Land Use/Cover Changes & Modeling Urban Expansion of Nairobi City

Overview

- ✓ Introduction
- ✓ Objectives
- ✓ Land use/cover changes
- ✓ Modeling with Cellular Automata
- ✓ Conclusions

Introduction

Urban land use/cover types and distribution necessary for monitoring growth and evaluation of urban policies and development strategies.

Because of rapid urban growth, models are needed to provide understanding of the consequences of planning policies.

African Cities

- ✓ Experiencing most rapid spatial expansion of all regions (Cohen, 2004).
- ✓ Urban growth sprawl coupled with explosive population growth
- ✓ Inadequate infrastructure and basic amenities
- ✓ Consequences – unsuitable land uses, traffic congestion, environmental and social effects

Objectives

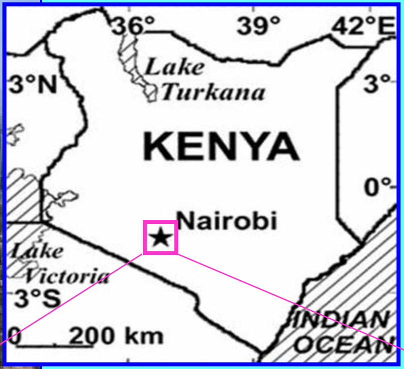
- ✓ To analyze the dynamics of land use/cover changes
- ✓ To model the urban growth and simulate urban expansion using Cellular Automata and GIS

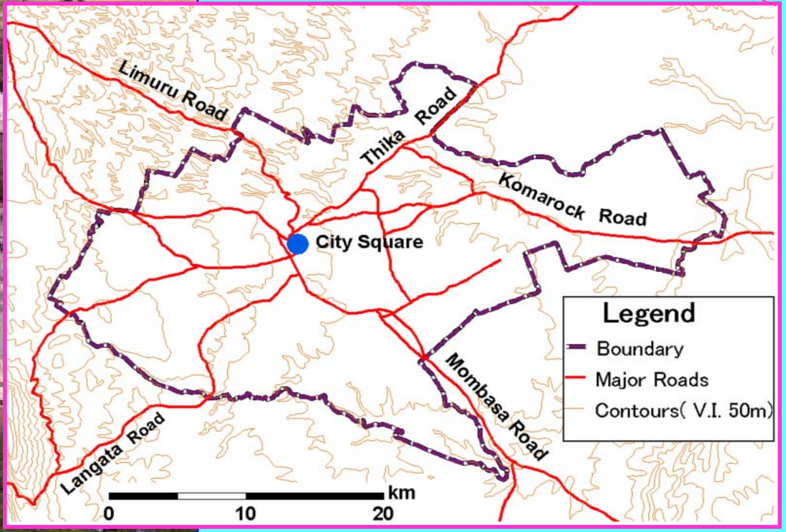
Study Area - Nairobi

Administrative Area: 713 km^2

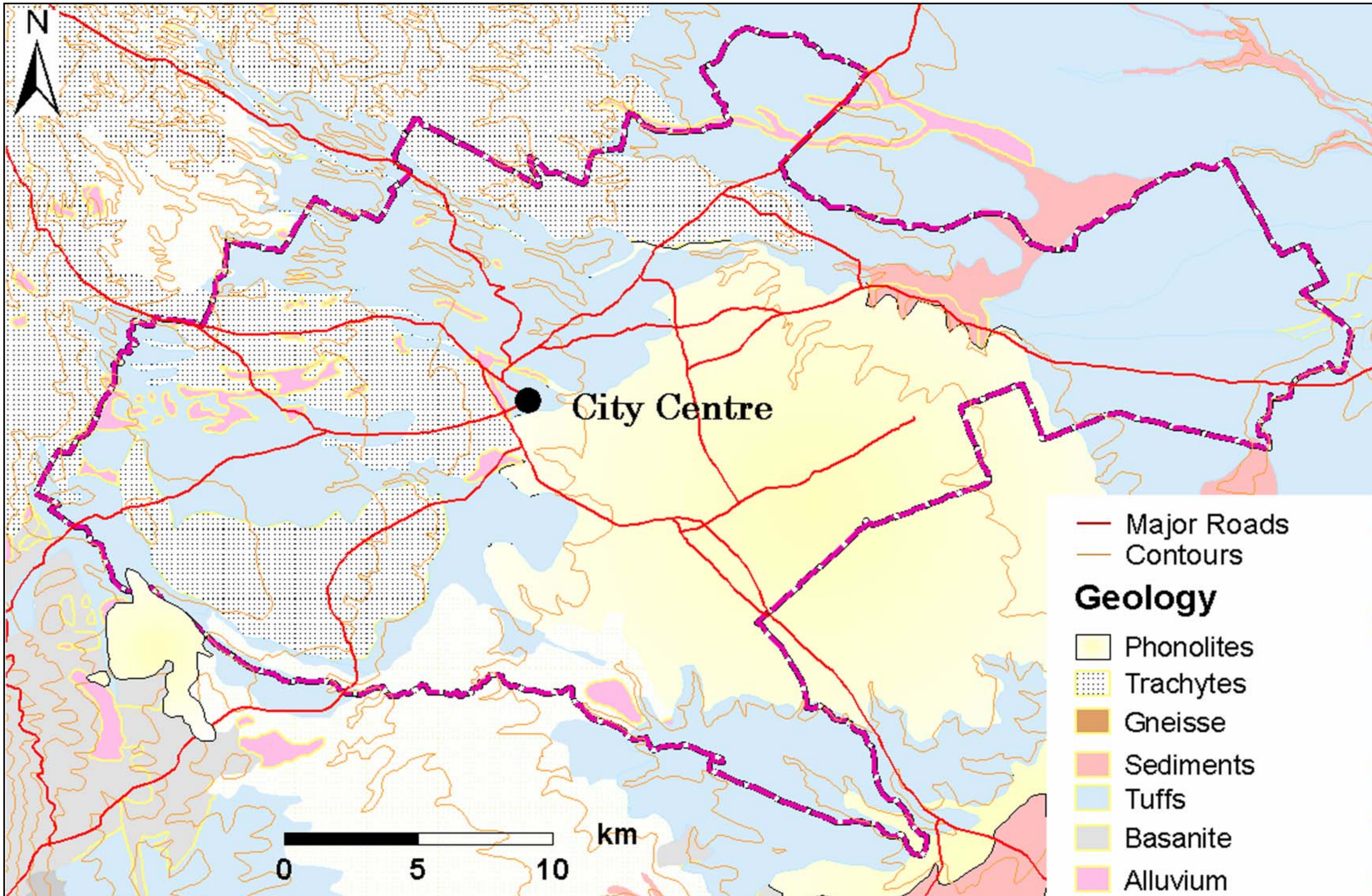
Average Altitude: 1700m asl

Population: 3.5 Million

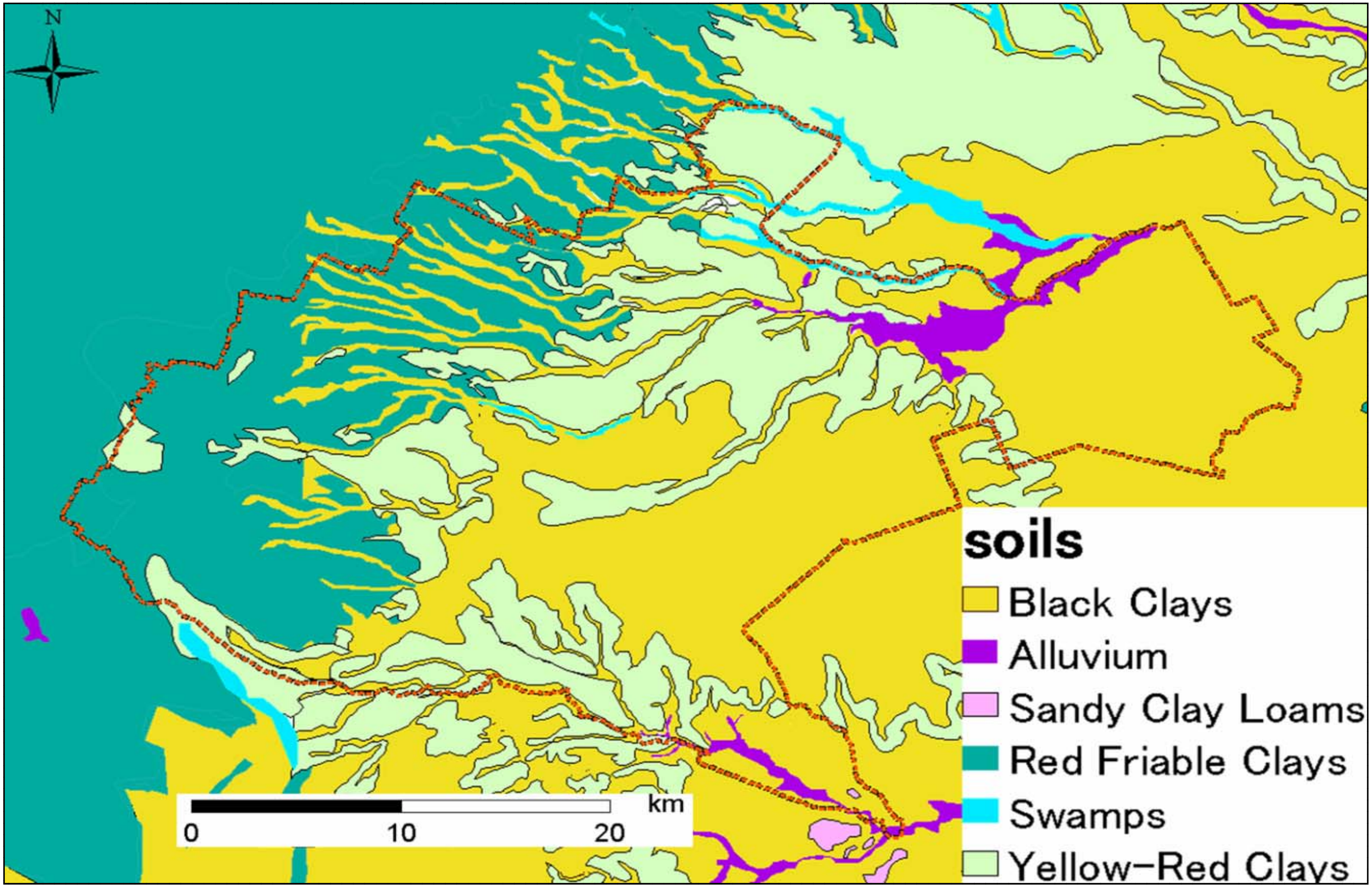




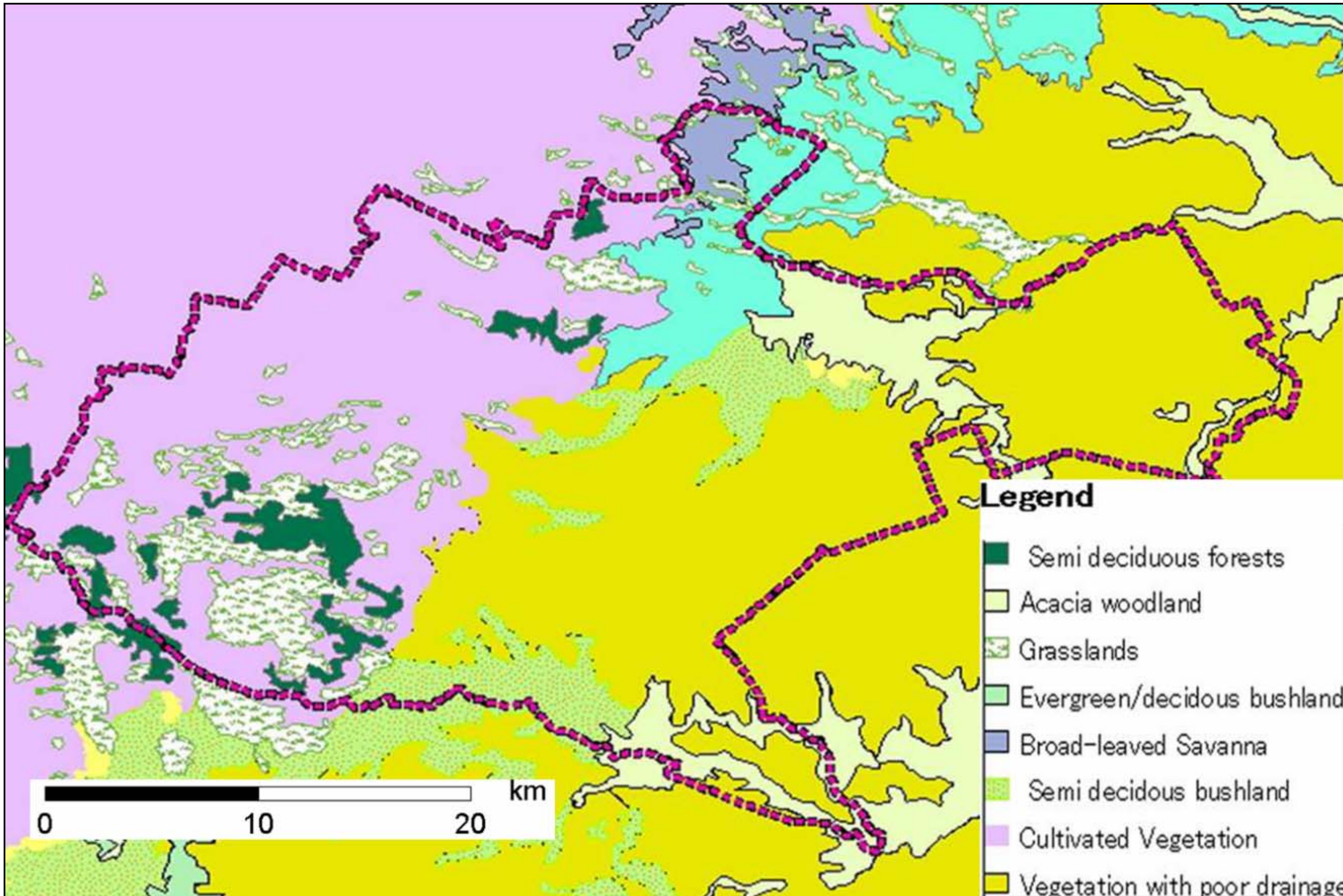
Nairobi - Geology



Soils

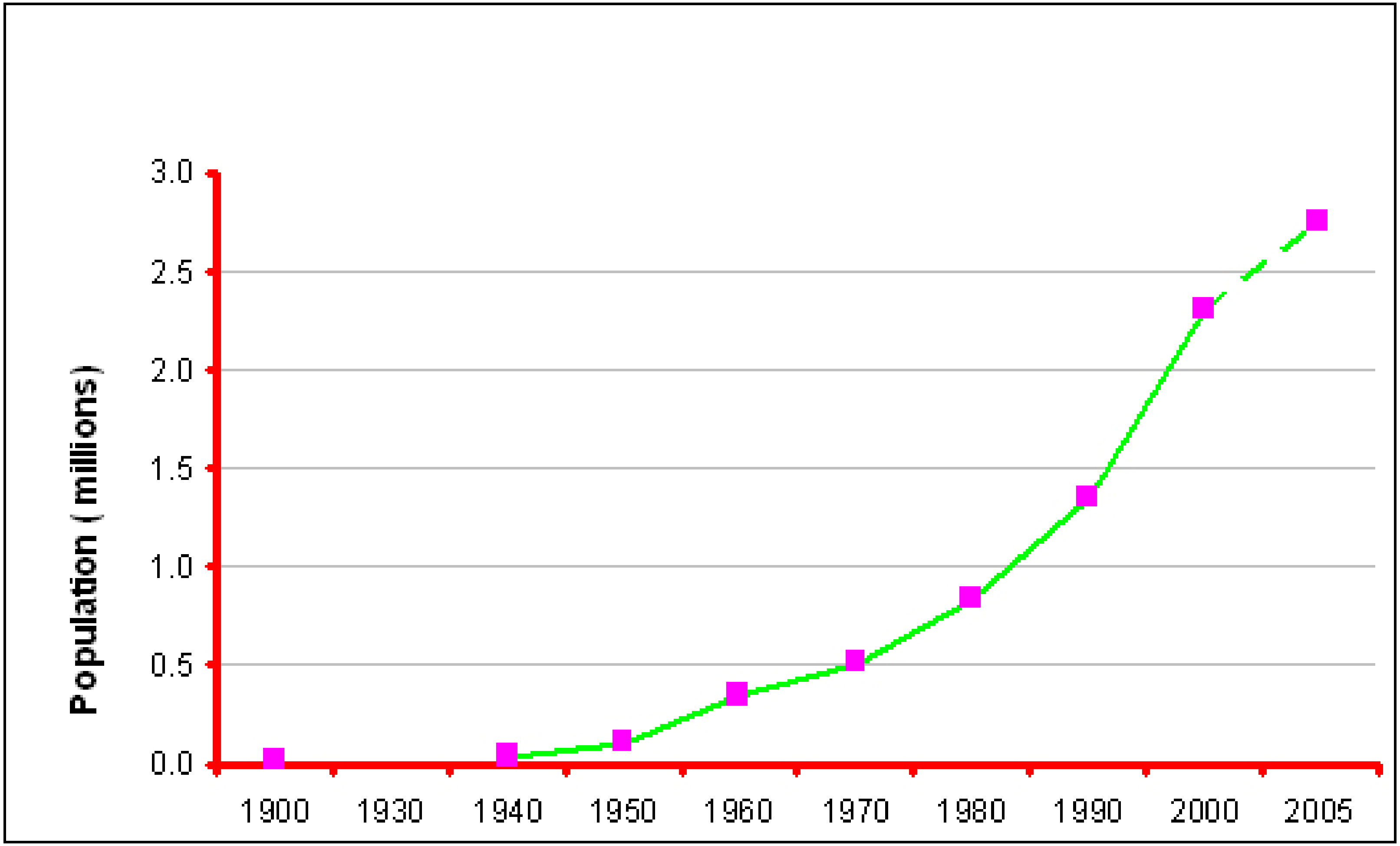

N
km
0
10
20
soils
Black Clays
Alluvium
Sandy Clay Loams
Red Friable Clays
Swamps
Yellow-Red Clays

Vegetation



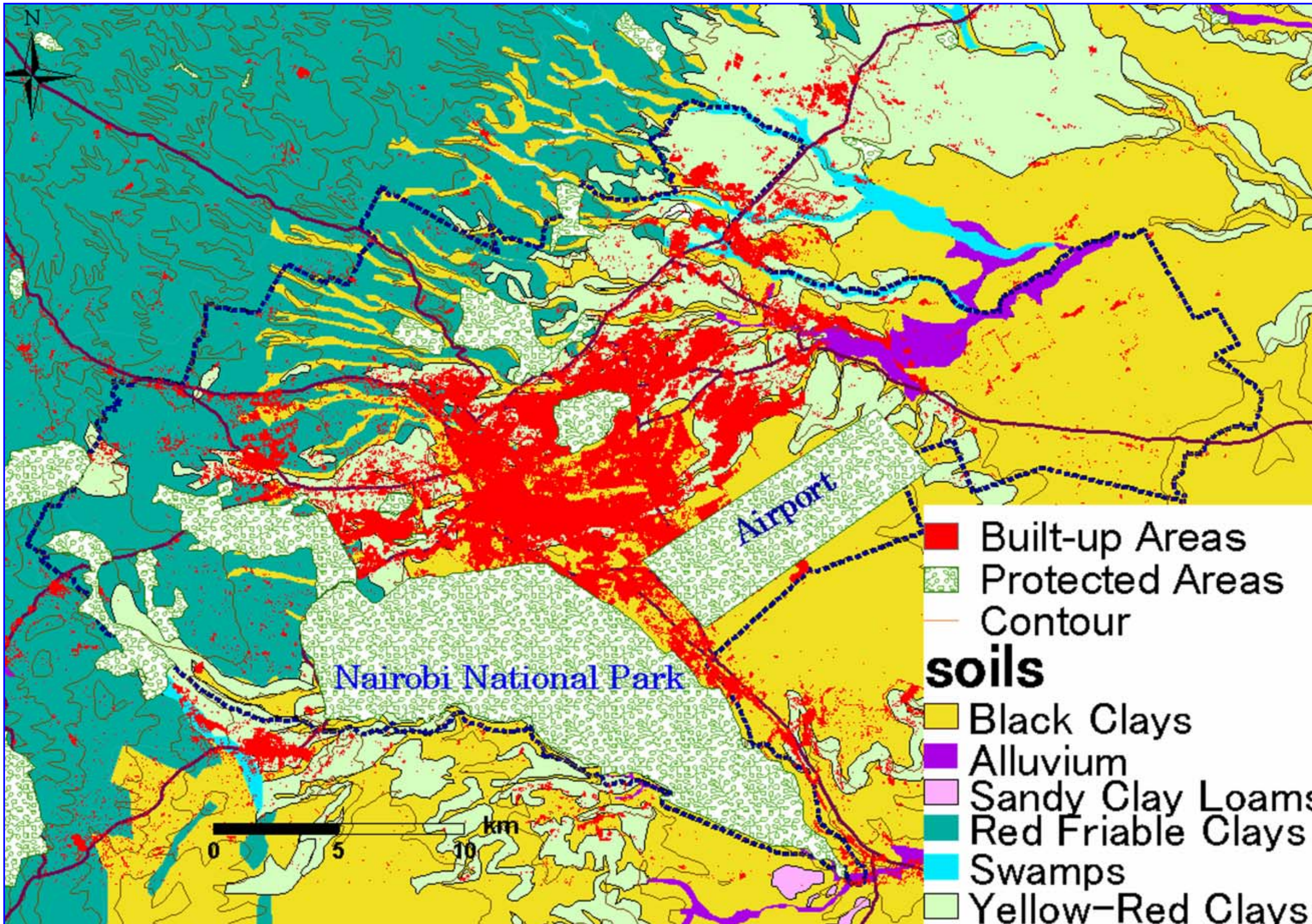
Legend
Semi deciduous forests
Acacia woodland
Grasslands
Evergreen/decidous bushland
Broad-leaved Savanna
Semi decidous bushland
Cultivated Vegetation
Vegetation with poor drainage
0
10
20
km

Population



Population (millions)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1900
1930
1940
1950
1960
1970
1980
1990
2000
2005

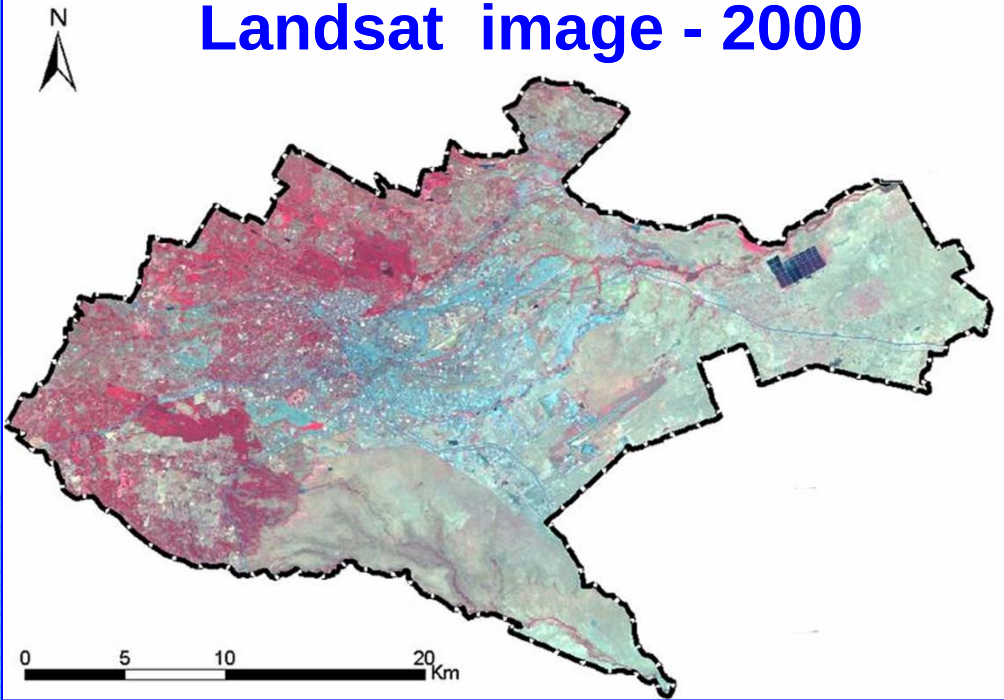
Constraints



Analysis of Land Use/cover changes

- ✓ Use of multi-temporal Landsat images
  - ☑(resampling)
- ✓ Change detection to map spatial dynamics of land use/cover.
- ✓ Physical and socio-economic data for factors influencing land use/cover changes.

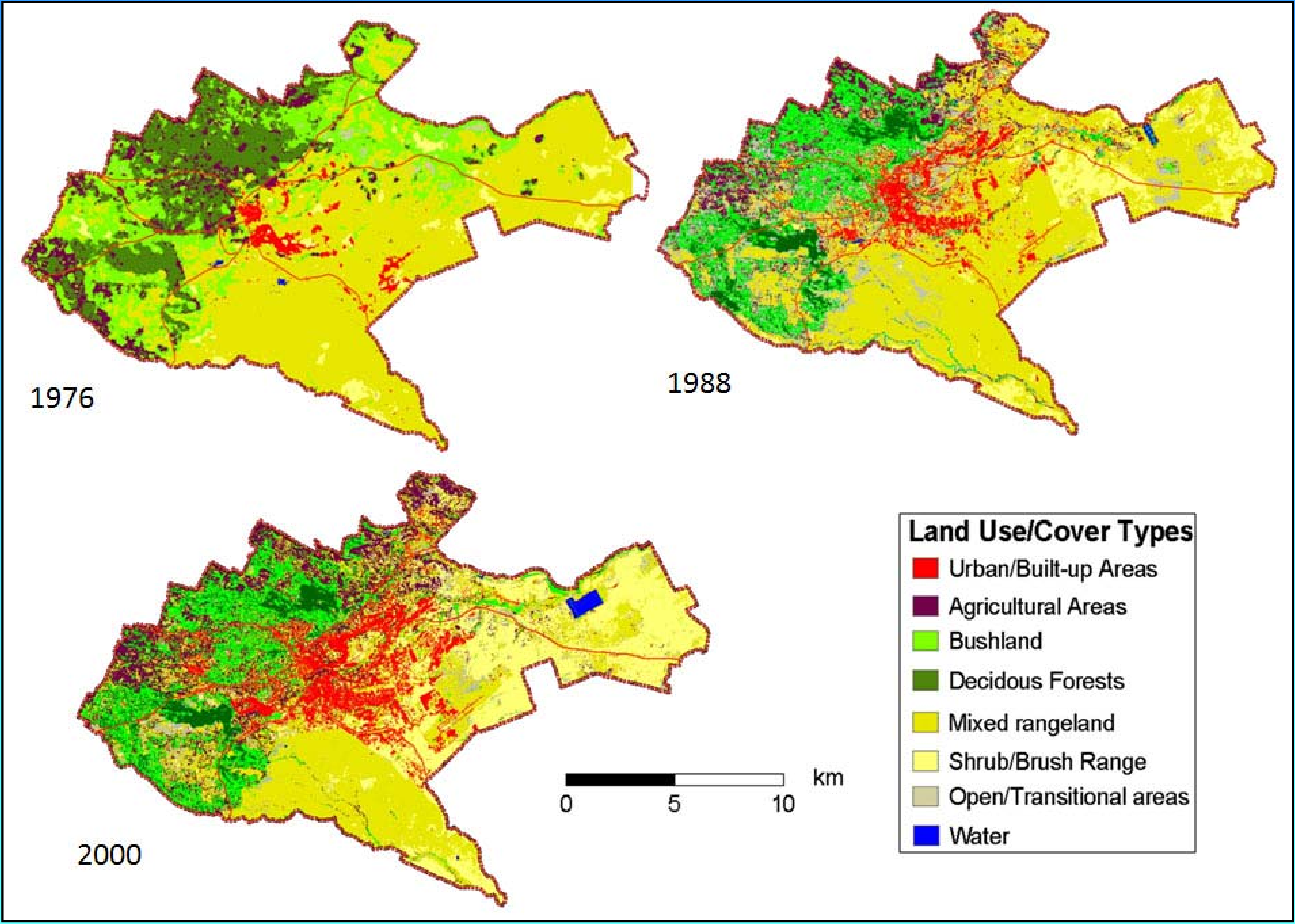
Landsat image - 2000



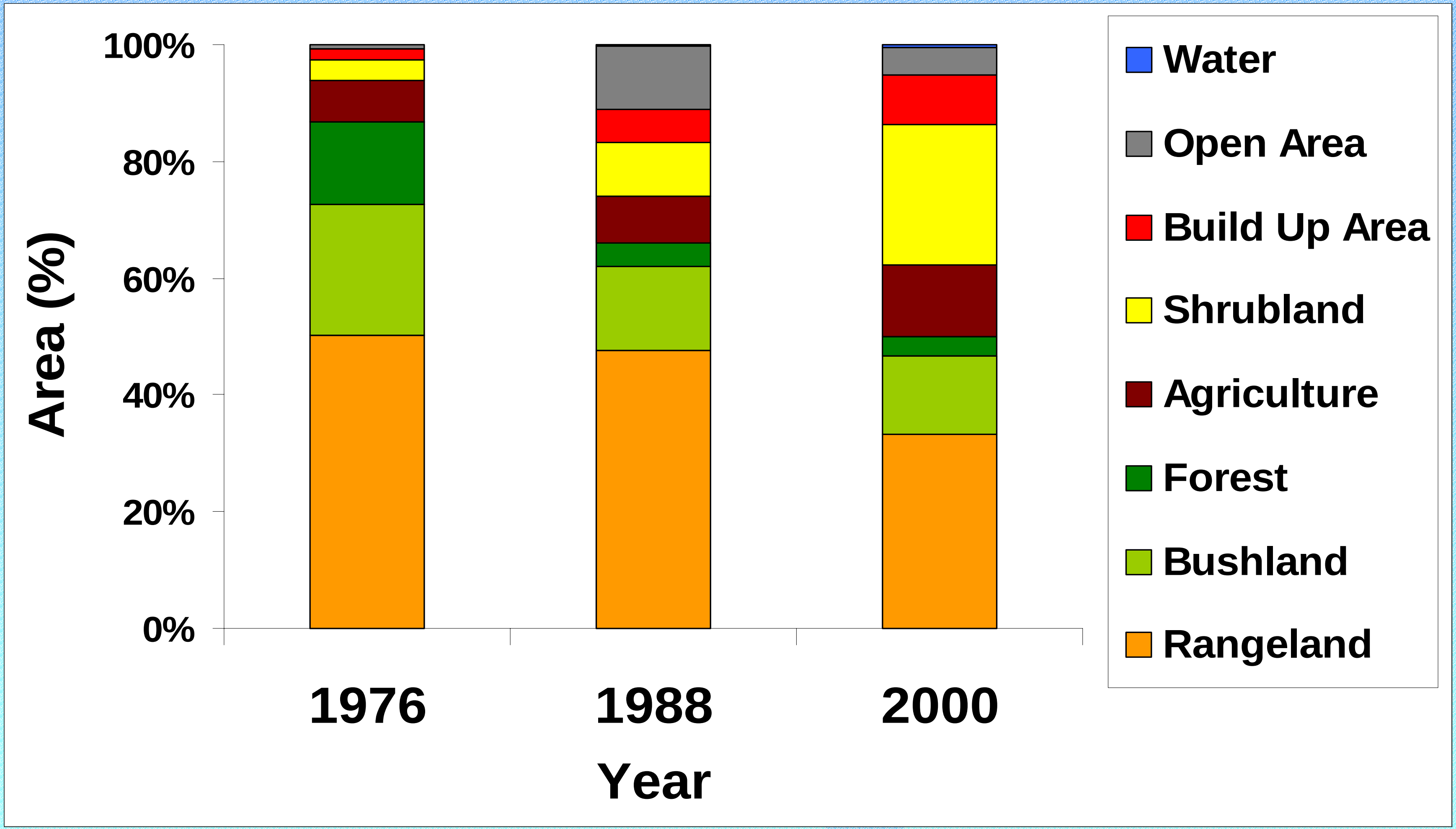
Satellite Data

Sensor	Resolution	Date
Landsat MSS	79/120	Feb./ 1976
Landsat TM	30/120	Oct./1988
Landsat ETM+	15/30/60	Feb./ 2000

Land Use/Cover in Nairobi



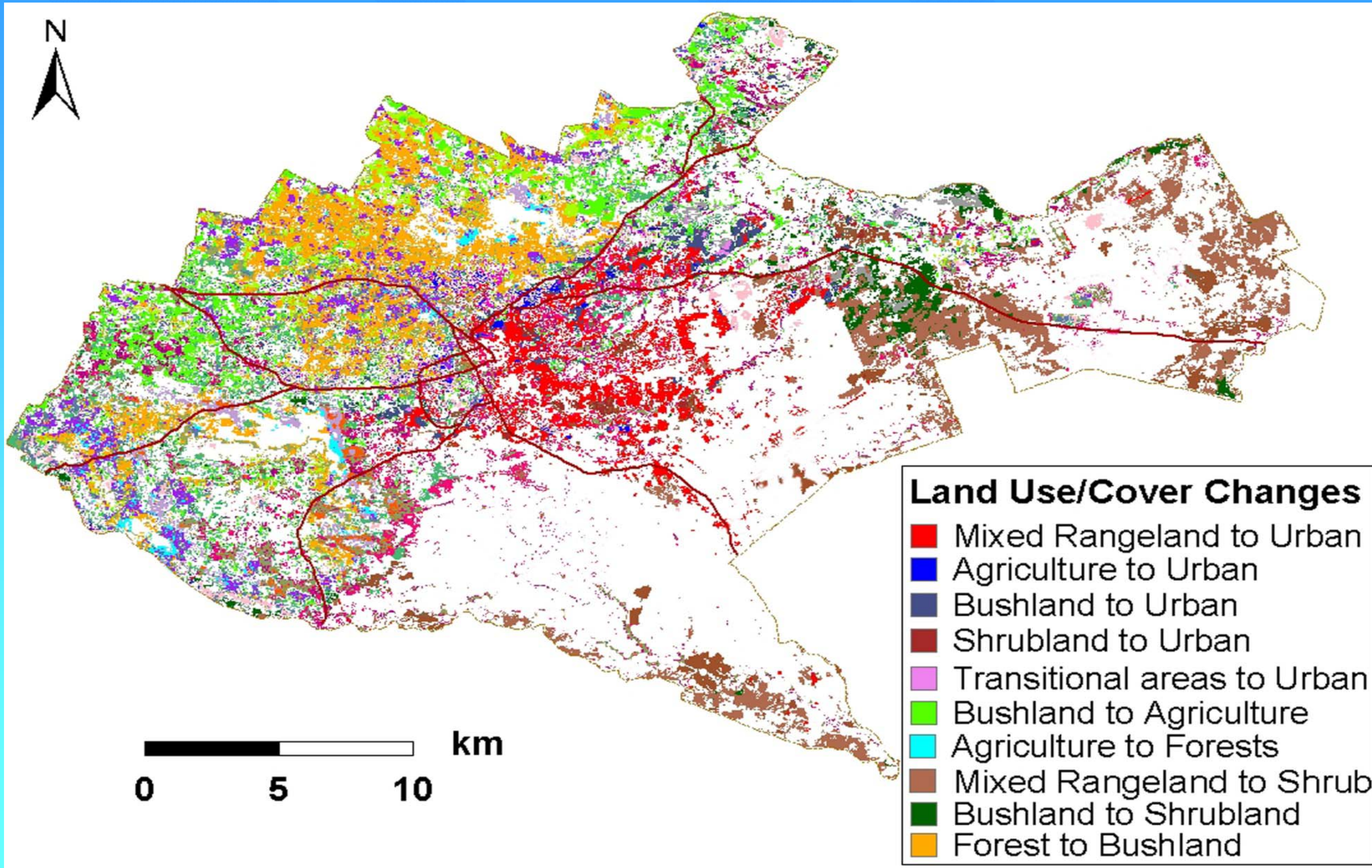
Trends in Land Use/Cover



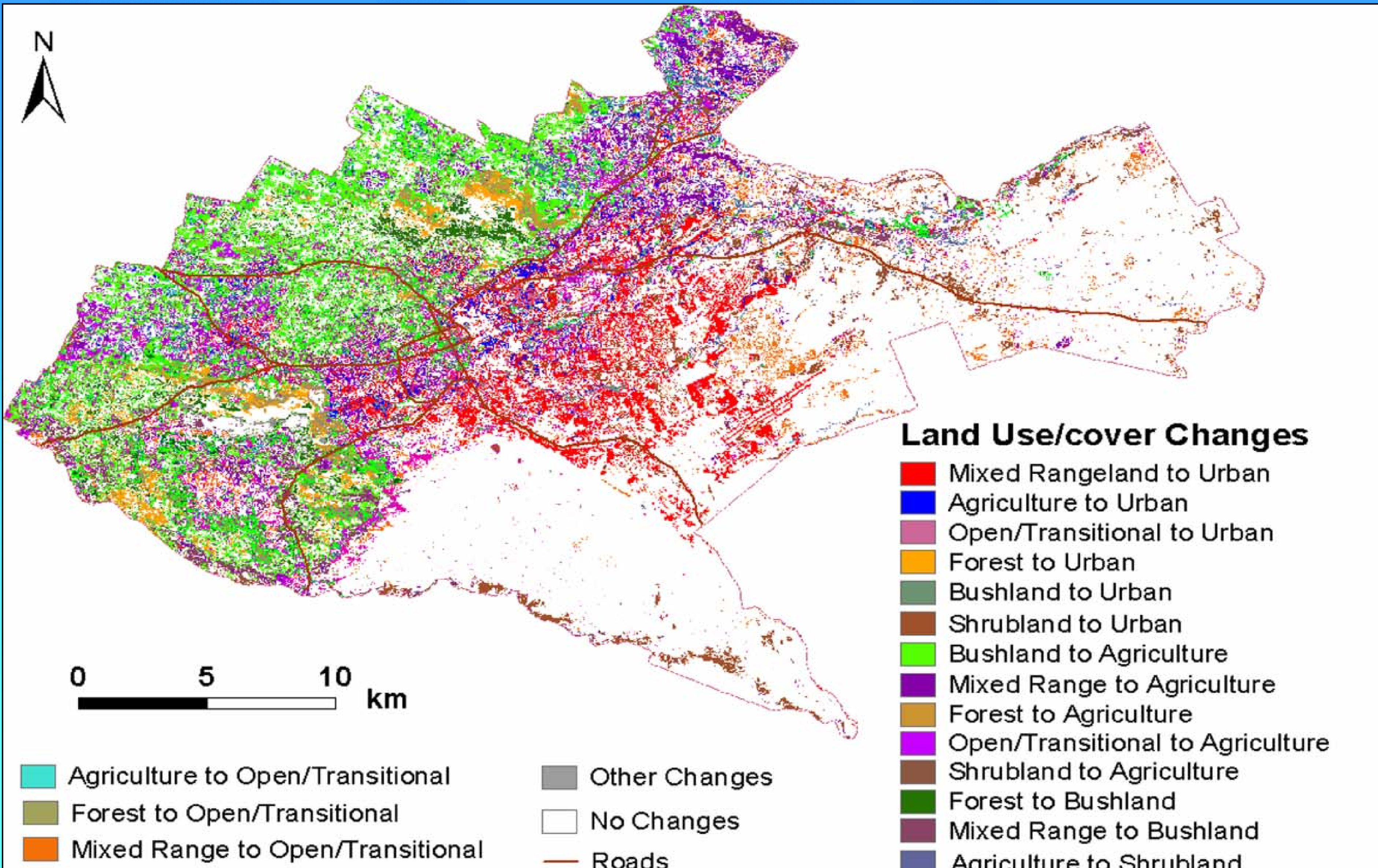
Statistics in Land Use/Cover Changes

Year	1976		1988		2000	
Land Use/cover	Area (km^2)	%	Area (Km^2)	%	Area (Km2)	%
Urban	13.99	1.9	41.18	5.8	61.23	8.6
Agriculture	49.83	6.9	57.83	8.1	87.78	12.3
Forests	100.15	14.0	29.09	4.1	23.56	3.3
Bushlands	154.48	22.3	101.49	14.2	95.98	13.5
Mixed rangelands	357.32	50.1	340.62	47.7	237.63	33.3
Shrub/Brush range	25.22	3.5	64.19	8.9	170.78	23.9
Open/Transitional	6.92	0.9	77.96	10.9	32.72	4.6
Water	0.50	0.1	1.09	0.2	3.77	0.5
Total	713.41	100.0	713.44	100.0	713.45	100.0

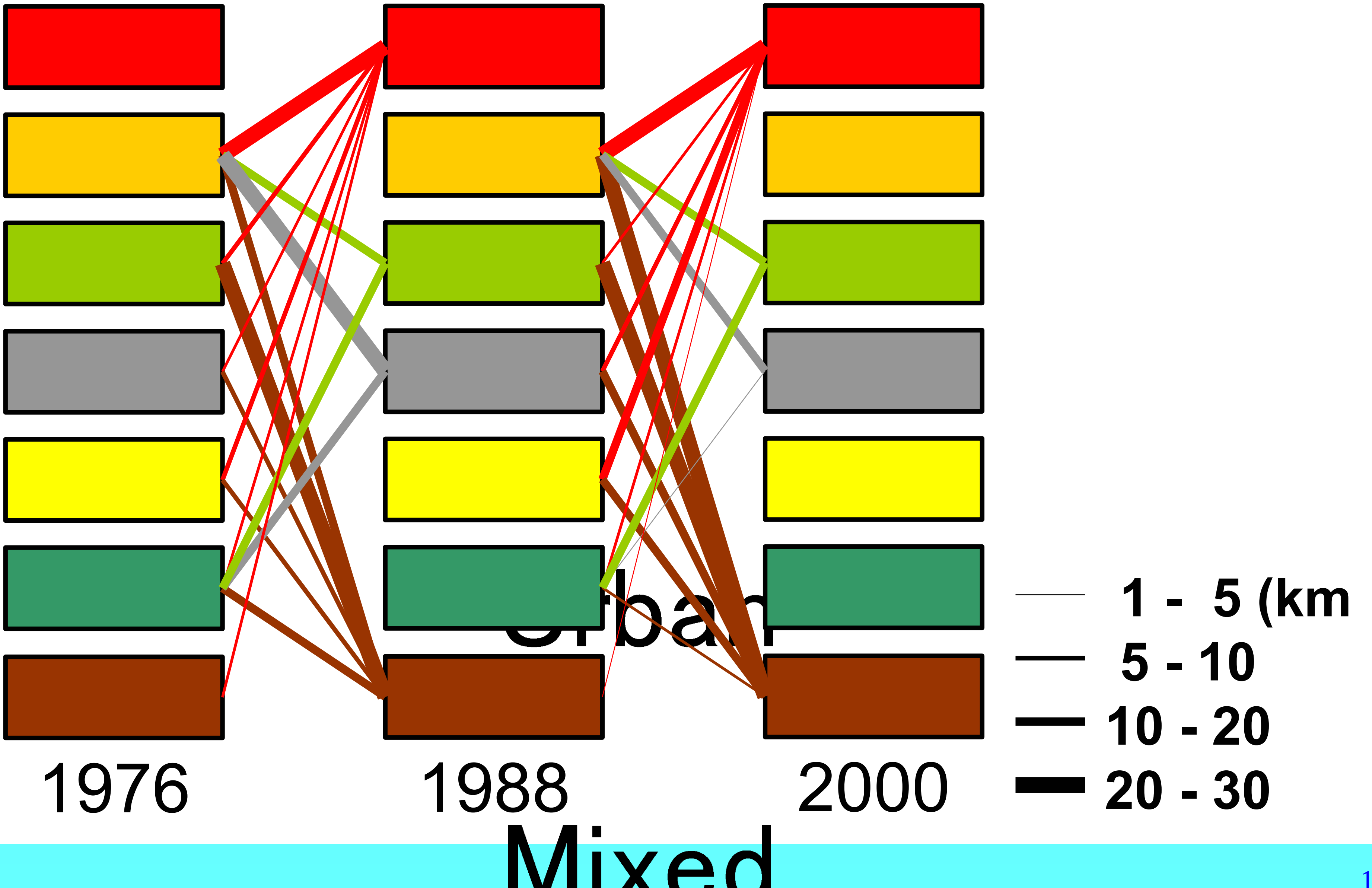
Major Land Use/Cover Conversions 1976-1988



Major Land Use/Cover Conversions 1988-2000



Land Use/Cover Conversion Trends



Land Use/Cover Conversions

"From"	"To"	1976-1988 (km^2)	1988-2000 (km^2)
Mixed Rangeland	Urban	22.00	29.61
	Agriculture	10.90	22.01
	Bush Land	12.98	16.48
	Transitional	27.95	16.67
Bush Land	Urban	8.40	3.65
	Agriculture	24.20	21.53
Transitional	Urban	4.38	8.56
	Agriculture	6.34	19.34
Shrub/Bush range	Urban	8.61	11.27
	Agriculture	7.90	10.38
Forest	Urban	4.03	2.75
	Agriculture	12.99	4.99
	Transition	13.95	1.02
	Bush Land	13.38	10.06
Agriculture	Urban	2.07	3.76

Modeling Nairobi's urban growth using Cellular Automata

Urban Modelling with Clarke CA Model

General formula for cell states in Cellular Automata (CA) Model

$$S_{t+1} = f\,(S_t\ \Omega_t\ TP)$$

Where : S_{t+1} is cell's state ,Ω_t ,neighbourhood and, TP transition potential

$$^{t}TP_{u,x,y} = (1 + {}^{t}A_{r,u,x,y})\,(1 + S_{u,x,y}) \times (1 + {}^{t}Z_{u,x,y})\,({}^{t}N_{u,x,y})\,{}^{t}\nu$$

Where,

$Tp_{u,x,y}$ is the CA transition potential of cell (x, y) for land use u at time t

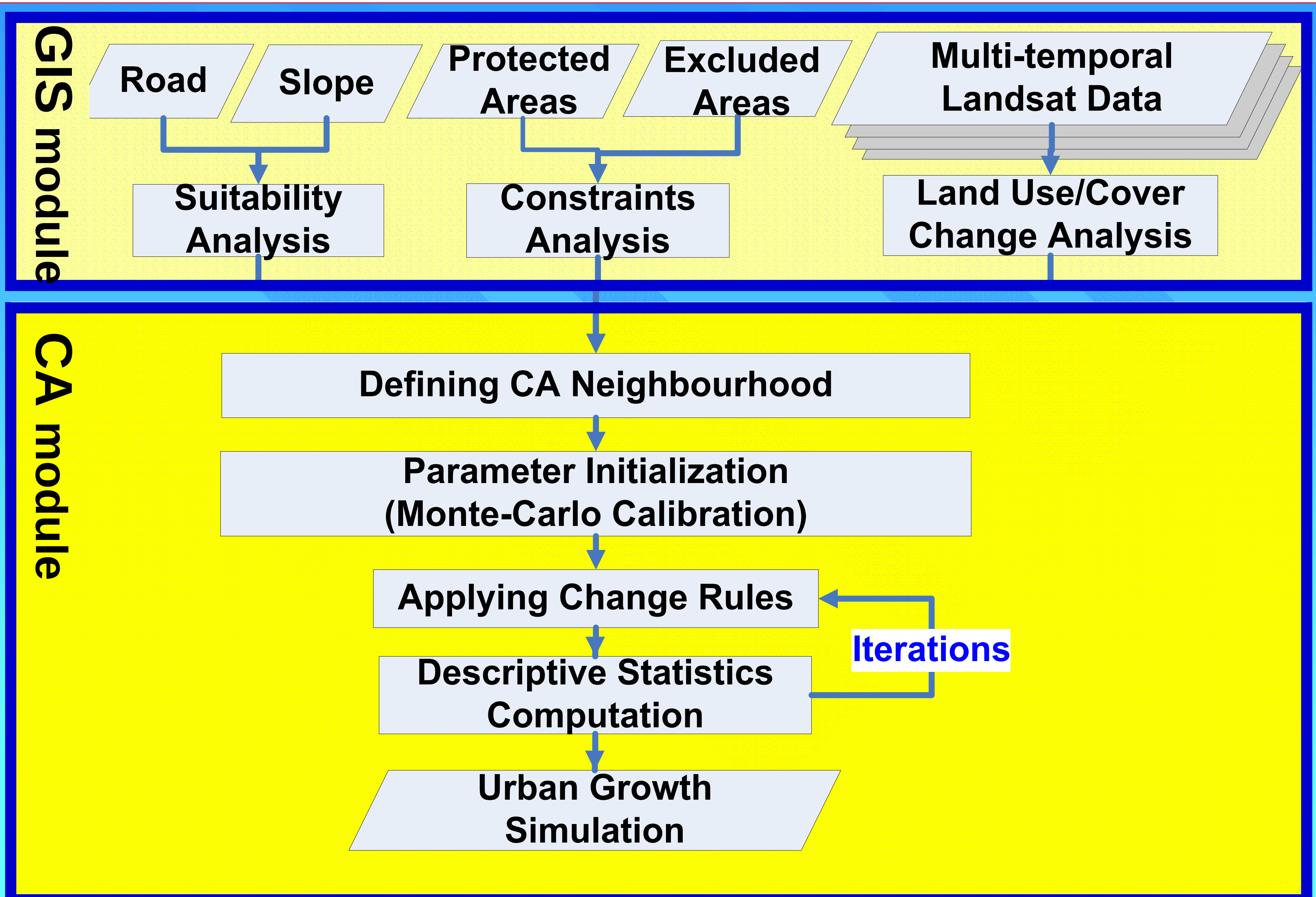
$t\,A_{r,u,x,y}$ is the accessibility of cell (x, y)

$S_{u,x,y}$ is the suitability of cell x, y for land use u

$t\,Z_{u,x,y}$ is the zoning status

ν Is the scalable random perturbation

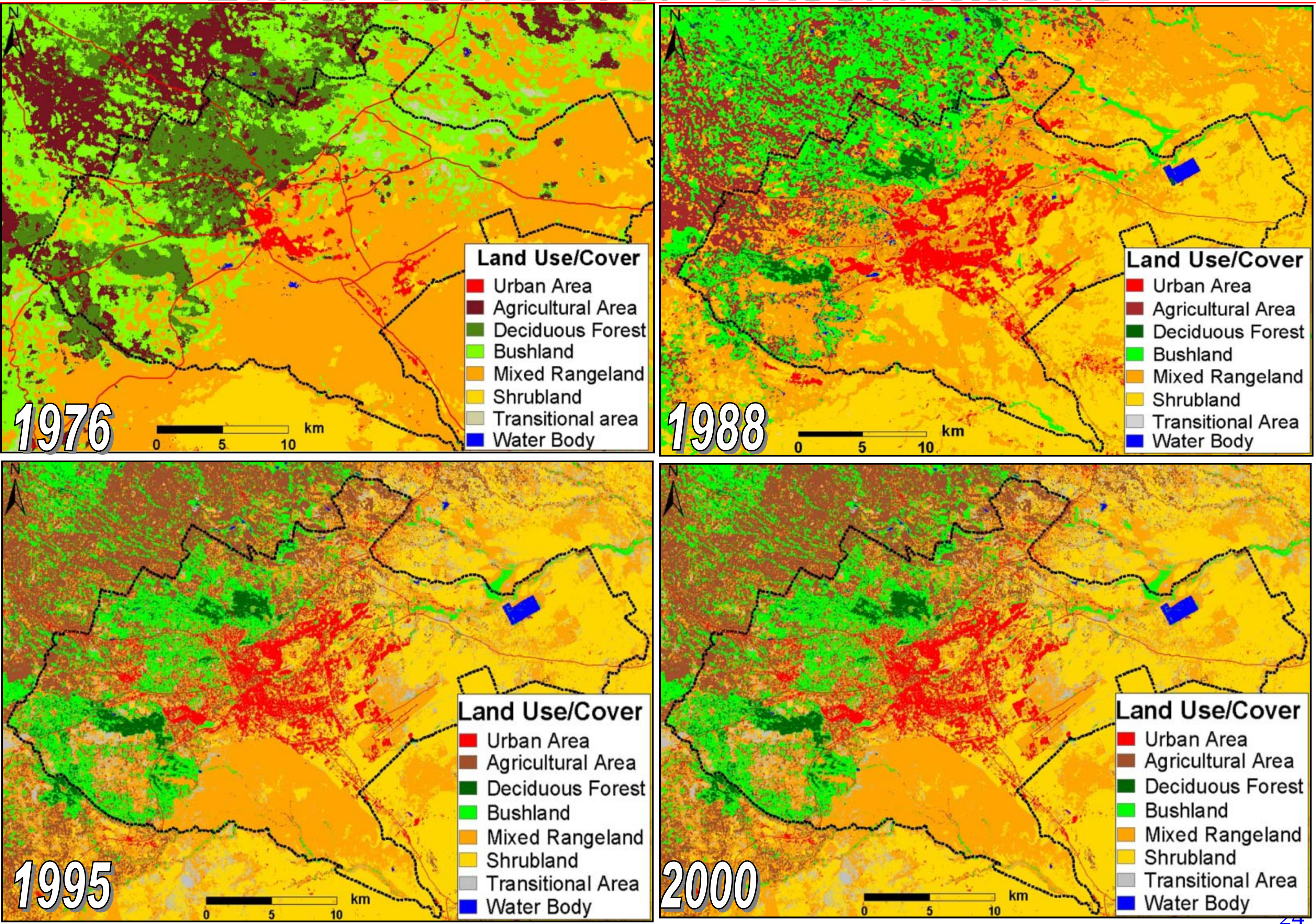
Model Framework



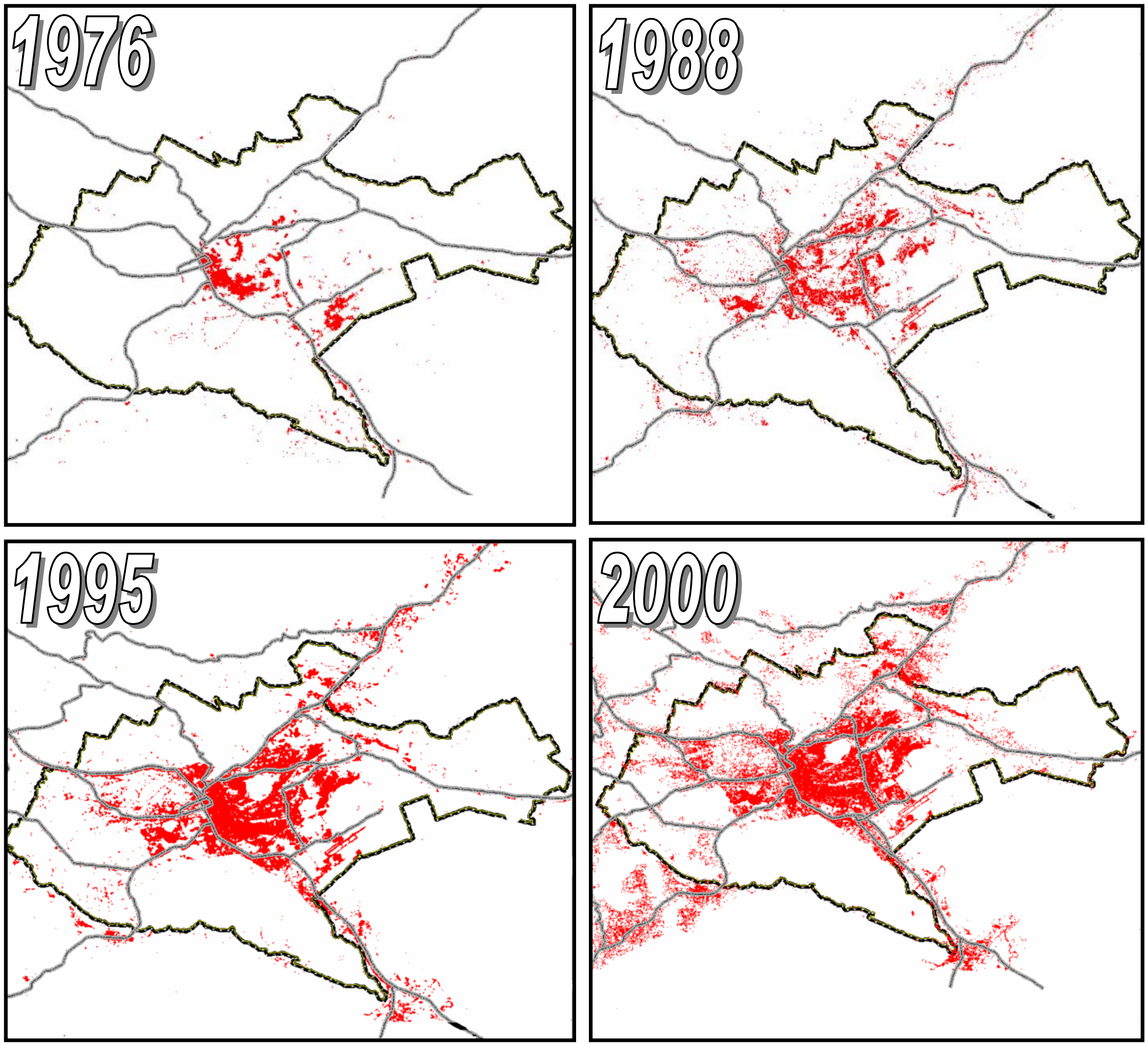
Data for Model Building

Data	Source
Land use/cover (Urban Extent)	Landsat Images (1976,1988,1995,2000)
Slope	1:50,000 Topographic Map
Excluded Areas	1:50,000 Topographic Map
Roads	Road map (1976,1988)
Hillshade	*1:50,000 Topographic Map*
Population	*Population census*
GDP	*Economic Survey*
Etc.	

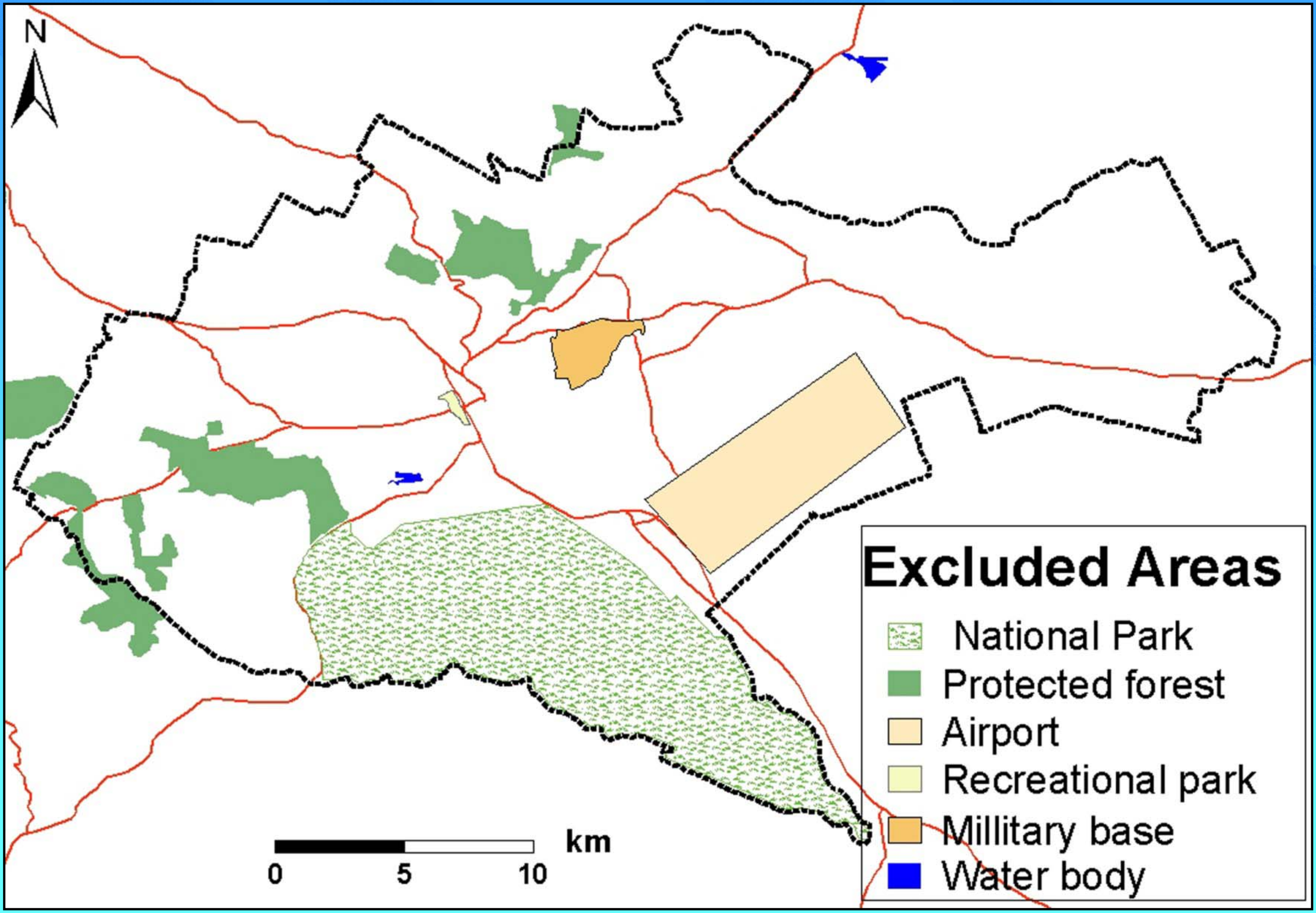
Land Use/Cover Classifications



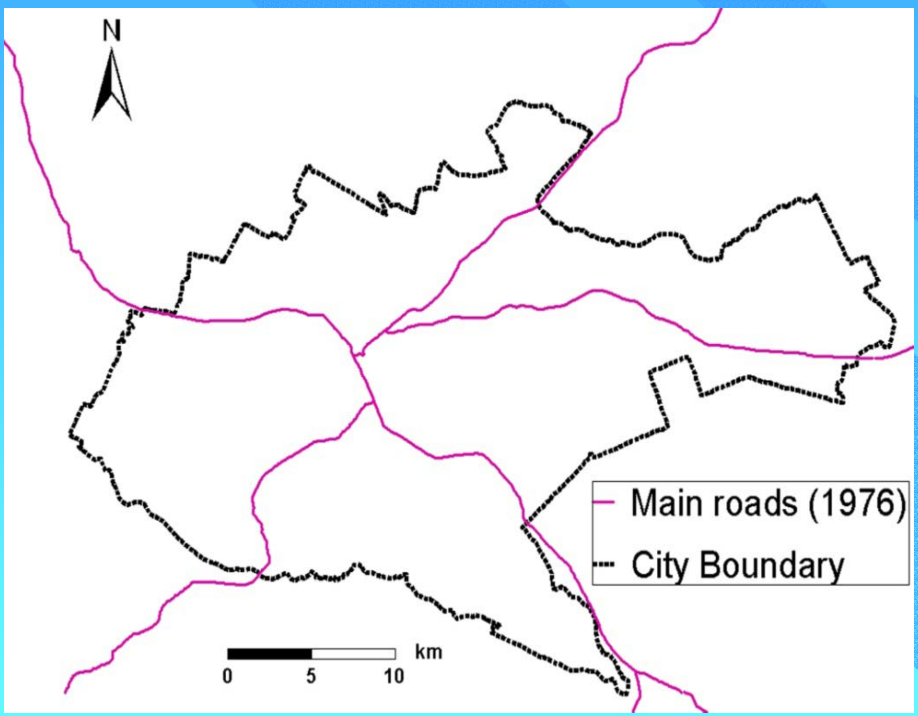
Urban Extents



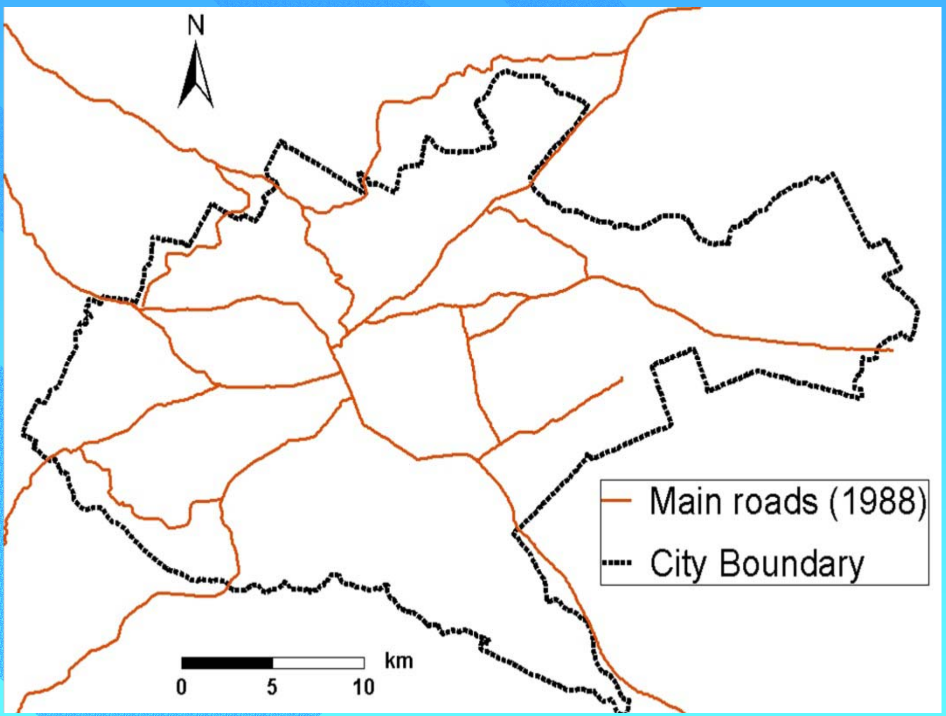
Areas Excluded From Urban Growth



Network of Main Roads

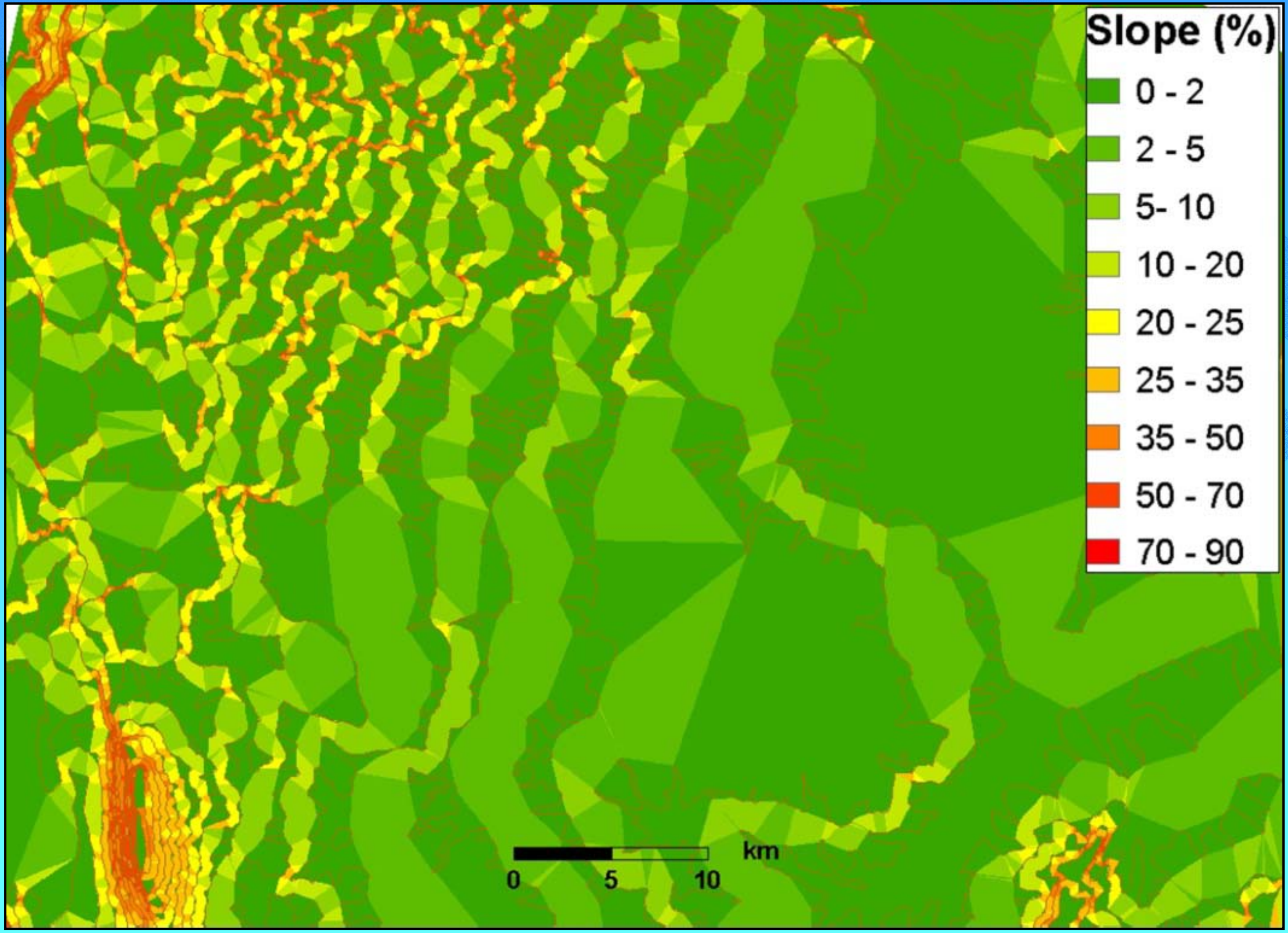


1976

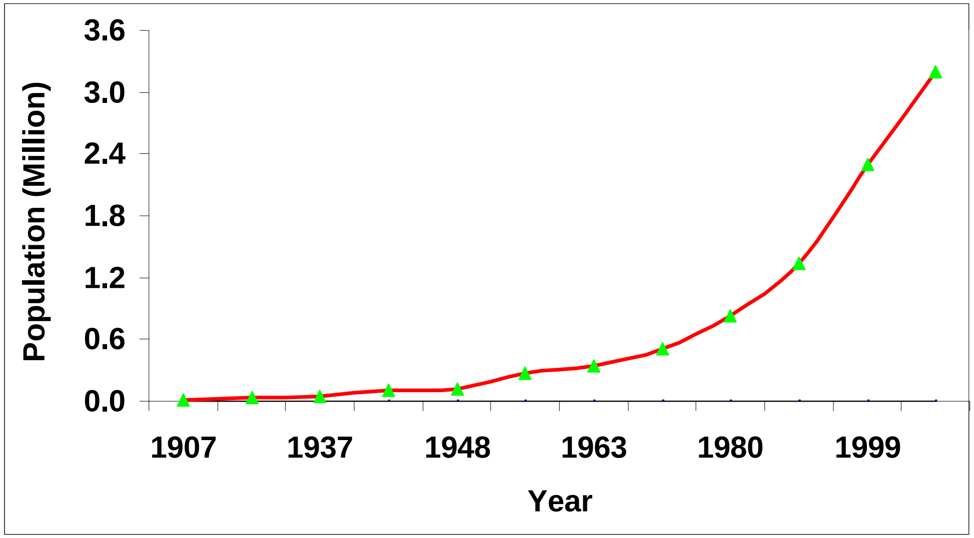


1988

Slope

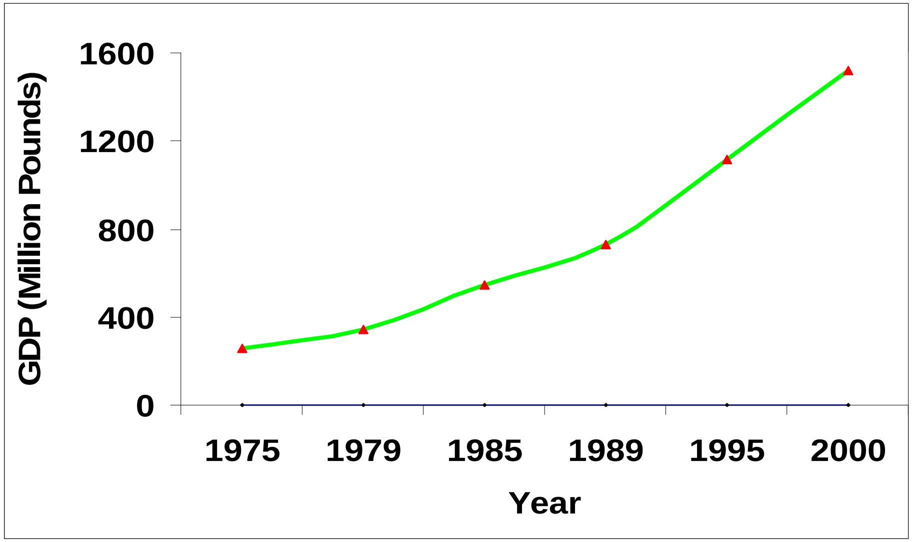


Socio-economics



Population in Nairobi

Source: Population census

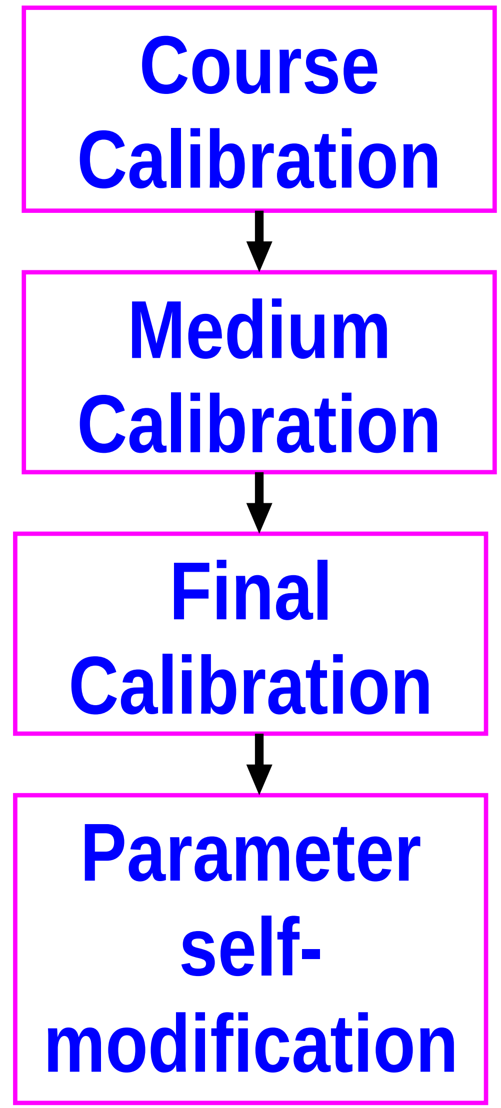


Nairobi's GDP values

Source: Economic surveys

Model Calibration

- ✓ Control data used to identify growth parameters through Monte Carlo iterations
- ✓ Sequential multi-stage reduction (Brute Force Calibration)



Model parameters and Growth Types

Model Parameters

Diffusion

Breed

Spread

Road gravity

Slope resistance

Model Growth Types

Spontaneous growth

New spreading center growth

Edge growth

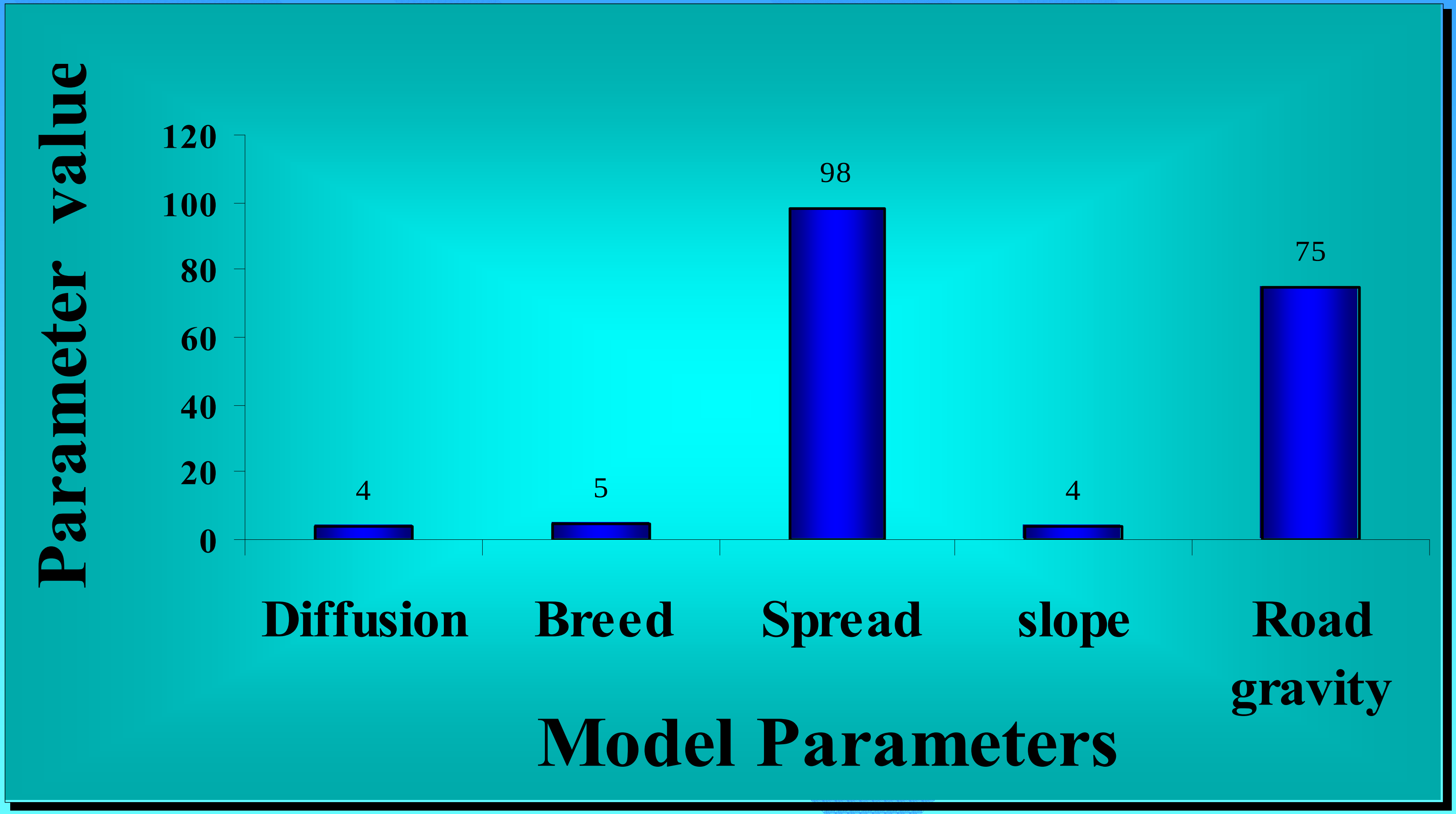
Road-influenced growth

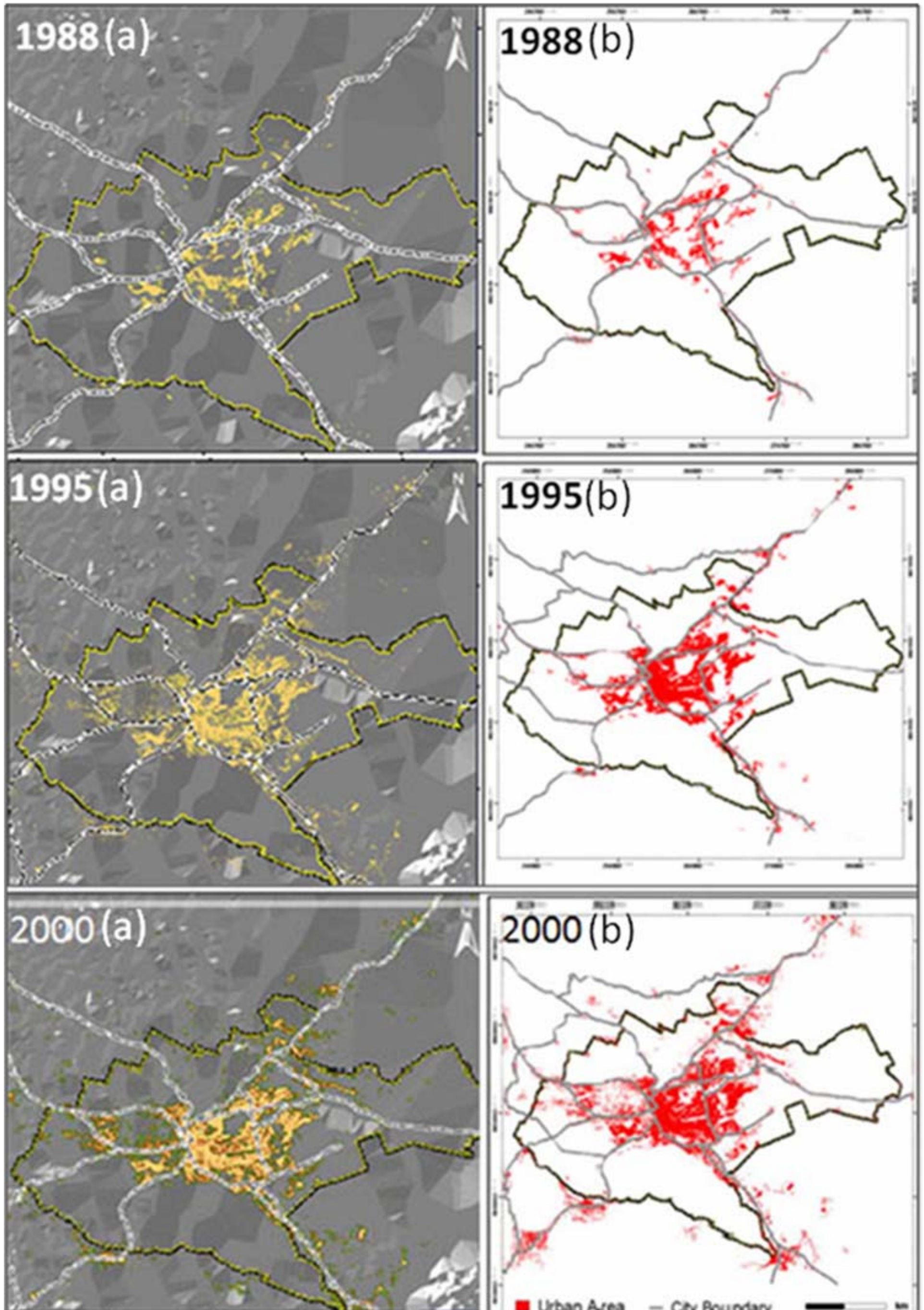
Growth on Slope

Best Overall Calibration Coefficients

Cluster r^2	0.90
Edges	0.89
Population (urban pixels) r^2	0.86
Compare	0.99
LeeSallee	0.40
Diffusion	4
Breed	5
Spread	**98**
Slope	4
Road gravity	**75**

Final Model Parameters





Accuracy assessment

(a) Model results

(b) Actual (from Satellite data)

Accuracy Assessment

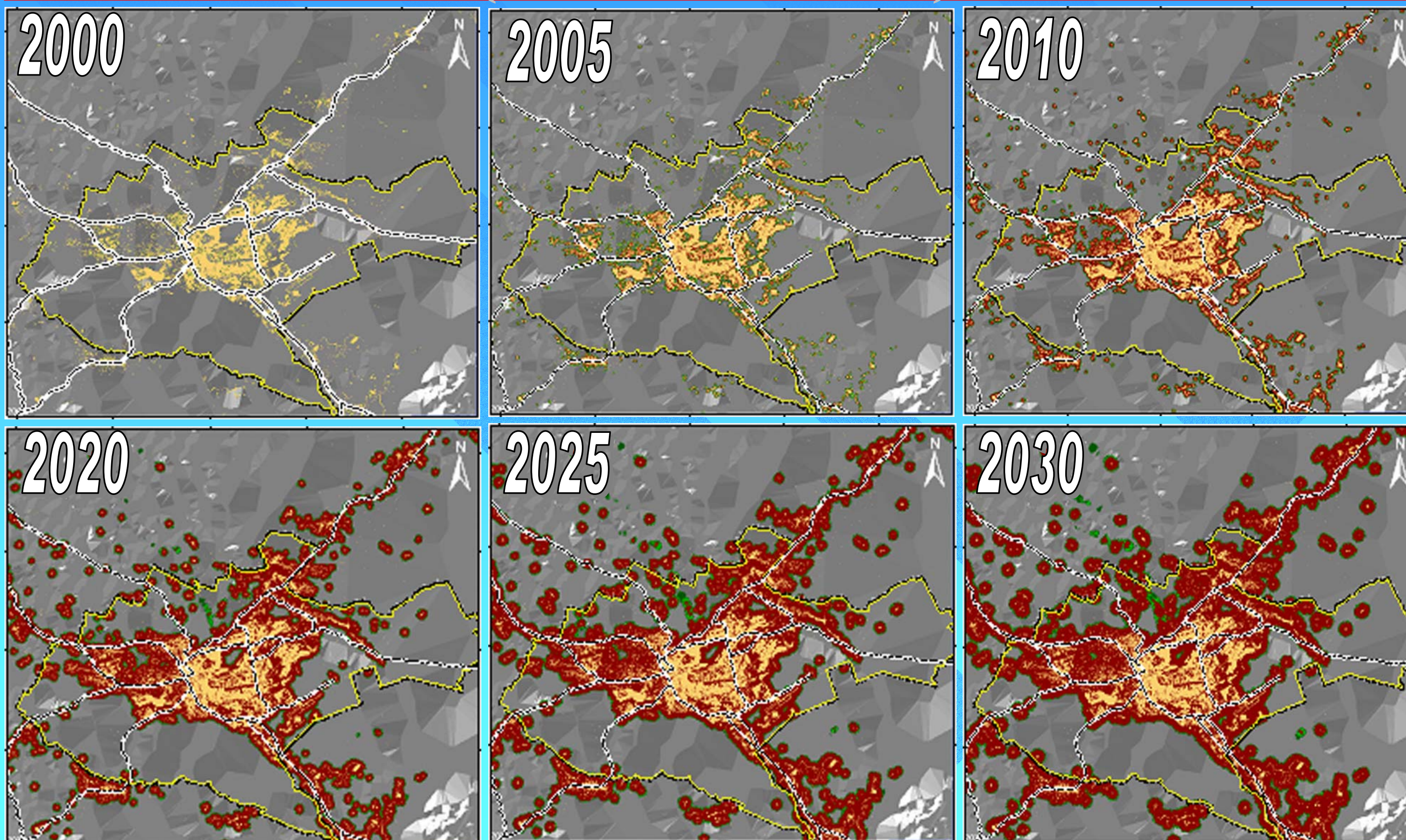
Year 1995

Class Name	Producer's Accuracy (omission)	User's Accuracy (commission)
Urban	47.2 %	**69.6 %**
Non-Urban	95.4 %	79.9 %
Overall Accuracy = **80.0%, Overall κ = 0.81**		

Year 2000

Class Name	Producer's Accuracy	User's Accuracy
Urban	45.2 %	**67.6 %**
Non-Urban	97.4 %	80.9 %
Overall Accuracy = **86.0%, Overall κ = 0.83**		

Simulated Urban Expansion (2000 – 2030)



Legend: Existing urban (2000) | Expanded Area | High urbanization Potential Area

Conclusions

- ✓ Substantial Land use/cover changes have taken place, with notable rapid urban expansion.
- ✓ CA based Simulated results show rapid urban growth of Nairobi by 2030
- ✓ CA modeling for policy scenarios is useful in planning and sustainable management of land resources.
- ✓ Simulated pattern of urban sprawl will have significant implications in policy making and urban planning

Further Research

Modeling urban growth patterns in data-sparse environments: A new approach.

- **Simulation of spatial patterns**
- **Spatial-temporal processes**
- **Social economic variables**

Spatial logistic regression + Marcov Chain ?

Thank You.

Summary of Growth types simulated by model

Growth cycle order	Growth type	Controlling Coefficient	Summary description
1.	Spontaneous	dispersion	Randomly selects potential new growth cells
2.	New spreading	breed	Growing urban centers from spontaneous growth
3.	Edge	spread	Old or new urban centers spawns additional growth
4.	Road-influenced	road gravity	Newly urbanized cell spawns growth along transportation network.
Throughout	Slope resistance	slope	Effect of slope on reducing urbanization
Throughout	Excluded layer	user-defined	Areas resistant or excluded to development specified

Simulation Flow