by classifying impervious surface proportions within each grid cell. The proportions were derived by resampling Naga City's land-cover map that was produced from a Worldview2 pansharpened image with a pixel resolution of 0.5 meters.

A neural network algorithm (multi-layer perceptron) from the scikit-learn project was used to classify the grid with an average accuracy score of 0.71 for three trials and a high score of 0.86. The confusion matrix below shows the classes that have been correctly and incorrectly classified by the algorithm. The results with the highest score was used for this map.

Please refer to the technical narrative of the project for the detailed methodology used to produce this map.

Sources:

Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org

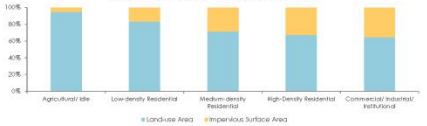
Boundary data from Naga City Local Government Unit

API design for machine learning software: experiences from the scikit-learn project, Buitinck et al., 2013.

Urban land-use and impervious surface (IS) areas

Land-Use Class	Area (ha)	IS (ha)
Agricultural / Idle	1032	58.39
Low-density Residential	525	105.61
Medium-density Residential	469	188.15
High-density Residential	212	104.67
Commercial/ Industrial/ Institutional	92	50.94
Total	2330	507.76

Proportions of land-use area versus impervious surface area



Confusion Matrix for the Multi-Layer Perceptron Algorithm

True \ Predicted	Agricultural/ Idle	Low-density Residential	Medium-density Residential	High-Density Residential	Commercial/ Industrial/ Institutional	All
Agricultural/ Idle	9	0	0	0	0	9
Low-density Residential	0	3	0	0	0	3
Medium-density Residential	0	0	4	1	0	5
High-Density Residential	0	0	1	8	0	9
Commercial/ Industrial/ Institutional	0	0	1	2	7	10
All	9	3	6	11	7	36

Printed on: 5/24/2017
Scaled for printing on paper size A3

1,200 600 0 1,200 Meters

1:25,000

Universal Tranverse Mercator Zone 51 North
World Geodetic System Datum 1984

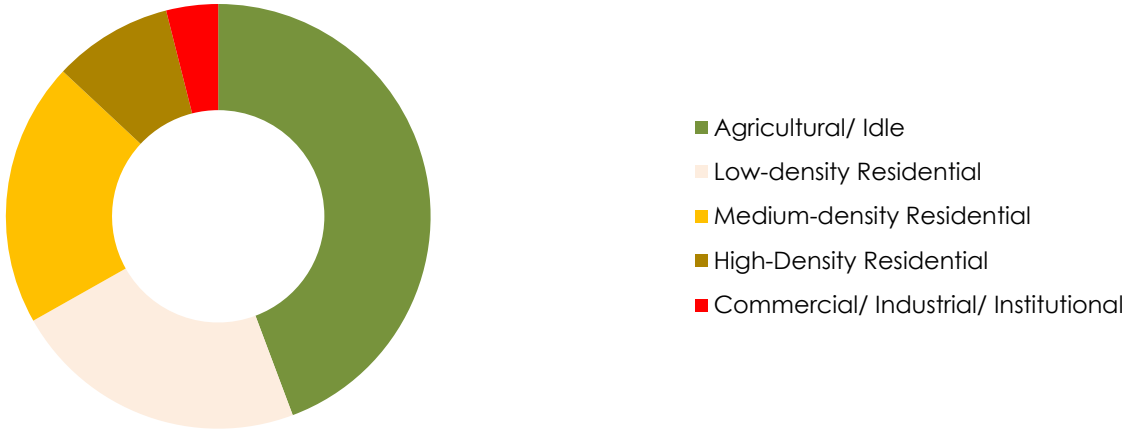
Land-use area and impervious surface area per land-use

Land-Use Class	Area (ha)	Impervious Surface Area (ha)
Agricultural / Idle	1032	58.39
Low-density Residential	525	105.61
Medium-density Residential	469	188.15
High-Density Residential	212	104.67
Commercial/ Industrial/ Institutional	92	50.94
Total	2330	507.76

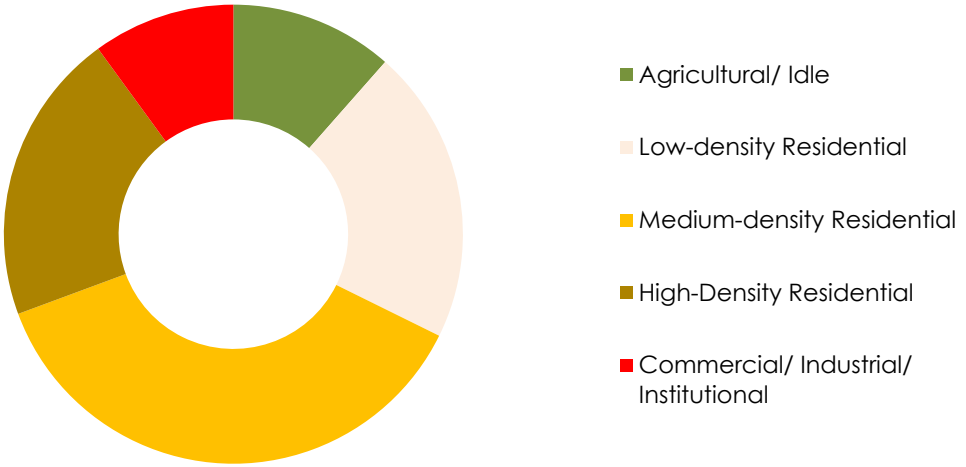
Approximately 22% of total urban land-use of Naga City is impervious surface.

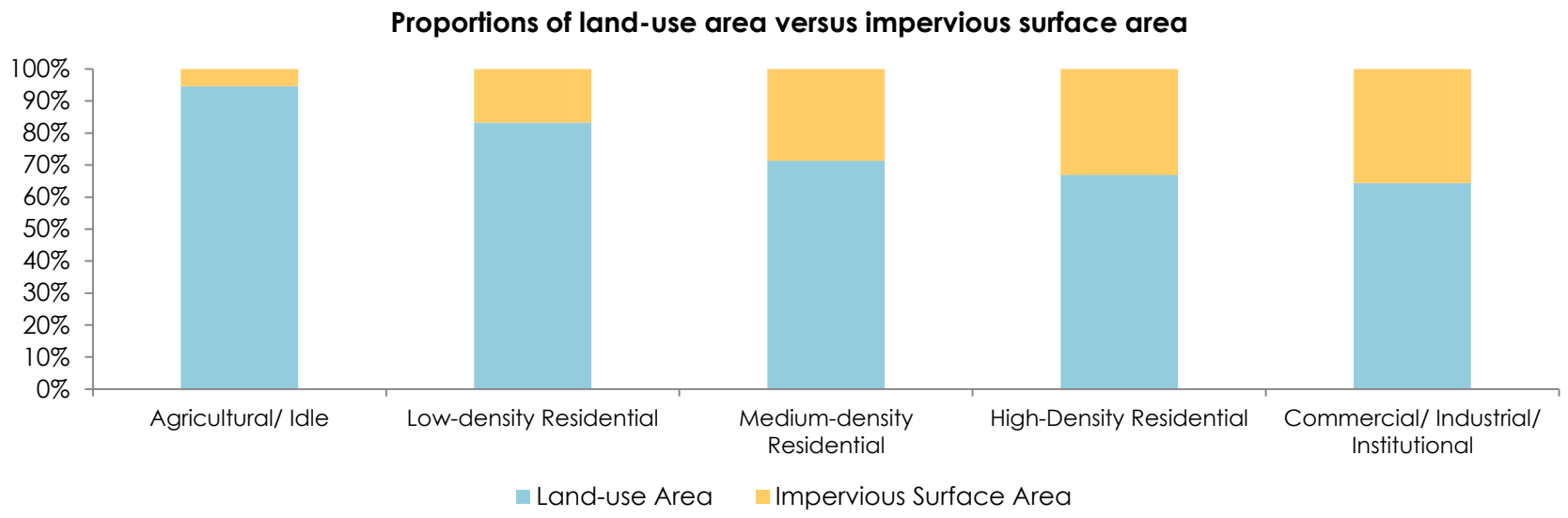
Let's take a closer look at the results…

Land-Use area (hectares) classified from the Worldview2 image with the Multi-Layer Perceptron Algorithm

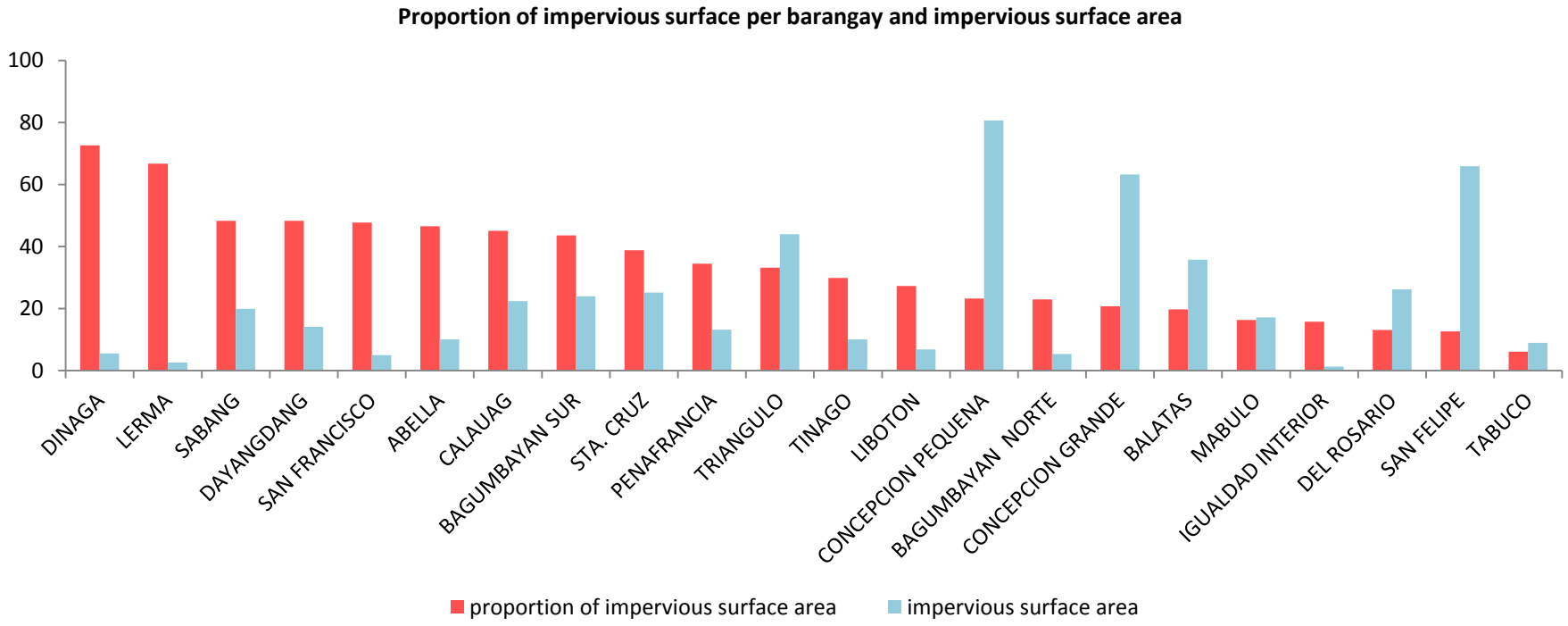


Impervious surface area (hectares) per land-use

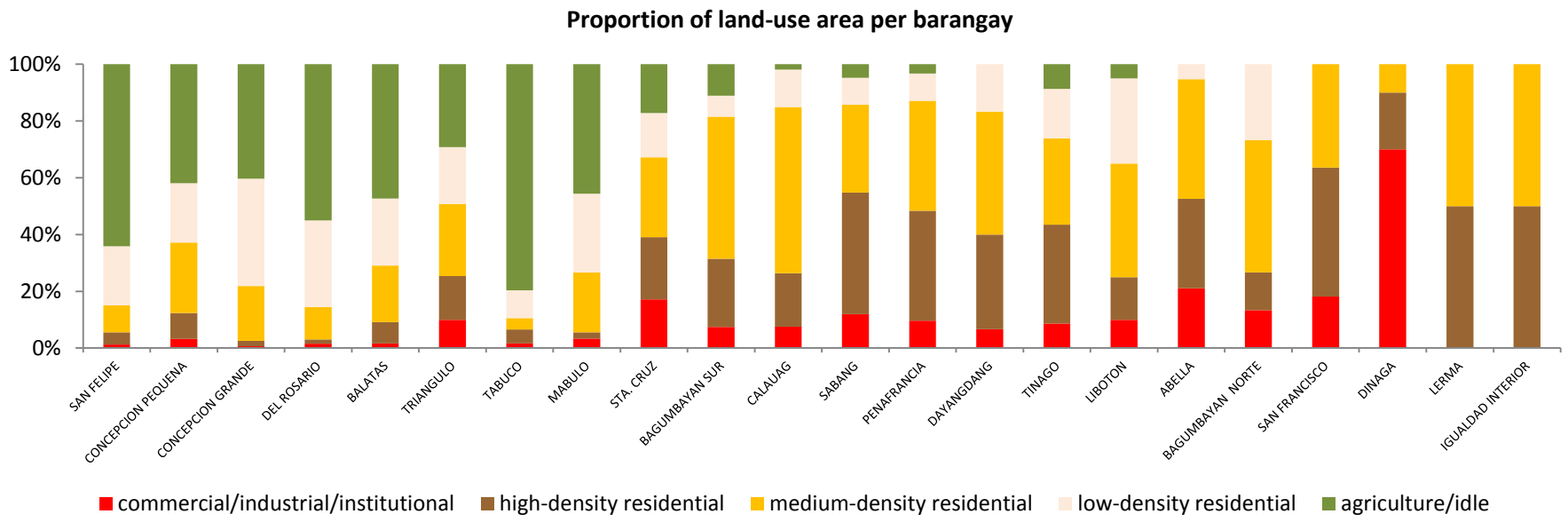



Proportions of land-use area versus impervious surface area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Agricultural/ Idle
Low-density Residential
Medium-density Residential
High-Density Residential
Commercial/ Industrial/ Institutional
Land-use Area
Impervious Surface Area

Breaking down impervious surface coverage per barangay



Breaking down land-use per barangay



Discussion

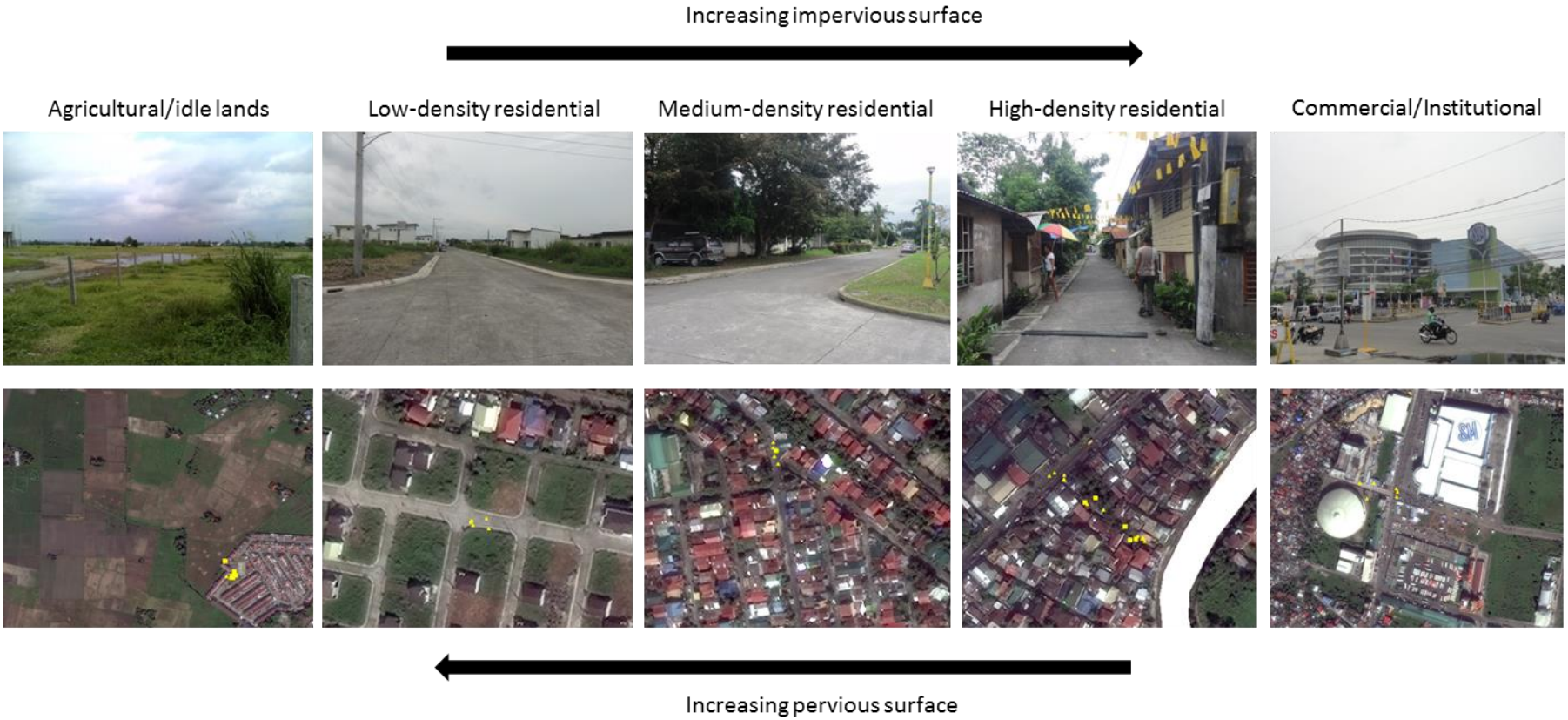
Commercial/industrial/institutional land-uses have the largest proportion of impervious surface area versus land-use area (higher density?)

Residential land-uses have larger IS areas (greater sprawl?)

Agricultural/idle land-uses have the smallest impervious surface proportions.

Increase in impervious surface proportions correlated with intensive residential and commercial activity within barangays.

Ground-truth



Opportunities for Further Research

Optimal parameters for classification algorithms

Time series study on urban land-cover and land-use change
-Landsat series
-Diwata

Correlation with data from other sensors
-MODIS

Correlation with different kinds of data
-Population / Demographics
-Economic spatial analysis
-Peri-urban research

Multi-resolution image analysis