Topic: The Impact of Land Use Change on Hydrological Ecosystem Services in the Tano River Basin, Ghana

By

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Outline of Presentation

1 Introduction

Background challenges Objectives

2 Methodology

Study area Methods

3 Results and Discussion

Summary and key findings

4 Conclusion

Introduction

Global Land Degradation (Human Footprint on the Earth's Ecosystems)

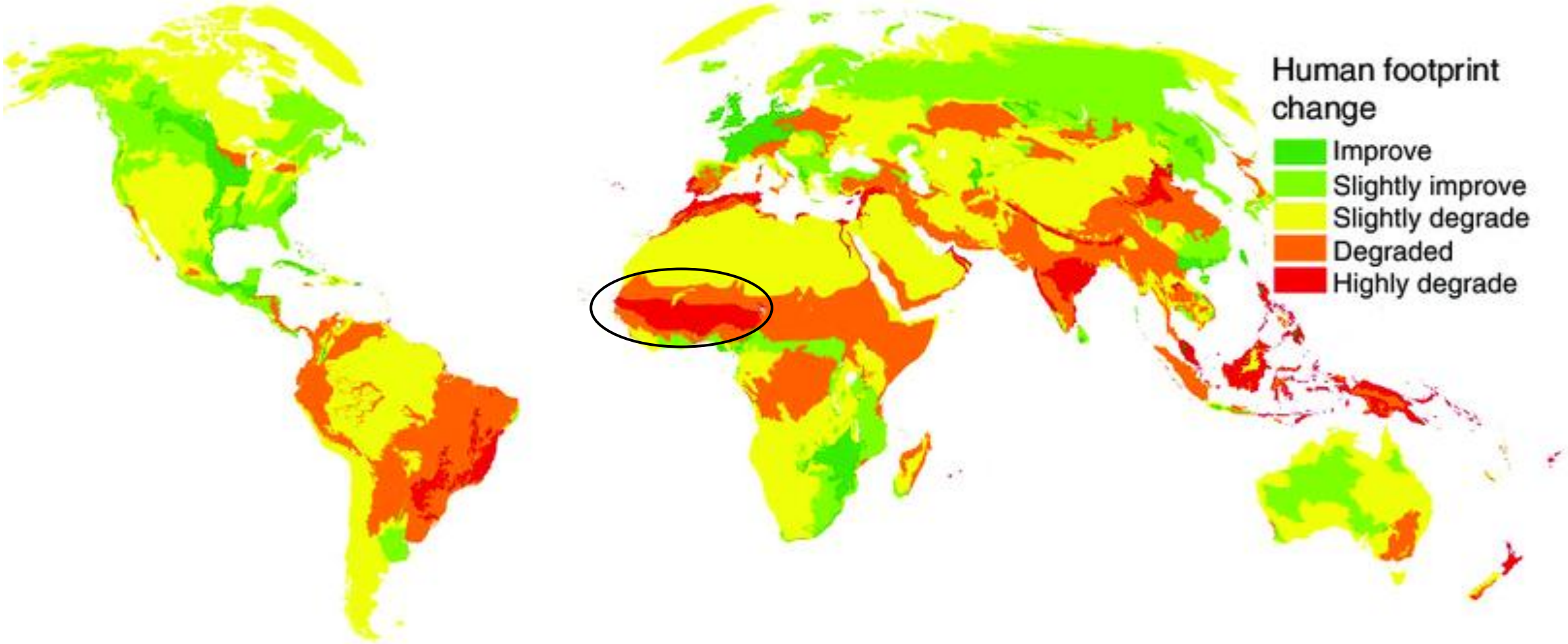
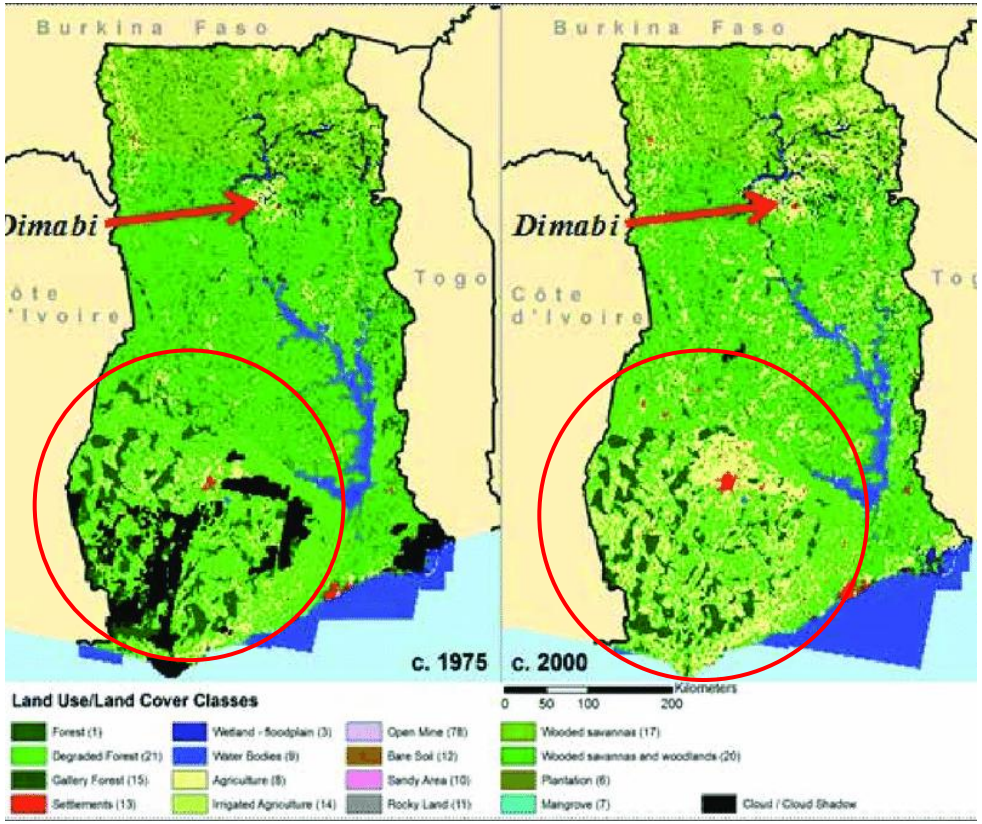


Figure 1: This map shows human impact on the environment, categorizing regions by the extent of alteration from improved to highly degraded areas over sixteen years from 1993 to 2009. (Source; Mason 2016)

Introduction

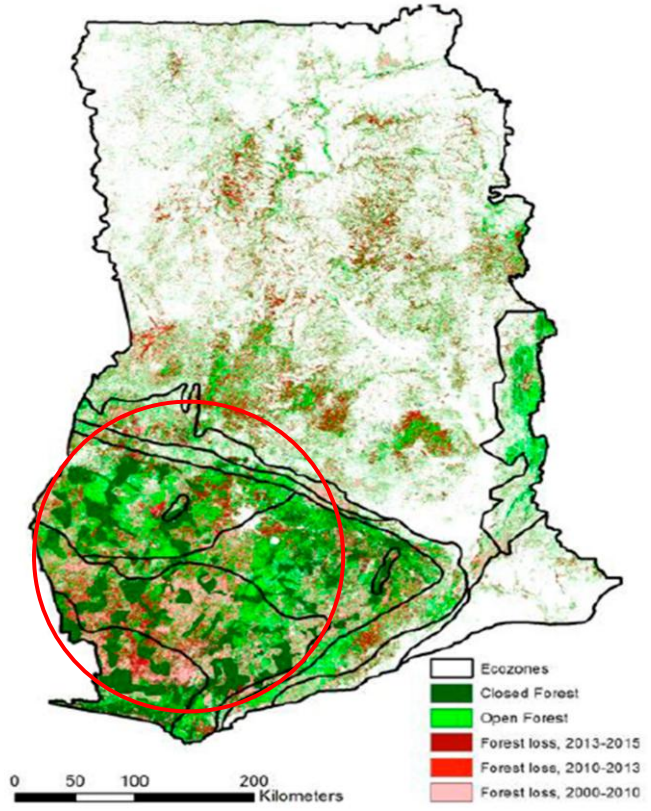
Humans impact on Land cover change in Ghana

1975 2000



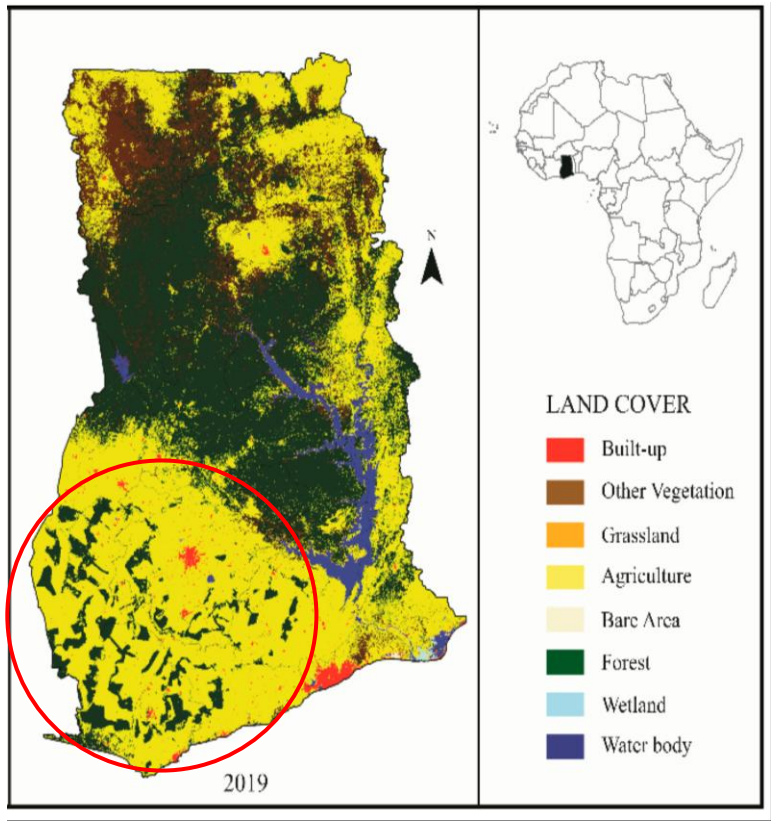
Land use and land use change in Ghana. Source: USGS (http://lca.usgs.gov/)

2000-2015



Kyere-Boateng and Marek 2021

2019



Ampim et al. 2021

Key Issues?

- Massive vegetation cover loss

  (Awuku 2016; Nyantakyi, Fei-Baffoe, and Akoto 2020)

- Rivers are projected to decrease in Ghana

  (Macdonald, Lund, and vanEtten 2020)

- Reduction in ecosystem services in the Tano River Basin

Study objectives

- Analyze LULC from 1986 to 2022 in the Tano River Basin.
- Simulate possible future LULC for the years 2032 and 2052.
- Assess the impact of LULC on hydrological ecosystem services (water yield)

Study Area

- Tano River Basin
- latitudes 5° N and 7° 40' N, and longitudes 2° 00' W and 3° 15' W
- Elevation is 518 meters
- Mean annual temperature is 25.9°C
- 15,000 km^2 catchment area

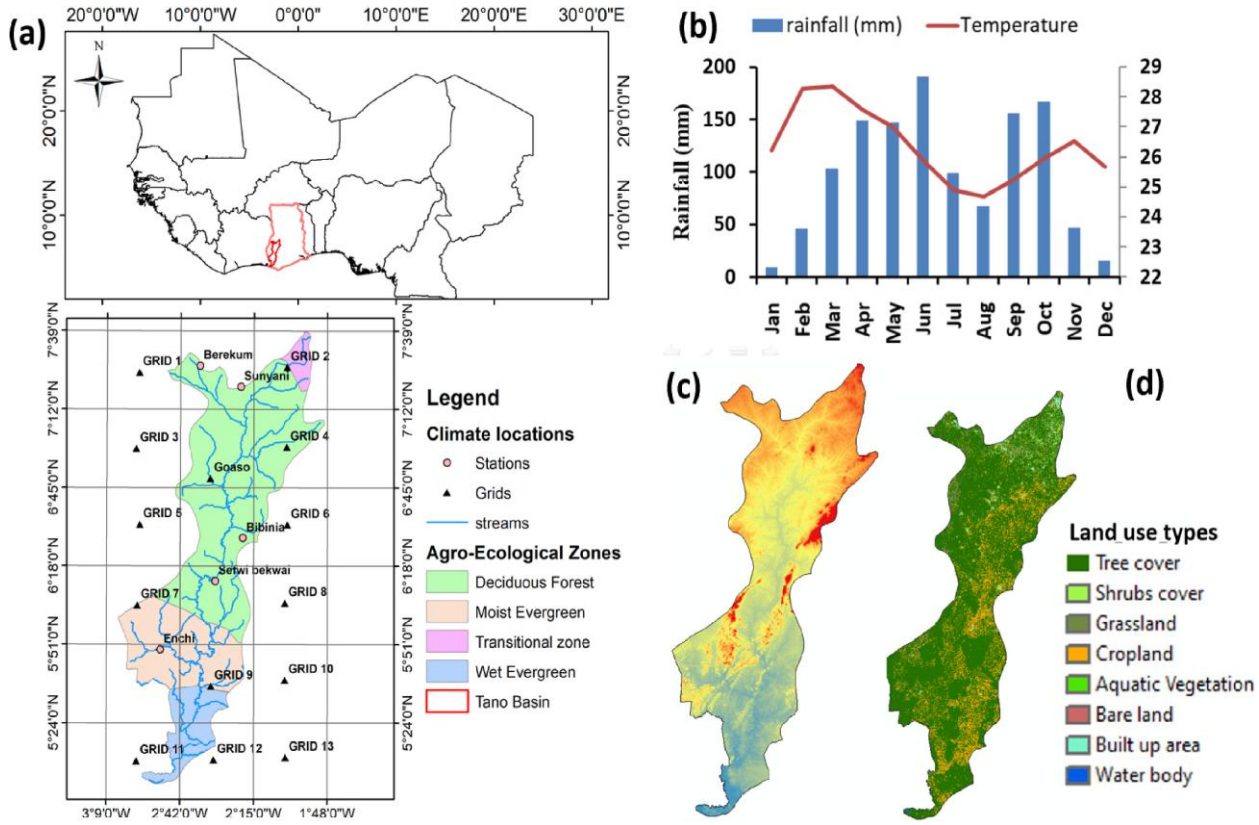


Figure 2: A Map of the Tano River Basin within Ghana and the locations of climate observations (b) rainfall and temperature distribution for the period 1985–2016, (c) elevation, and (d) LULC types (Source: Larbi 2023).

Flow chart for LULC analysis

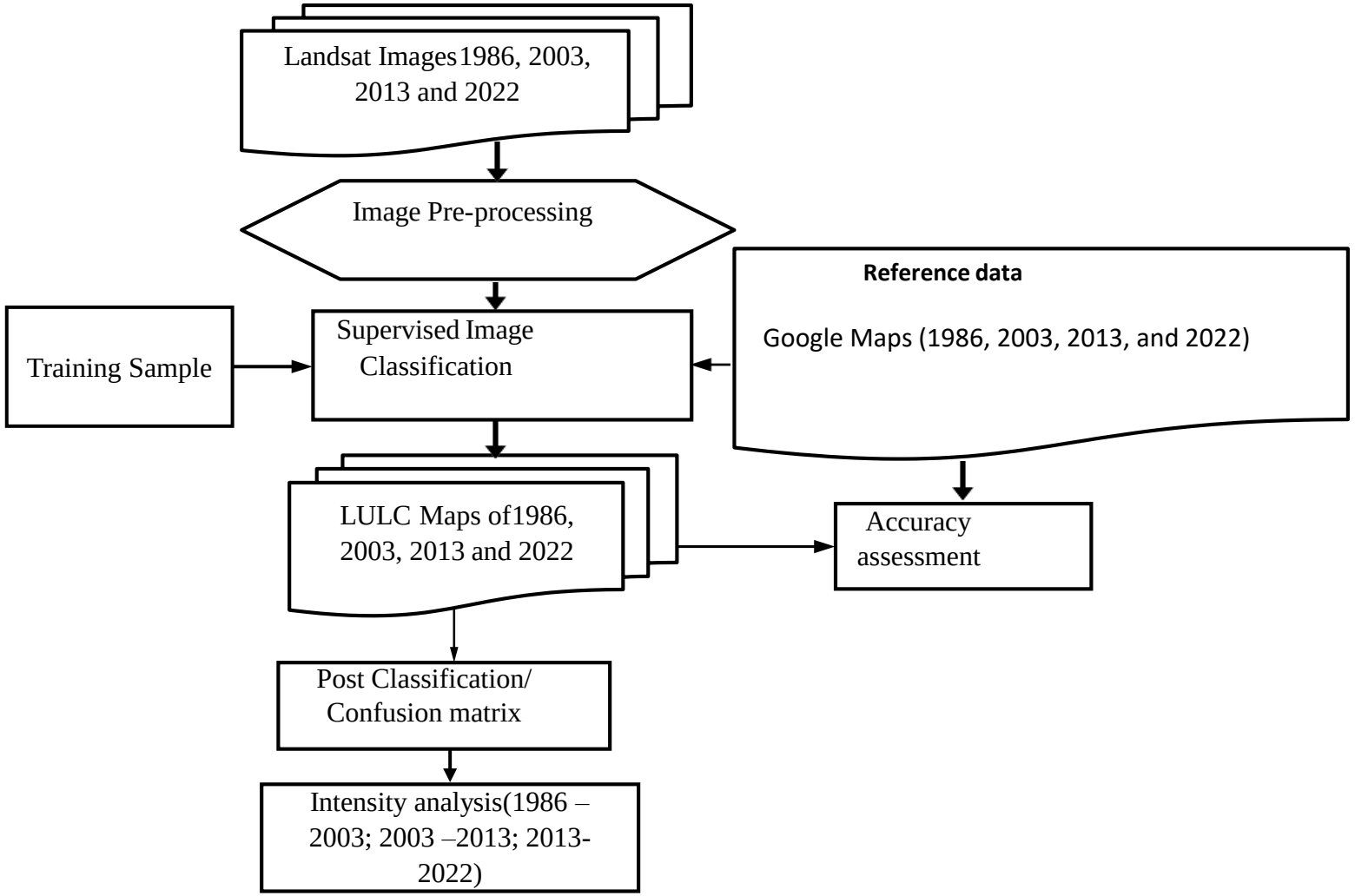


Figure 3: Land use change analysis

Results and Discussion

LULC maps

1986 LULC Overall Accuracy = 88%

(Kappa Accuracy = 0.83)

2003 LULC Overall Accuracy = 89%
(Kappa Accuracy = 0.86)

2013 LULC Overall Accuracy = 91%
(Kappa Accuracy = 0.89)

2022 LULC Overall Accuracy = 94%
(Kappa Accuracy = 0.92)

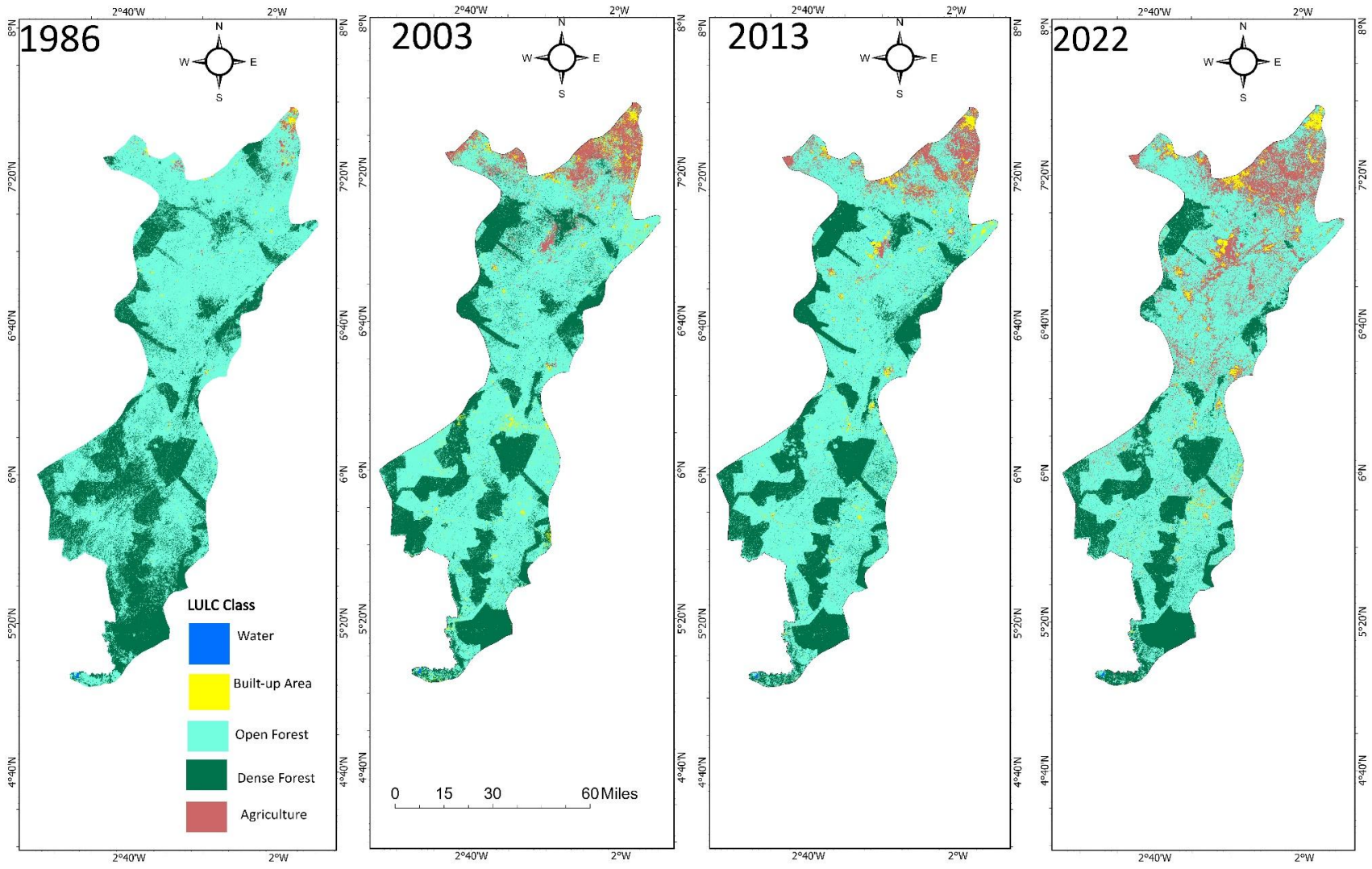


Figure 4: LULC of Tano River Basin from 1986-2022

Results and Discussion

Change detection

Table 1. Percentage of Land use/cover change in Tano River Basin from 1986 – 2022.

Years	Surface Water (%)	Built-up Area (%)	Open Forest (%)	Dense Forest (%)	Agriculture (%)	Total (%)
1986	0.04	0.50	63.88	34.87	0.72	100.00
2003	0.03	2.44	62.44	28.67	6.41	100.00
2013	0.08	1.98	64.78	27.73	5.43	100.00
2022	0.09	2.58	61.71	22.18	13.43	100.00
1986-2003	-0.01	1.95	-1.44	-6.20	5.70	
2003-2013	0.04	-0.46	2.34	-0.93	-0.98	
2013-2022	0.02	0.60	-3.07	-5.55	8.00	
1986-2022	0.05	2.09	-2.17	-12.68	12.72	

Modeling LULC

Input datasets for LULC Projection

- Distance from agriculture
- Distance from roads
- Distance from place/towns
- Digital elevation model (DEM)
- Slope
- LULC

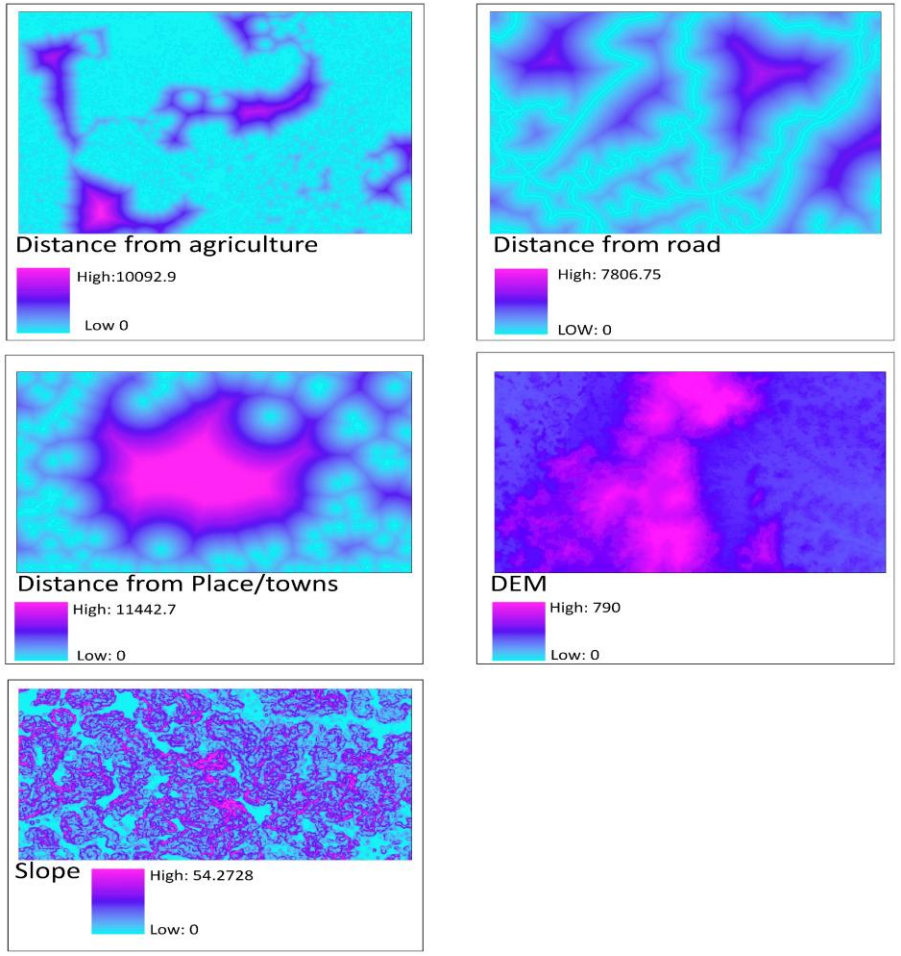


Figure 5: Drivers of land cover change

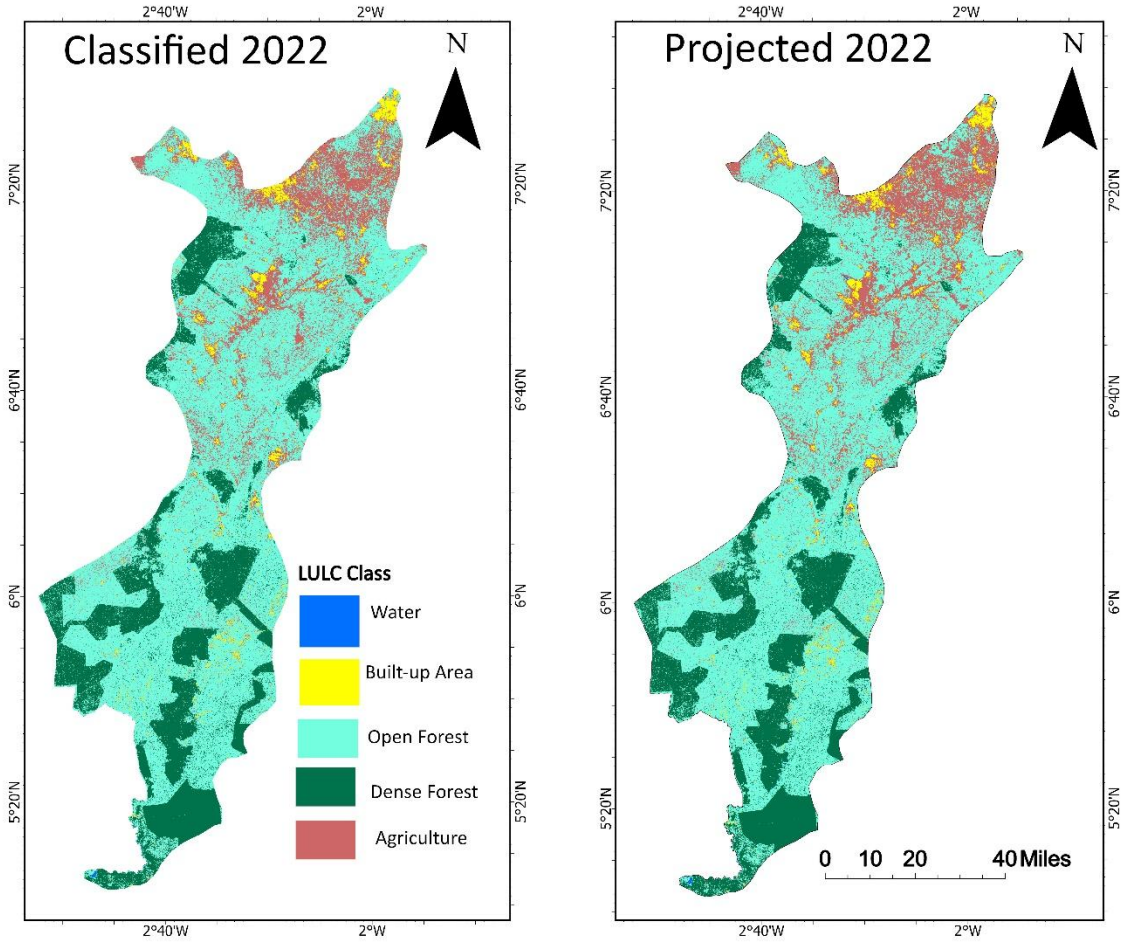
Modeling LULC

Modeling Validation

Table 2. Area coverage of classified and projected land cover classes

LULC	Area coverage (%)	
	2022C	2022P
Water	0.09	0.09
Built-up area	2.58	2.60
Open forest	61.71	61.53
Dense forest	22.18	22.16
Agriculture	13.43	13.61
Total	100.00	100.00

*C – Classified; P - Projected



2022 Simulated LULC Overall Accuracy = 92%

(Kappa Accuracy = 0.90)

Modeling LULC

Simulated Maps

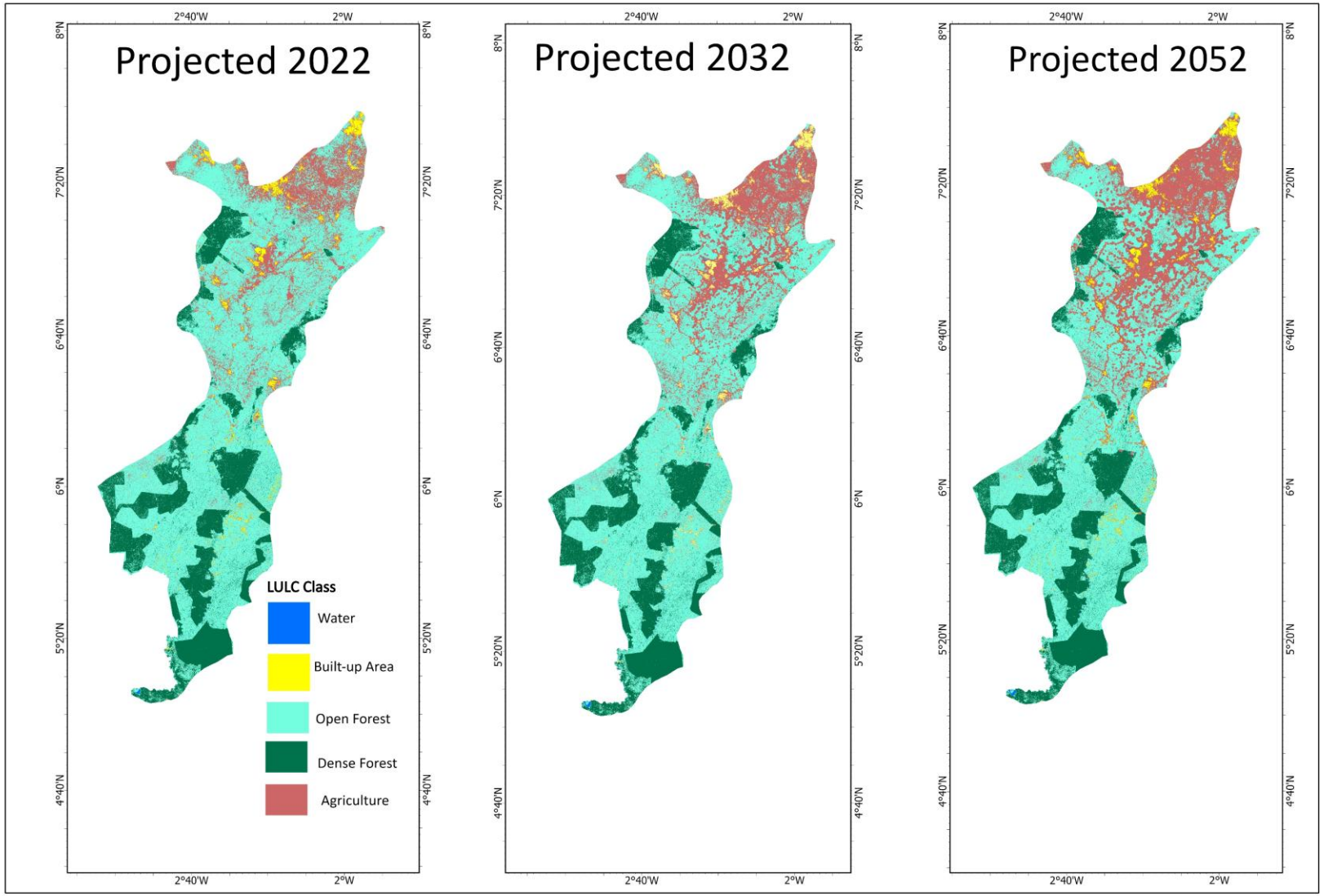


Figure 6: Projected land cover maps of the study area (2022 -2052)

Results and Discussion

Table 3. Area coverage of projected land cover classes in the study area

LULC	Area coverage (%)				Change detection (%)		
	2022C	2022P	2032	2052	2022C-2022P	2032-2022P	2052-2022P
Water	0.09	0.09	0.11	0.12	0.00	0.02	0.03
Built-up area	2.58	2.60	2.63	2.65	-0.02	0.03	0.05
Open forest	61.71	61.53	56.56	52.09	0.18	-4.97	-9.44
Dense forest	22.18	22.16	22.09	21.92	0.02	-0.07	-0.25
Agriculture	13.43	13.61	18.61	23.22	-0.18	4.99	9.61
Total	100.00	100.00	100.00	100.00			

*C – Classified; P - Projected

Assessing the Impact LULC on Hydrological Ecosystem Services (Water Yields)

Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)

Seasonal Water Yield

- Quick flow $= \frac{1}{a_{i,m}} \exp\left(-\frac{p}{a_{i,m}}\right)$

  Where $a_{i,m} = \frac{P_{i,m}}{n_m} / 25.4$ and

  $a_{i,m}$ is the mean rain depth on a rainy day at pixel i on month m [in],

  $n_{i,m}$ is the number of events at pixel i in month m [-],

  $P_{i,m}$ is the monthly precipitation for pixel i at month m[mm].

(Source: Sharp et al., 2016)

Materials and Methods

- Seasonal Water Yield Data Input

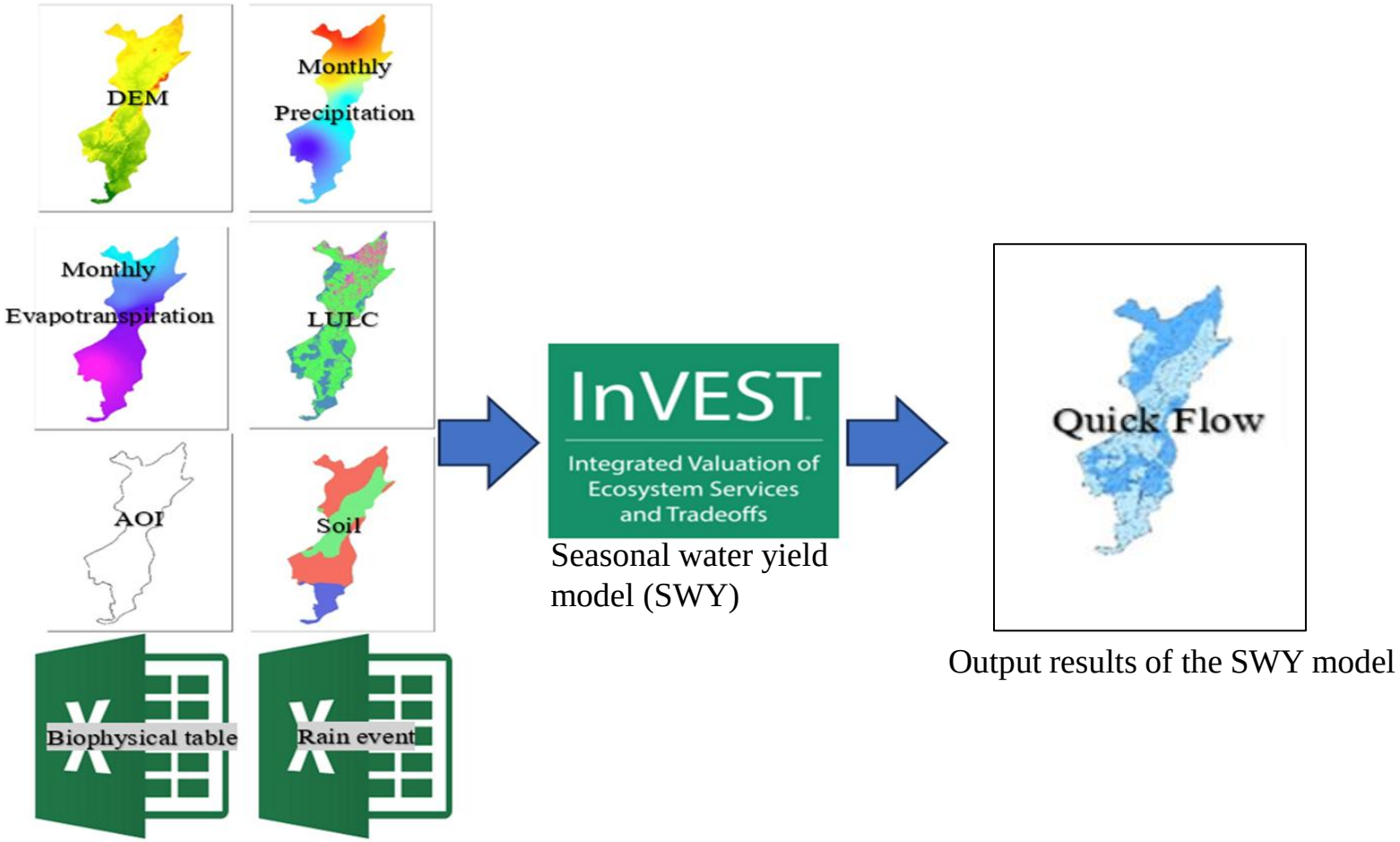
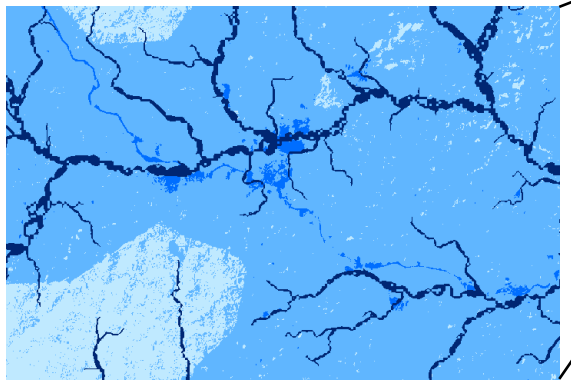


Figure 7: Data input for the InVEST model

Results and Discussion

The mean annual quick flow for 1986, 2003, 2013, and 2022 was 133.57 mm, 137.72 mm, 138.22 mm, and 142.54 mm respectively

maximum annual estimation of 1,492 mm



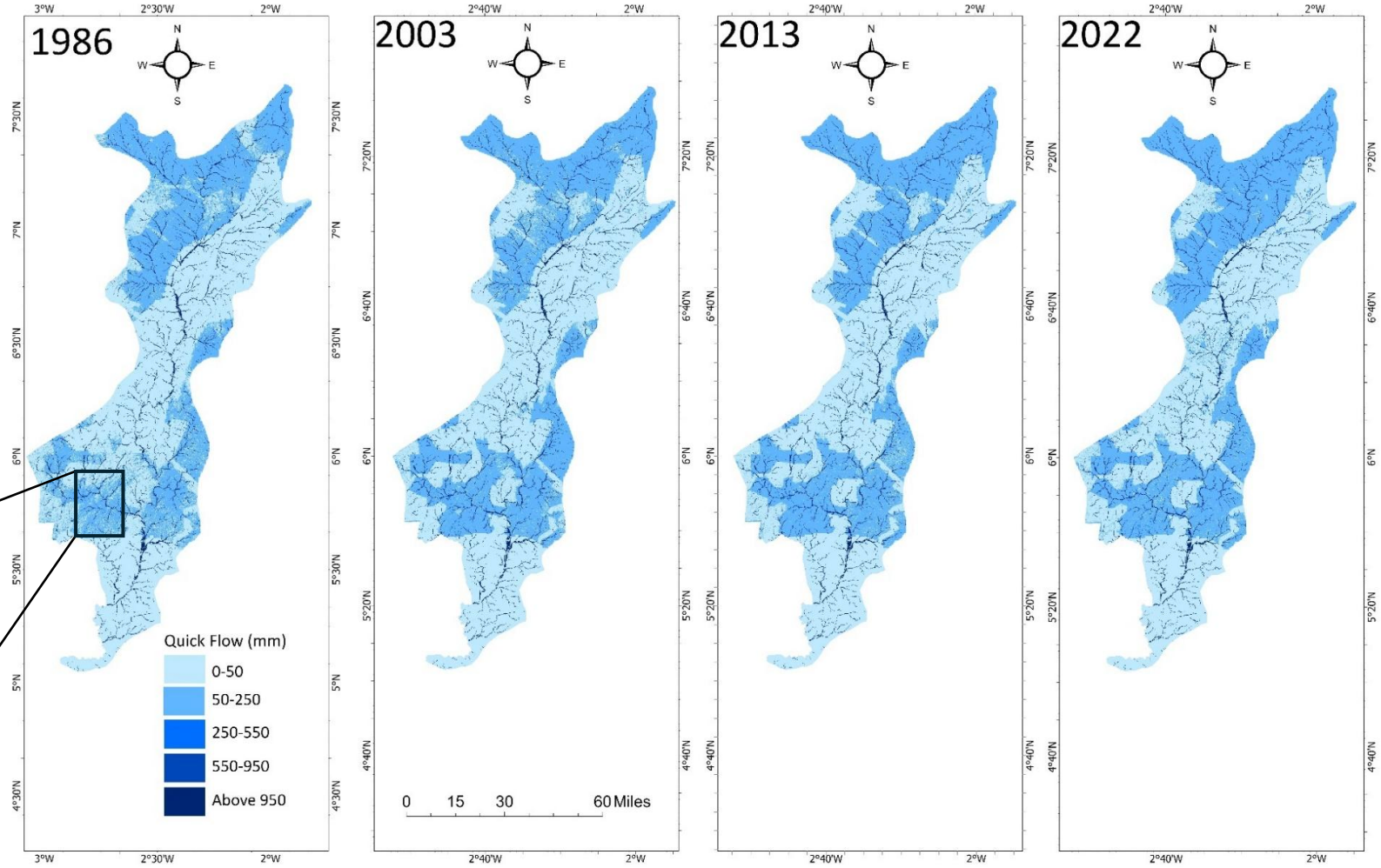


Figure 8: Quick flow distribution in the Tano River basin

Results and Discussion

- Changes in quick flow

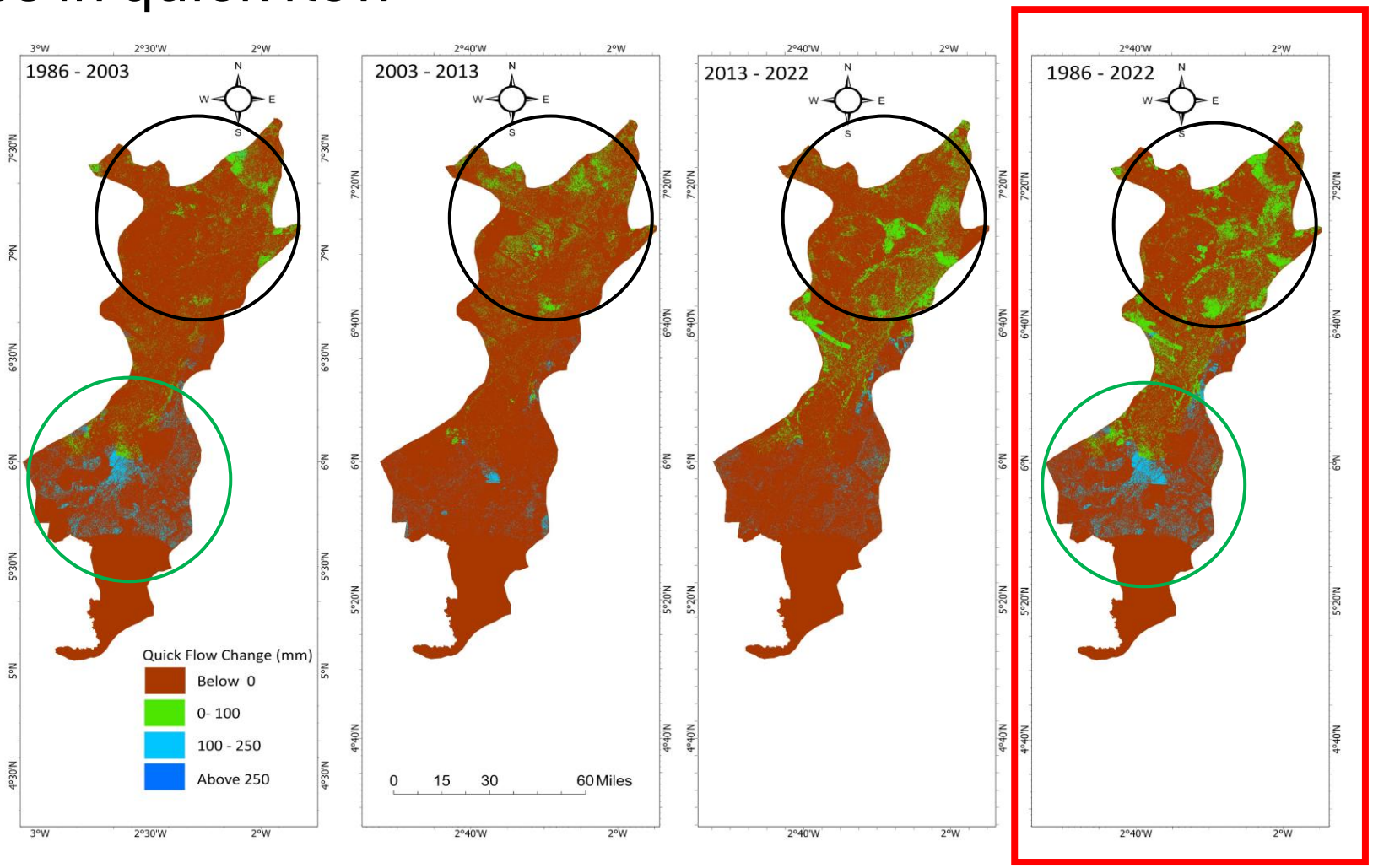


Figure 10: This shows the changes in quick flow from 1986-2022

Conclusion

- Open forest was the largest land cover in the study area
- There is an expansion of agricultural land, mainly from the conversion of open forest and dense forest
- Land use change influenced water yield
- Quick flow is increasing
- Flood intervention measures required

Thank You For Listening

Questions?

References

- Ampim, P. A. Y., M. Ogbe, E. Obeng, E. K. Akley, and D. S. MacCarthy. 2021. Land Cover Changes in Ghana over the Past 24 Years. *Sustainability* 13 (9):4951.
- Awuku, E. T. 2016. Indigenous knowledge in water resource management in the upper Tano river basin, Ghana. *University of Cape Coast*:172.
- Bennett, E. M., G. D. Peterson, and L. J. Gordon. 2009. Understanding relationships among multiple ecosystem services. *Ecology Letters* 12 (12):1394–1404.
- Celentano, D., Rousseau, G. X., Engel, V. L., Zelarayán, M., Oliveira, E. C., Araujo, A. C. M., & De Moura, E. G. 2017. Degradation of Riparian Forest Affects Soil Properties and Ecosystem Services Provision in Eastern Amazon of Brazil. *Land Degradation & Development*, *28*(2), 482–493. https://doi.org/10.1002/ldr.2547
- Ehlui, K. S., W. Atakpama, H. von Wehrden, A. Bah, E. Kola, C. Anthony-Krueger, H. Egbelou, K. B. Kokou, and T. Boukpessi. 2024. Anthropogenic Threats to Degraded Forest Land in the Savannahs' Region of Togo from 1984 to 2020, West Africa. *Journal of Geoscience and Environment Protection* 12 (1):164–179.
- Damptey, F. G., E. Adofo, A. Duah-Gyamfi, D. Adusu, and E. Opuni-Frimpong. 2023. Logging effects on seedling regeneration and diversity in a tropical moist semi-deciduous forest in Ghana. *Geology, Ecology, and Landscapes* 7 (4):269–280.
- Duan, K., G. Sun, S. Sun, P. V. Caldwell, E. C. Cohen, S. G. McNulty, H. D. Aldridge, and Y. Zhang. 2016. Divergence of ecosystem services in U.S. National Forests and Grasslands under a changing climate. *Scientific Reports* 6 (1):24441.
- Edwards, F. A., D. P. Edwards, S. Sloan, and K. C. Hamer. 2014. Sustainable management in crop monocultures: the impact of retaining forest on oil palm yield. *PLoS One* 9 (3):e91695.
- Halder, S., S. Das, and S. Basu. 2022. Estimation of seasonal water yield using InVEST model: a case study from West Bengal, India. *Arabian Journal of Geosciences* 15 (14):1293.
- Kyere-Boateng, R., and M. V. Marek. 2021. Analysis of the Social-Ecological Causes of Deforestation and Forest Degradation in Ghana: Application of the DPSIR Framework. *Forests* 12 (4):409.
- Land use and land use change in Ghana. Source: USGS... *ResearchGate*. https://www.researchgate.net/figure/Land-use-and-land-use-change-in-Ghana-Source-USGS-http-lcausgsgov_fig7_283458146 (last accessed 13 March 2024).
- Macdonald, K. F., M. Lund, and E. vanEtten. 2020. Riverine biota as environmental indicators of artisanal small-scale and large-scale gold mining impacts on riverine ecosystems in Brong Ahafo Region Ghana. *IOP Conference Series: Earth and Environmental Science* 413 (1):012014.
- Nyantakyi, J. A., Fei-Baffoe, B., & Akoto, O. (2020). *Seasonal variations in physicochemical and nutrient water quality of River Tano in Ghana*. https://ir.knust.edu.gh/handle/123456789/12394
- Sharp, R., Tallis, H. T., Ricketts, T., Guerry, A. D., Wood, S. A., Chaplin-Kramer, R., Nelson, E., Ennaanay, D., Wolny, S., & Olwero, N. 2016. *InVEST+ VERSION+ User's guide. The natural capital project*. Stanford university, university of Minnesota, the nature conservancy.
- Traoré, S., I. C. Zo-Bi, C. Piponiot, R. Aussenac, and B. Hérault. 2024. Fragmentation is the main driver of residual forest aboveground biomass in West African low forest-high deforestation landscapes. *Trees, Forests and People* 15:100477.
- Wingate, V. R., F. O. Akinyemi, C. J. Iheaturu, and C. Ifejika Speranza. 2022. A Remote Sensing-Based Inventory of West Africa Tropical Forest Patches: A Basis for Enhancing Their Conservation and Sustainable Use. *Remote Sensing* 14 (24):6251.