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Exploring the Spatial and Temporal Variation of Air Temperature in the Extreme Desert Climate of Doha, Qatar

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Doha Qatar

- Average high temperature in summer is 38 ^{o}C
- Average yearly rainfall is 98 mm
- Prevailing winds are from N/NE
- Since 2005, Qatar has the highest urban growth rate among the other States of the GCC Countries.
- In 2013, Qatar's total population was 1.8 million
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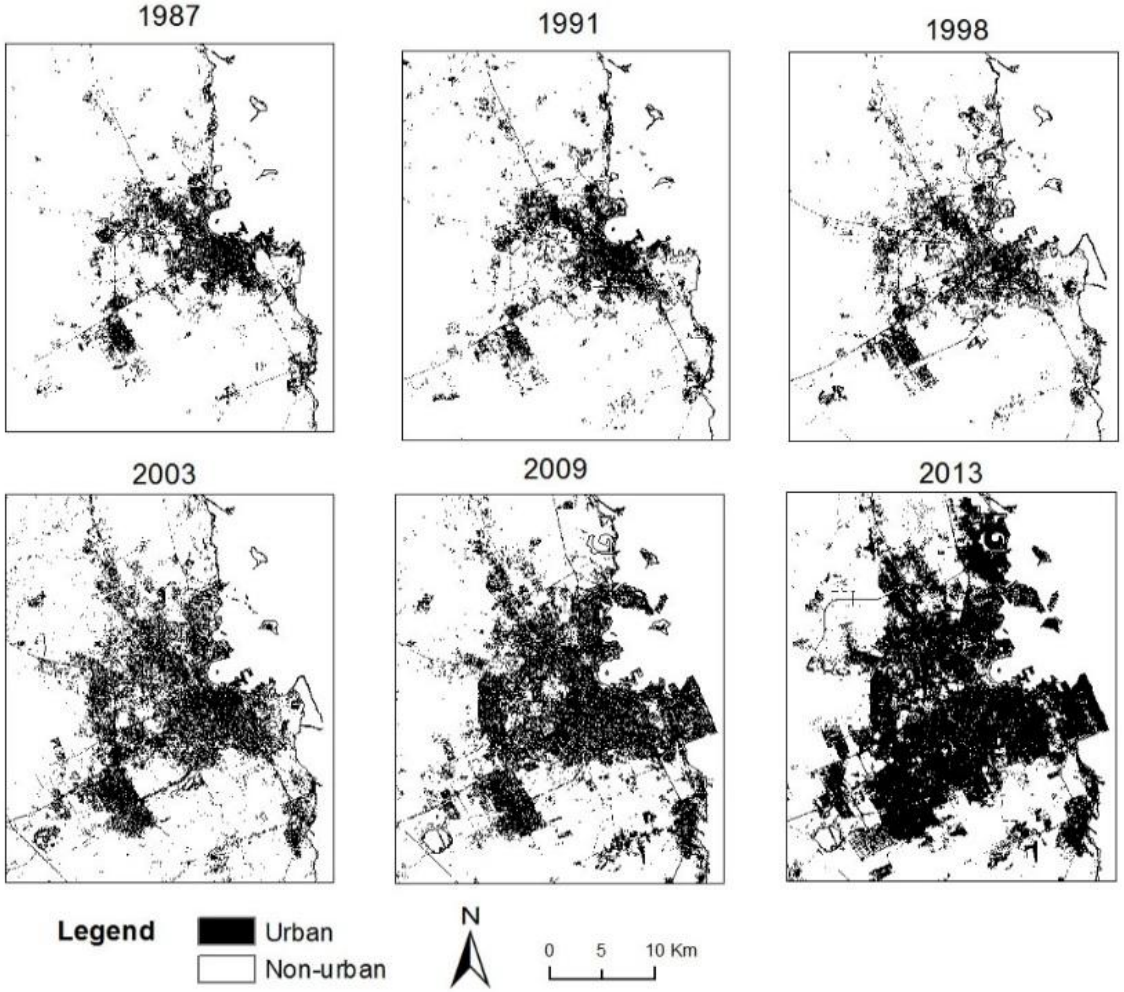
Eco-District Strategy for Doha

- Research question:
  - How does urbanization, its speed, quality, and extent impact neighborhood-scale environmental conditions?
- Research outline:
  - Assess urban development patterns in Doha
  - Monitor environmental conditions
  - Engage local researchers and decision-makers with scientific questions and research results

Assessing Urban Development Patterns

- Using satellite imagery of Doha from 1987 – 2013 we:
  - (1) Categorized land cover into four classes (built, vegetation, bare soil, water);
  - (2) Characterized urban growth trajectories; and
  - (3) Developed typology of land use patterns.

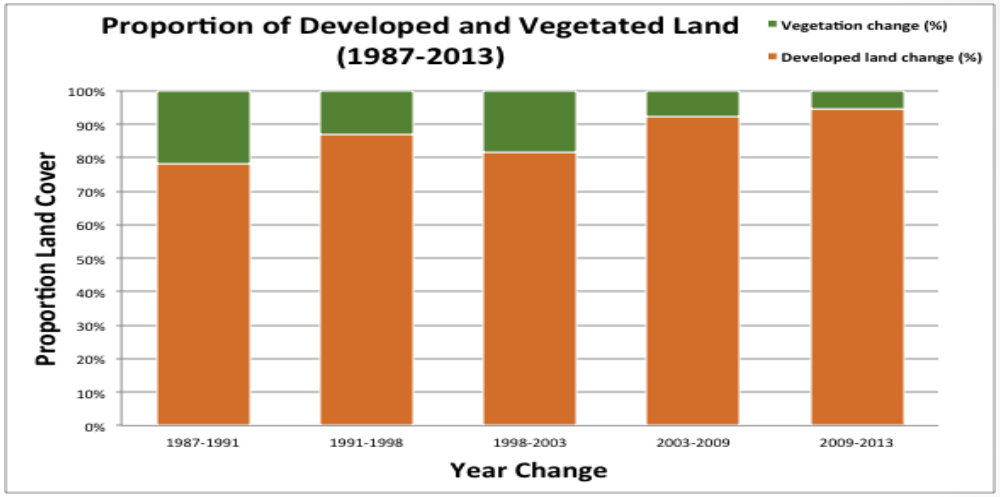
Study area: 31.2km x 37.8km



Land cover development from 1987 to 2013

Summary of Urban Development Patterns

- Amount & rate of conversion to developed land is accelerating
- Amount & proportion of vegetation is decreasing
- Implications on environmental conditions?



LAND COVER	YEAR				
	1987-1991	1991-1998	1998-2003	2003-2009	2009-2013
Converted to Developed Land (km)	18	53	53	90	131
Converted to Vegetation (km)	5	8	12	7	8

Meeting the Challenge with Responsive Design for Regional Hot Climate

- Eco-district concept is a responsive solution for the negative consequences of global warming and climate change.
- It provides a sustainable built environment by mitigating the harsh hot days.
- A first step in estimating the potential for mitigating heat is to understand the spatial and temporal variation of air temperature throughout the city.
- Then develop predictive models that relate physical characteristics to the corresponding variations in near-surface air temperatures.
- Assess the extent to which the built environment, including vegetation, affect intra-urban variability of temperature in Doha, Qatar.

Based on empirically derived temperature readings, we address three research questions:

1. to what extent does the air temperature vary during the day?
2. what landscape factors best explain how the temperature varies? And
3. how do analytical techniques for estimating intra-urban temperature affect the accuracy of predictions?

Methods

- Conducted traverses to determine spatial differences in summertime air temperature across the city.
- Fast response (time constant < 1s; accuracy +/- 0.5 ^{o}C) temperature sensors connected to data loggers
- A time synchronous GPS system was also attached to each car so that each temperature measurement could be paired with a GPS location, with a sampling frequency of 5s.

Fig. 1 Coverage of Sept 8 and 9, 2014 vehicle temperature traverse across the study area, Doha

- We subsequently computed Land Cover/Land Use (LCLU) characteristics that can be attributable to local urban temperatures.
- Landsat OLI imagery was used to classify the study area into four categories: urban/built-up, vegetation, soil, and water.
- We employed supervised classification and unsupervised classification.
- We derived four variables at each pixel (30m): urban/non-urban, vegetation/non-vegetation, albedo and distance to coastal line.

- In order to reveal the area of influence for each separate temperature measurement, we plotted linear regression correlation coefficients between temperature and three variables (urban density, vegetation density, and mean Albedo) for buffer sizes ranging from 50m to 1000m.

Table. 1 Buffer sizes for each variable (meter)

Buffer sizes	9/8/2014			9/9/2014		
	6am	1pm	7pm	6am	1pm	7pm
Urban	600	600	600	600	600	600
Vegetation	100	400	150	600	350	150
Albedo	50	600	50	50	600	50

Tree-structured Regression Models

- We employed tree-structured regression model to determine the importance of various land use and land cover characteristics.
- We used 70 % of traverse data as the training set and the remaining 30% as the test set.
- The study area is divided into four or five categories based on the node criteria. The values at each end node is the mean temperature for that terminating node, and multiple linear regression models are constructed to predict the temperature of each pixel.
- For both models, the first terminating node is the urban density, and it suggests that the percent urban area within 600m radius is the most important factor in the surface temperature in the evening.

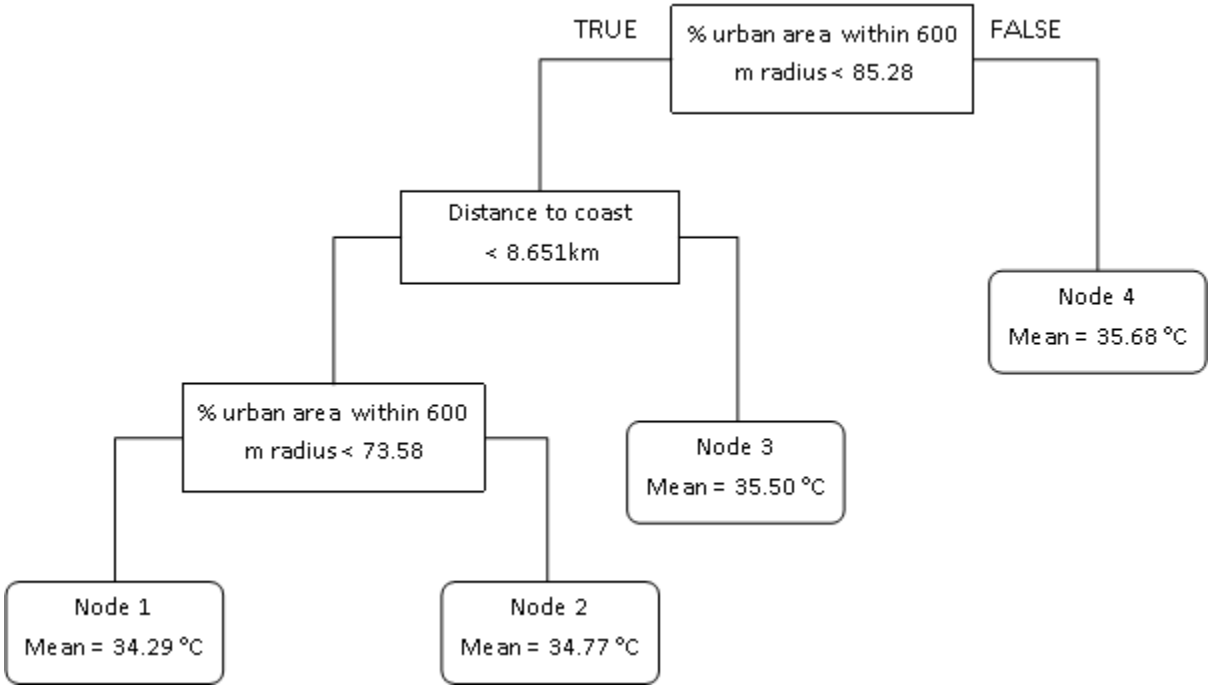


Fig. 2 Tree-structured regression model for 8th of Sept, 2014 7pm

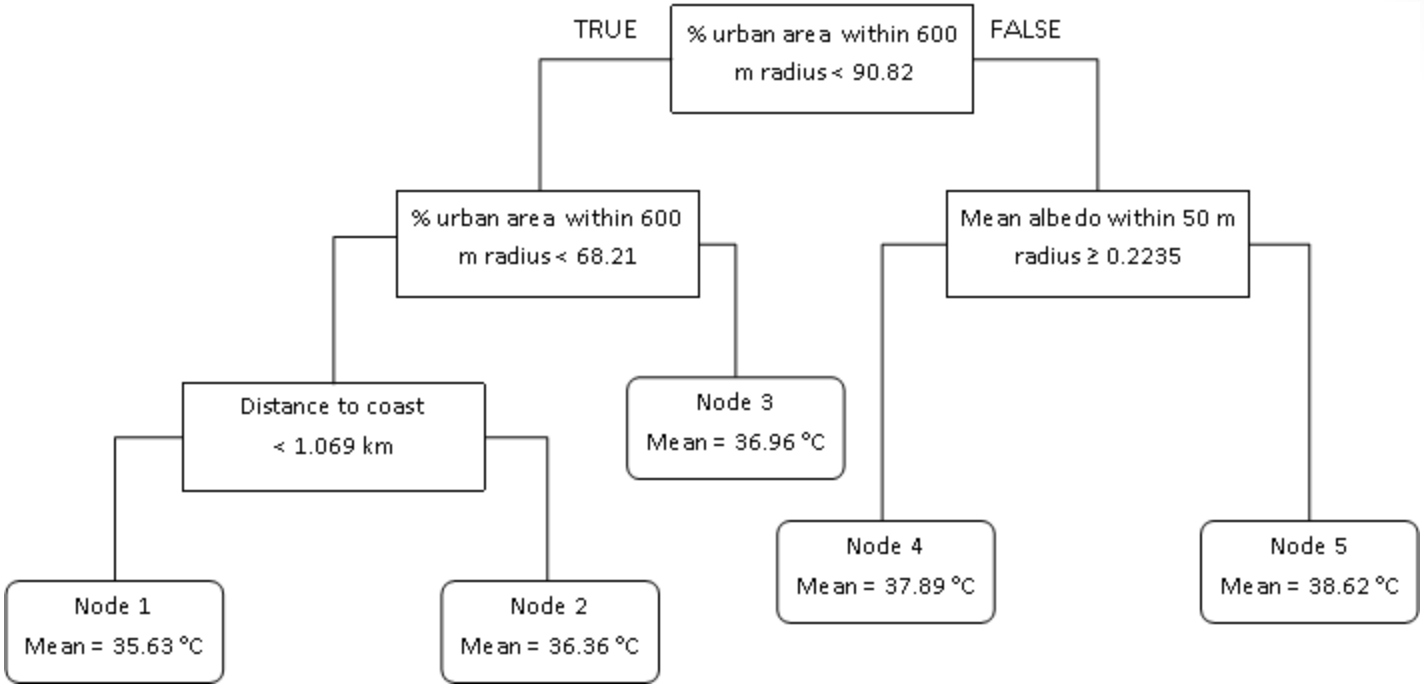


Fig. 3 Tree-structured regression model for 9th of Sept, 2014 7pm

Using the results of the regression tree analysis, we developed two spatial representations of temperature variability for 8th and 9th of Sept at 7pm (Figures 4 and 5).

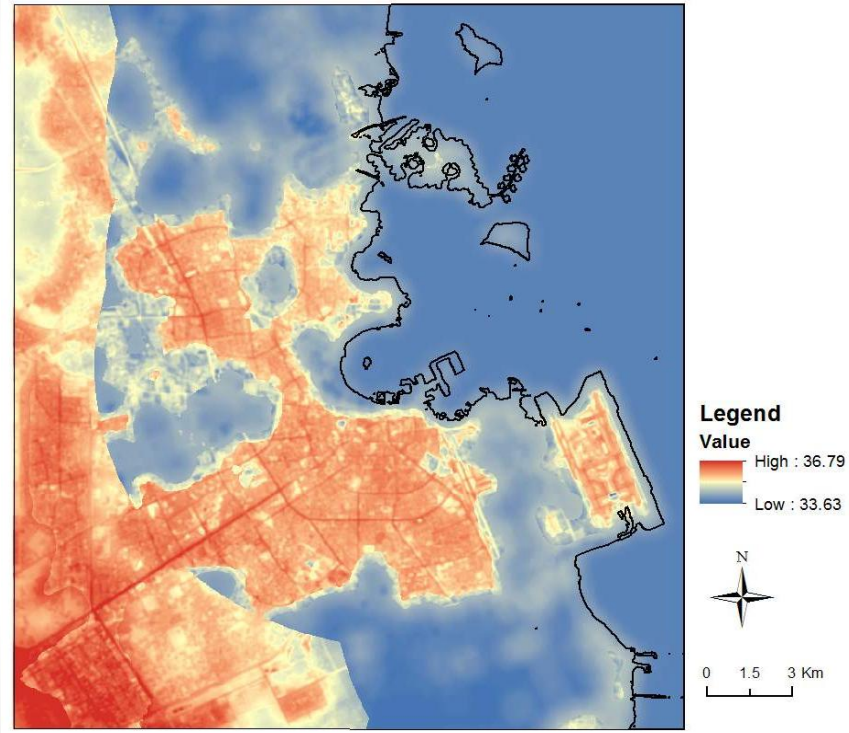


Fig. 4 Predicted surface map using tree-regression models (unit is in °C) for 9/8/2014 7pm

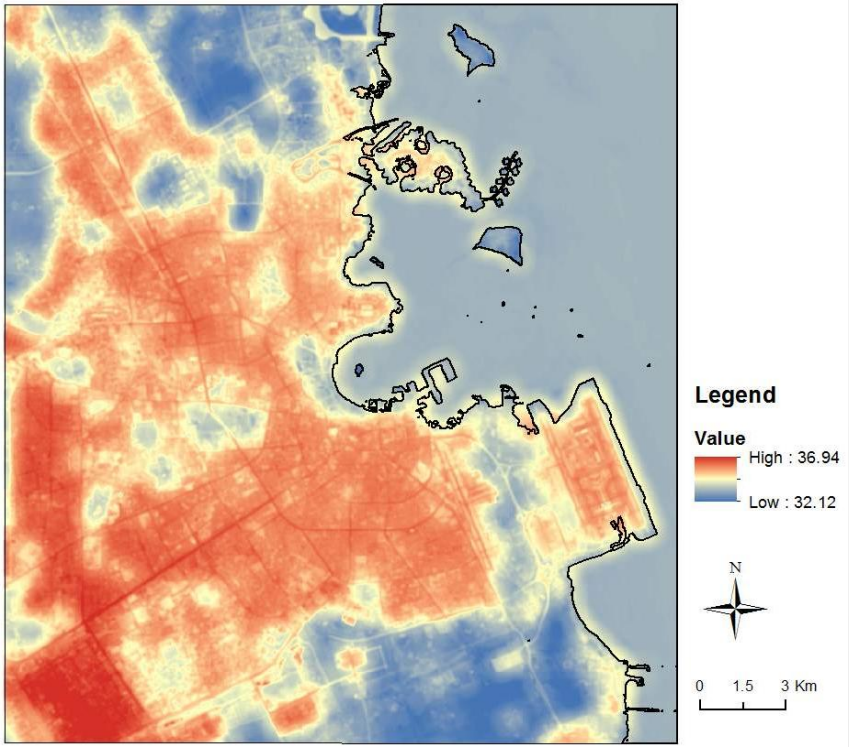


Fig. 5 Predicted surface map using linear regression models (unit is in °C) for 9/8/2014 7pm

- To validate the prediction of the UHI models, we conducted a Pearson's correlational analysis between estimated surface temperatures using 70 % of traverse data and true surface temperatures at remaining 30 % of traverse data.
- In all cases, the correlation coefficient is higher for using tree-structured regression models as opposed to the standard linear regression model.
- The Pearson's analysis suggests that the tree regression model more accurately predicts the surface temperatures than the linear regression model.

- *Table. 2 Pearson's correlation coefficient between estimated surface temperatures using 70 % of traverse data and true surface temperatures at remaining 30 % of traverse data*

	9/8/2014			9/9/2014		
	6am	1pm	7pm	6am	1pm	7pm
Tree Regression Model	0.394	0.697	0.724	0.633	0.809	0.750
Linear Regression Model	0.330	0.638	0.676	0.397	0.789	0.688

Conclusions

- Analysis of relationships between air temperatures and land-use/land-cover can provide insight into recommendations for future development in the region
- Percent urban area, distance to coast, and surface albedo were the key determinants of spatial variability of air temperature in Doha
- These characteristics can explain temperature variations of more then 3 ^{o}C across the city.

Thank You!

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