Evaluating Land Use Land Cover Change Effect on Streamflow Dynamics in the Gaborone Dam Catchment, Botswana

Presentation by

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WaterNet Symposium 2020

Date: 28-30 October 2020

Value of the Study to WeMAST Project

a. Exploration of free EO data in wetland assessment and monitoring;
b. Explore application of a semi-distributed hydrological model (SWAT) to inform policy and decision making to promote sustainable management of wetlands;
c. Gather in-situ LULC data upper Limpopo river basin and (LULC change implications on streamflows)
d. Explore free high spatial and temporal climate data for use in hydrological modelling

MODELLING PAST AND FUTURE LAND USE LAND COVER CHANGES IN THE GABORONE DAM CATCHMENT, UPPER LIMPOPO RIVER BASIN USING CA-MARKOV MODEL

Motivation of study

- Land use and land cover (LULC) change is considered a major global environmental challenge driving various environmental changes at all spatial and temporal scales (Behera et al. 2012; Gashaw et al., 2017)

- Driven by both biophysical and anthropogenic factors (Lambin et al, 2001)

- LULC changes have implications on essential parts of the natural capital for example; vegetation, water resources and biodiversity (Behera et al, 2012) and human life (Islam and Ahmed, 2011).

- LULC changes have potential impacts that manifest in climatological, hydrological and biodiversity responses

- Therefore, LULC change is a key factor affecting Water resources through modification of flow regimes and water availability

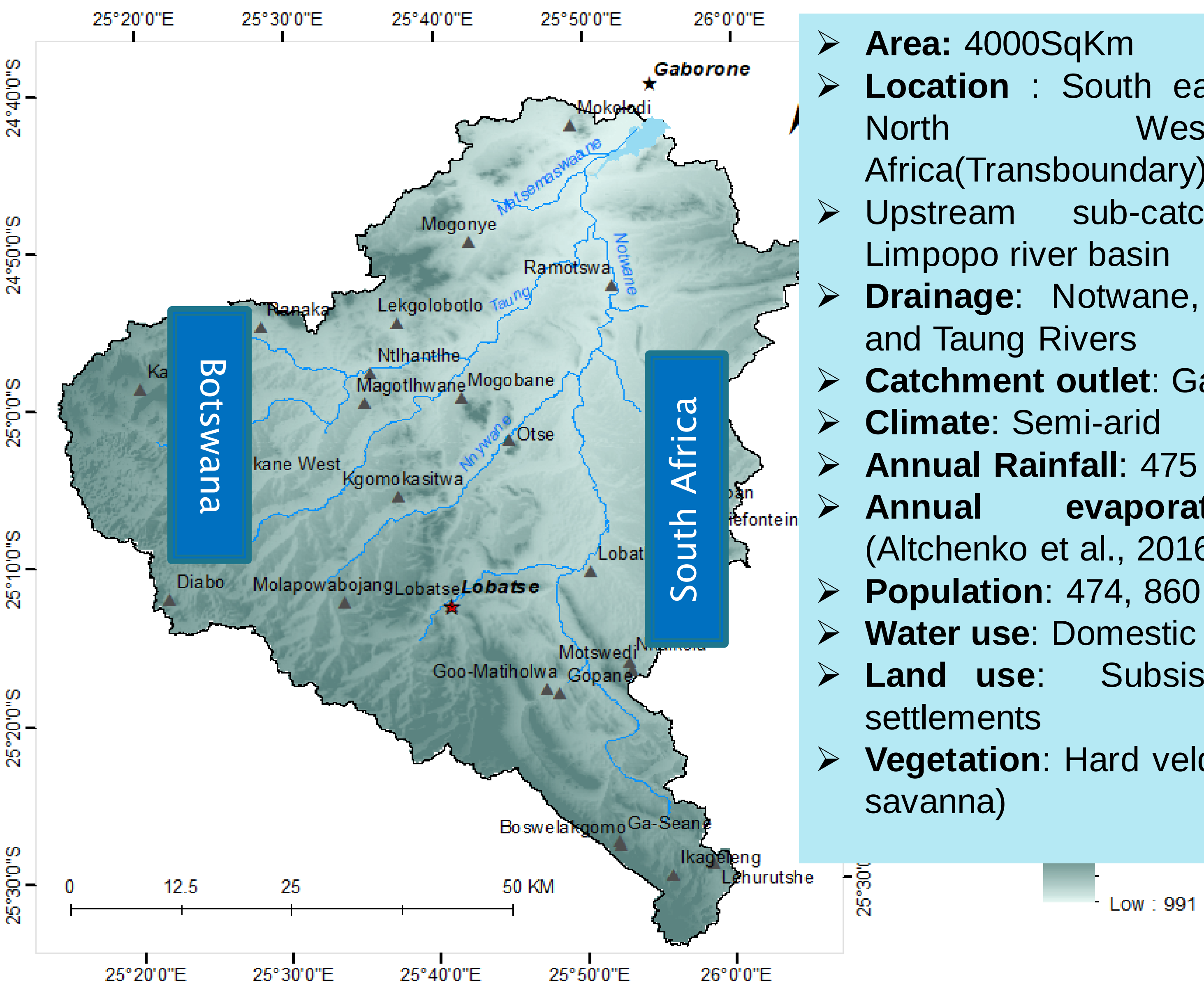
Background to the study

- Gaborone dam catchment:
  - Major water source to Gaborone city
  - Experiencing fluctuating water levels
  - Farmland expansion, urbanization and small dam's upstream attributed to fluctuating water levels

- LULC data unavailable for the catchment

- Hydro-meteorological observations are spatially and temporally sparse, limiting the application of physically based hydrological models in assessing catchment responses.

Study Area



- **Area:** 4000SqKm
- **Location** : South east Botswana and North West South Africa(Transboundary)
- Upstream sub-catchment of the Limpopo river basin
- **Drainage**: Notwane, Metsemaswaane and Taung Rivers
- **Catchment outlet**: Gaborone dam
- **Climate**: Semi-arid
- **Annual Rainfall**: 475 to 525 mm
- **Annual evaporation**: 2000mm (Altchenko et al., 2016).
- **Population**: 474, 860 (Botswana side)
- **Water use**: Domestic water supply
- **Land use**: Subsistence agriculture, settlements
- **Vegetation**: Hard veldt (Tree and shrub savanna)

Methodology

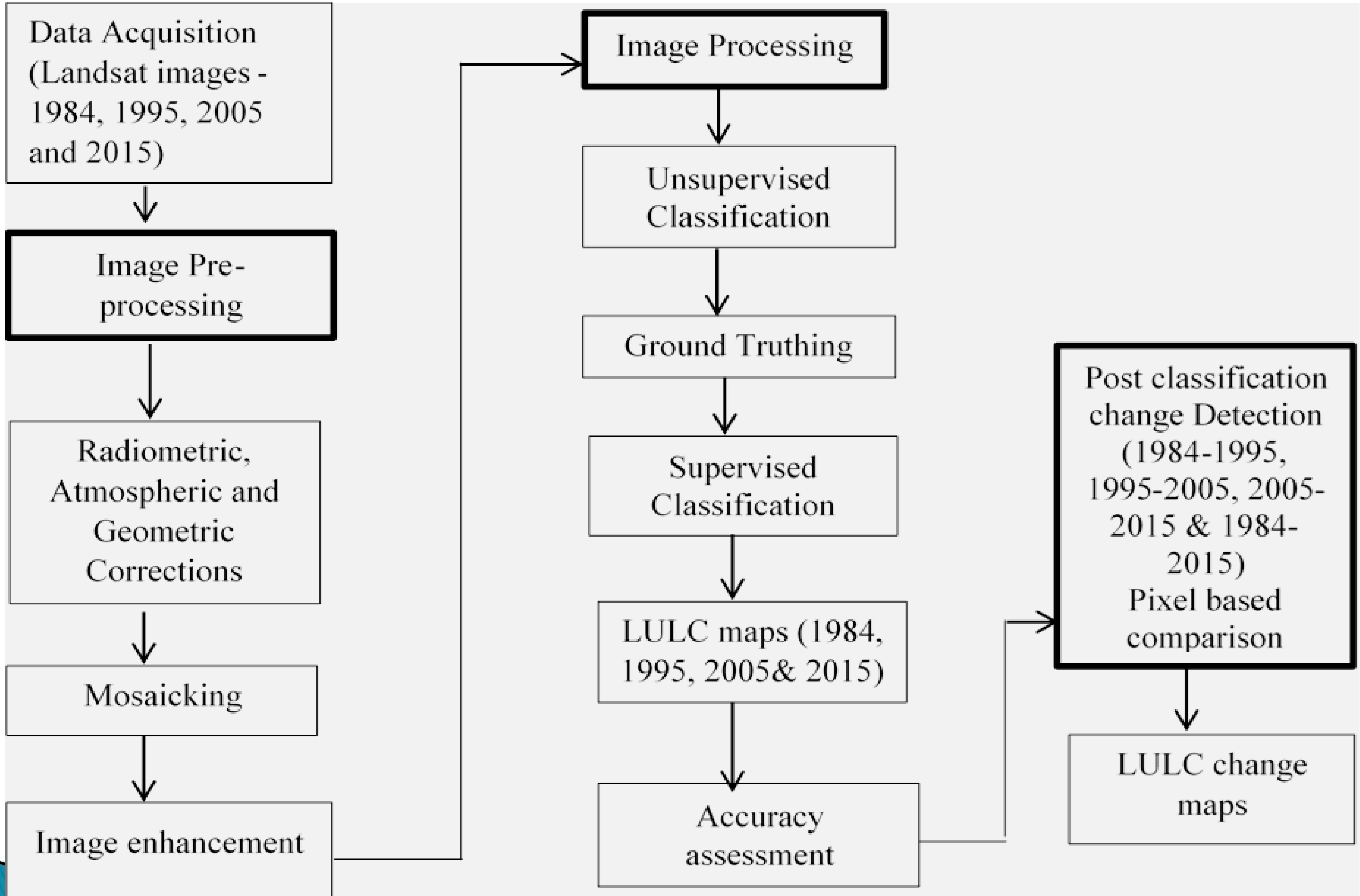


Figure 1: Summarised LULC change analysis methods

Methodology

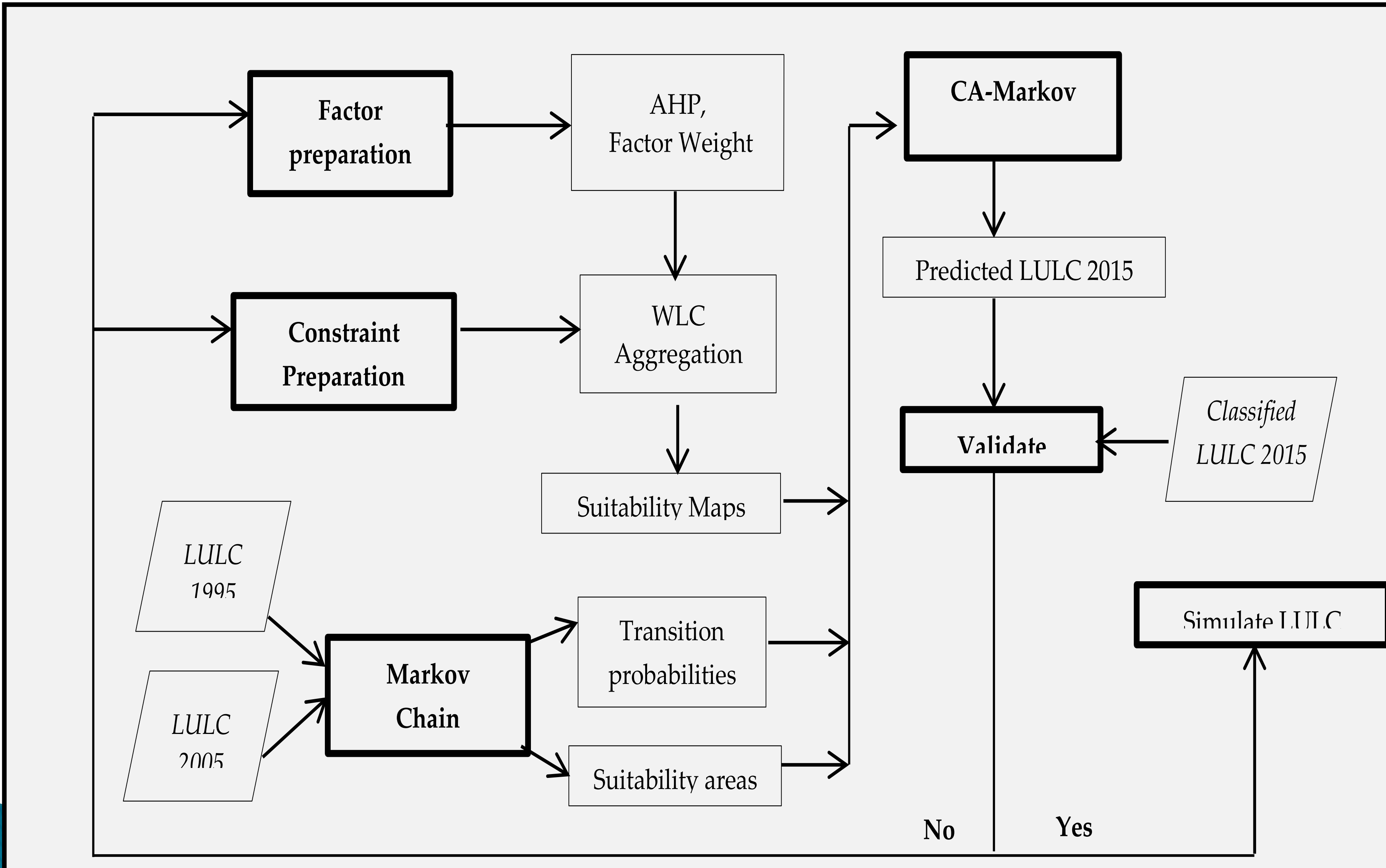
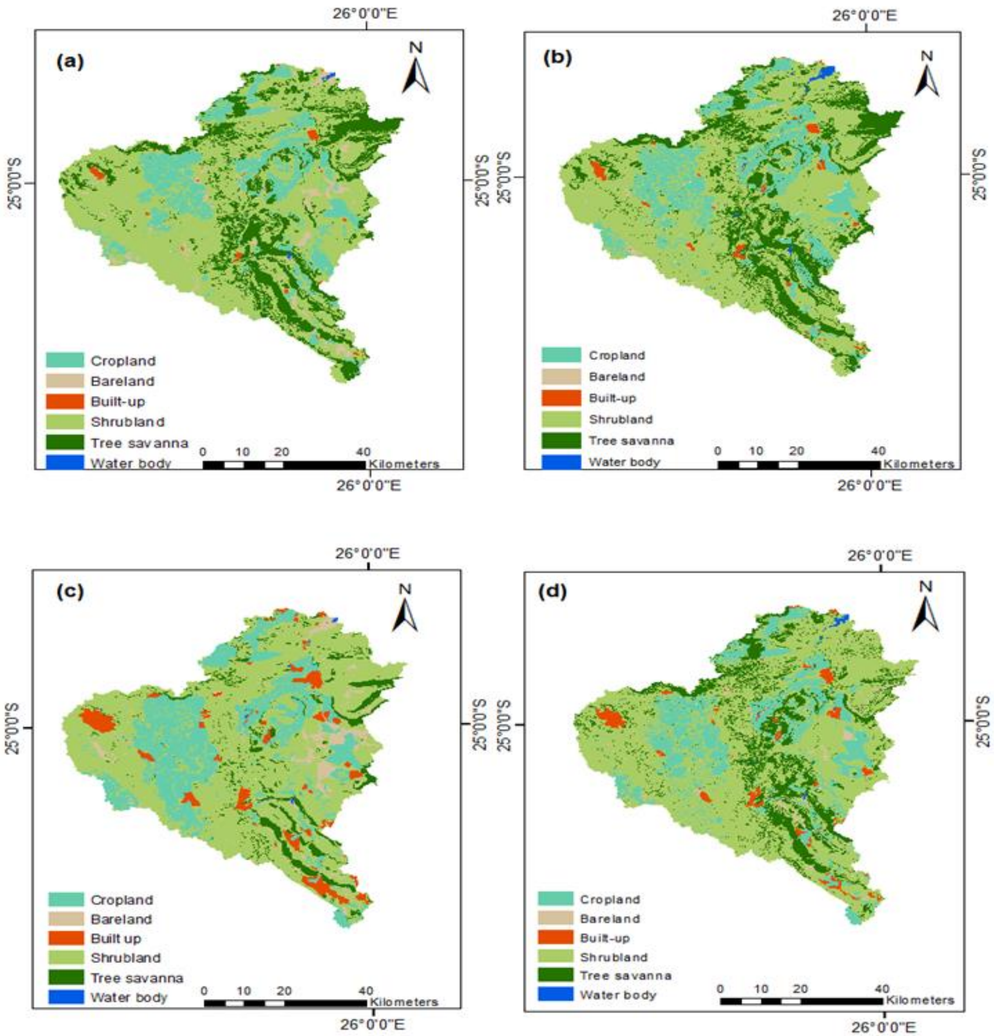


Figure 2: Summarized LULC change prediction methods

Results



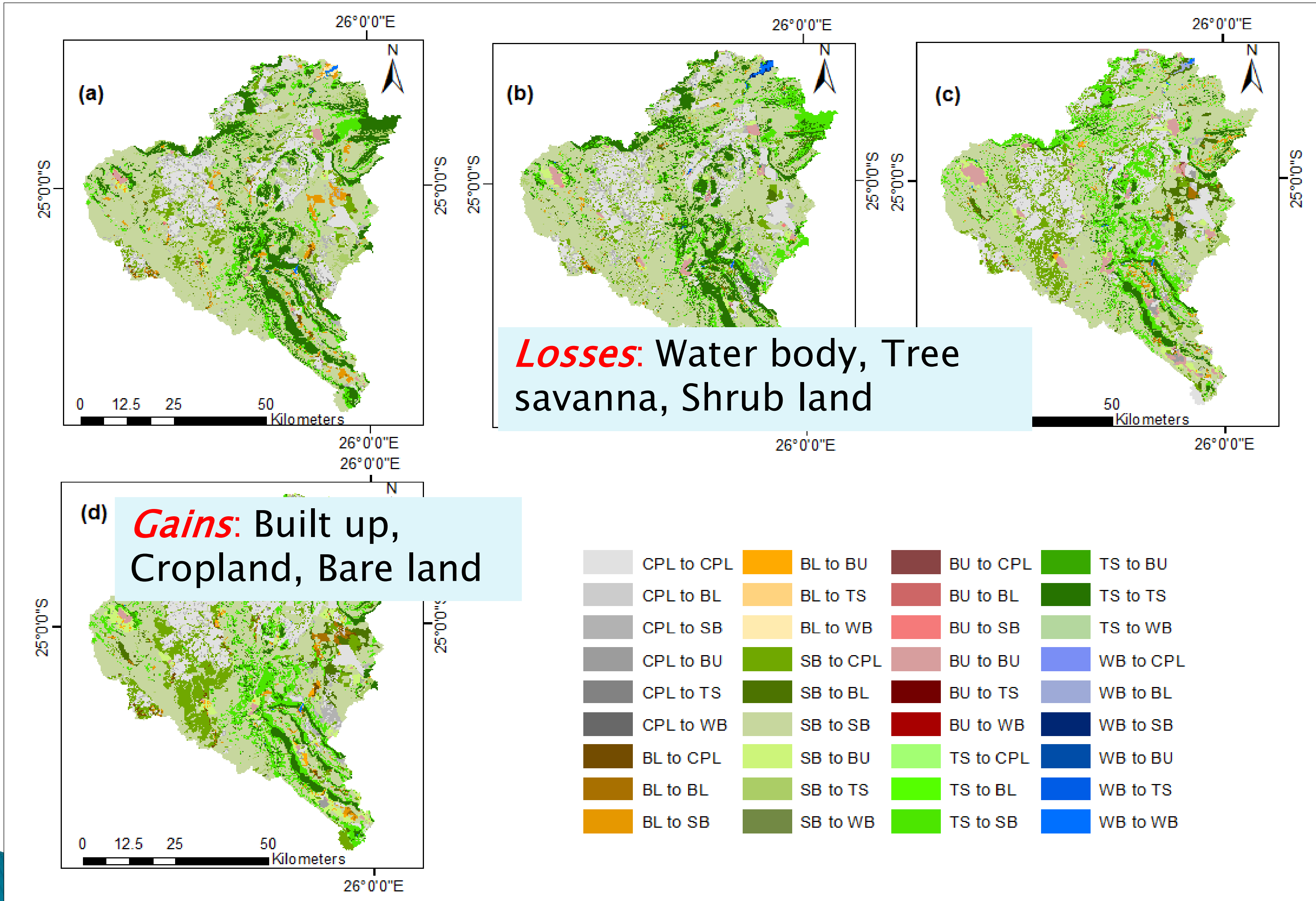
LULC categories: CPL: Cropland, BL: Bare land, SB: Shrub land, BU: Built-up, TS: Tree savanna, WB: Water body

Cropland
built-up
bare land

Shrub
land,
Tree
savanna,
Water
body

Figure 3: LULC maps of 1984 (a), 1995 (b), 2015 (c) & 2005 (d)

LULC change Losses and Gains Analysis

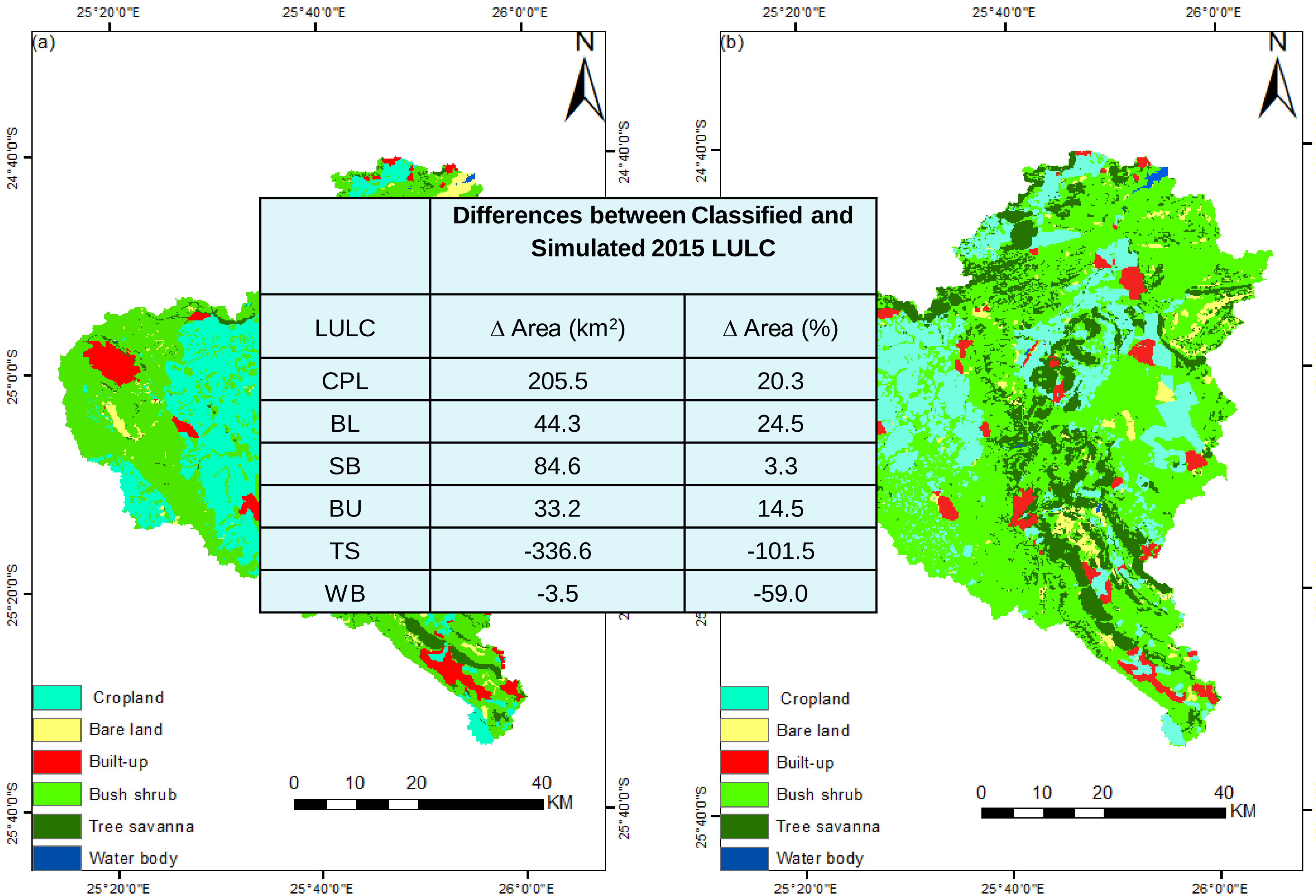


Losses: Water body, Tree savanna, Shrub land

Gains: Built up, Cropland, Bare land

Figure 4: LULC loss and gains from (a) 1984 to 1995; (b) 1995 to 2005 (c) 2005 to 2015 and (d) 1984 to 2015

LULC change Prediction



	Differences between Classified and Simulated 2015 LULC	
LULC	Δ Area (km^2)	Δ Area (%)
CPL	205.5	20.3
BL	44.3	24.5
SB	84.6	3.3
BU	33.2	14.5
TS	-336.6	-101.5
WB	-3.5	-59.0

Figure 5: Classified LULC 2015 (a) & Simulate LULC 2015 (b)

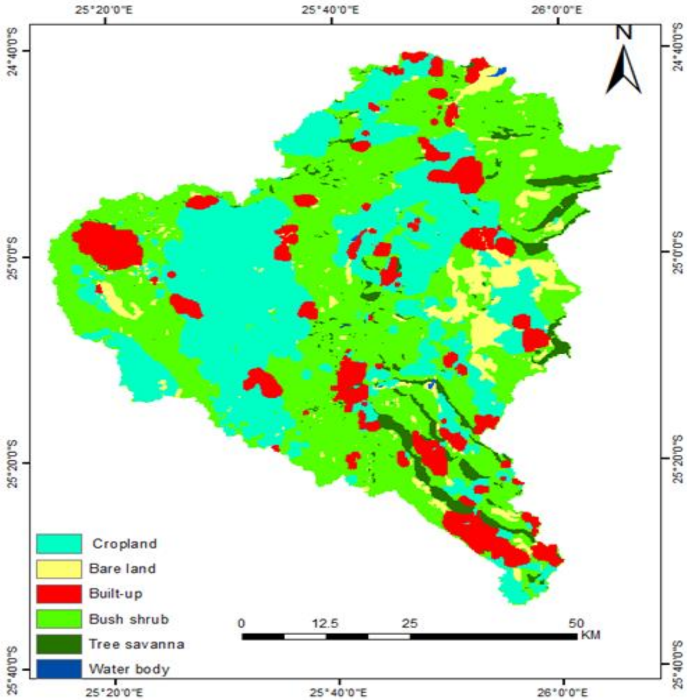
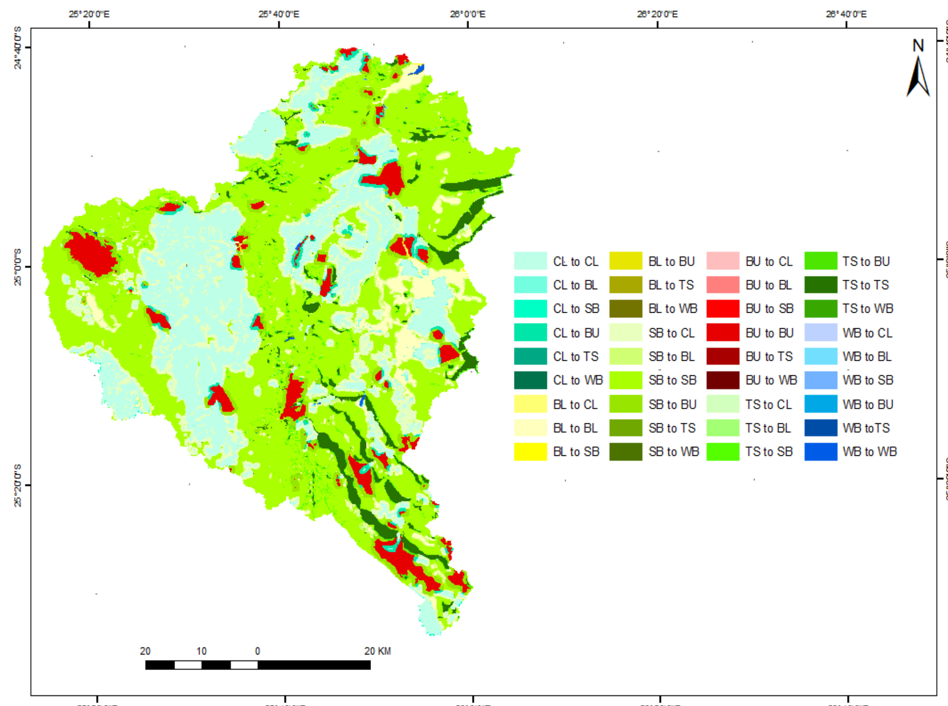


Figure 6: Simulated LULC 2035

	LULC Dynamics between 2015-2035			
LULC Type	Area (km^2)	Area (%)	Annual Change rate in km^2	%
CPL	410.1	40.6	20.5	2.0
BL	78	43.2	3.9	2.2
SB	-602	-23.2	-30.1	-1.2
BU	264.4	115.9	13.2	5.8
TS	-148.6	-44.8	-7.4	-2.2
WB	-1.69	-24.9	-0.1	-1.5

Cropland built-up bare land

Shrub land, Tree savanna, Water body



LULC change implications

a) Loss of quality forage leading to degradation
b) Water supply shortages
c) Changes in soil water holding capacity affecting groundwater recharge
d) Collapse of the ecosystem structure due to loss of indigenous woody species
e) Exacerbate climate extremes (floods and droughts)
f) Higher runoff rates resulting from vegetal cover loss, expansion of croplands and built-up areas
g) Increase in impervious surfaces- Urban heat islands and storm water increase
h) Alteration in rainfall-runoff response of the catchment

Way forward

- Test the applicability of a semi-distributed hydrological model (SWAT) in the GDC
- Explore high spatial and temporal climate data (ERA-Interim Reanalysis data)
- Evaluate LULC change effect on past and future streamflows

Publication:

- Matlhodi, B., Kenabatho, P. K., Parida, B. P., & Maphanyane, J. G. (2019). *Evaluating Land Use and Land Cover Change in the Gaborone Dam Catchment, Botswana, from 1984–2015 Using GIS and Remote Sensing*. Sustainability, 11(19), 5174.

References

- Behera, M., Borate, S. N., Panda, S. N., Behera, P. R., & Roy, P. S. (2012). Modelling and analyzing the watershed dynamics using Cellular Automata (CA)–Markov model–A geo-information based approach. *Journal of earth system science, 121*(4), 1011-1024

- Gashaw, T., Tulu, T., Argaw, M., & Worqlul, A. W. (2017). Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Environmental Systems Research, 6*(1), 17

- Lambin, E.F., B.L. Turner, H.J. Geist, S.B. Agbola, A. Angelsen, J.W. Bruce, O.T. Coomes, R. Dirzo, G. Fischer, C. Folke, P.S. George, K. Homewood, J. Imbernon, R. Leemans, X. Li, E.F. Moran, M. Mortimore, P.S. Ramakrishnan, J.F. Richards, H. Skånes, W. Steffen, G.D. Stone, U. Svedin, T.A. Veldkamp, C. Vogel, and J. Xu, *The causes of land-use and land-cover change: moving beyond the myths.* Global Environmental Change, 2001. **11**(4): p. 261-269

- Islam, M. S., & Ahmed, R. (2011). Land use change prediction in Dhaka city using GIS aided Markov chain modeling. *Journal of Life and Earth Science, 6*, 81-89.