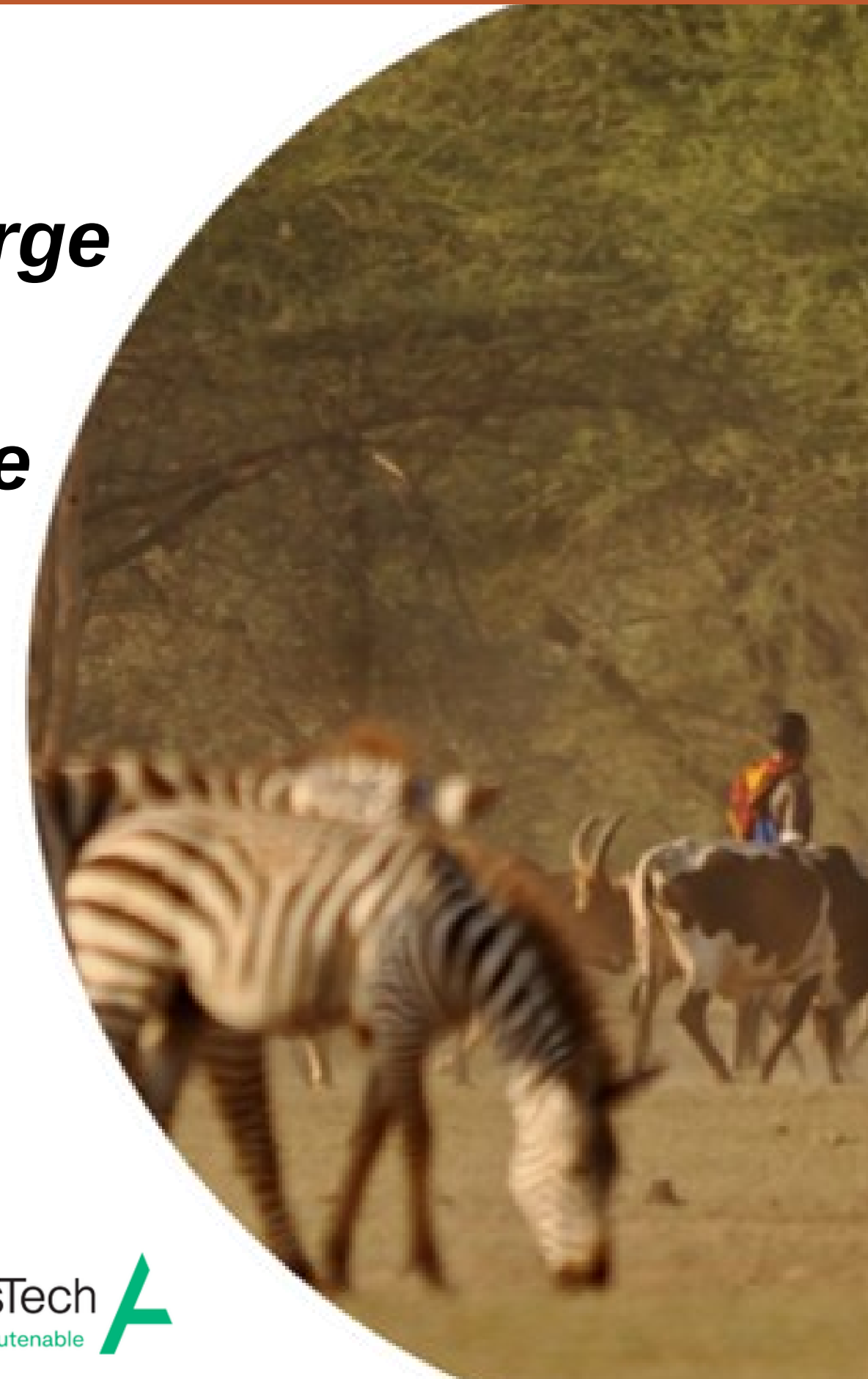


Remote Sensing and Spatial Modelling of Large Herbivores' Populations and Health in Response to Environmental Changes in the Amboseli Ecosystem, Kenya

Phd Student: **Angela M. Wanjiku**

Thesis director: **Dr. Annelise Tran**

Co-supervisors: **Dr. Renaud Marti** and **Dr. Victor Mose**



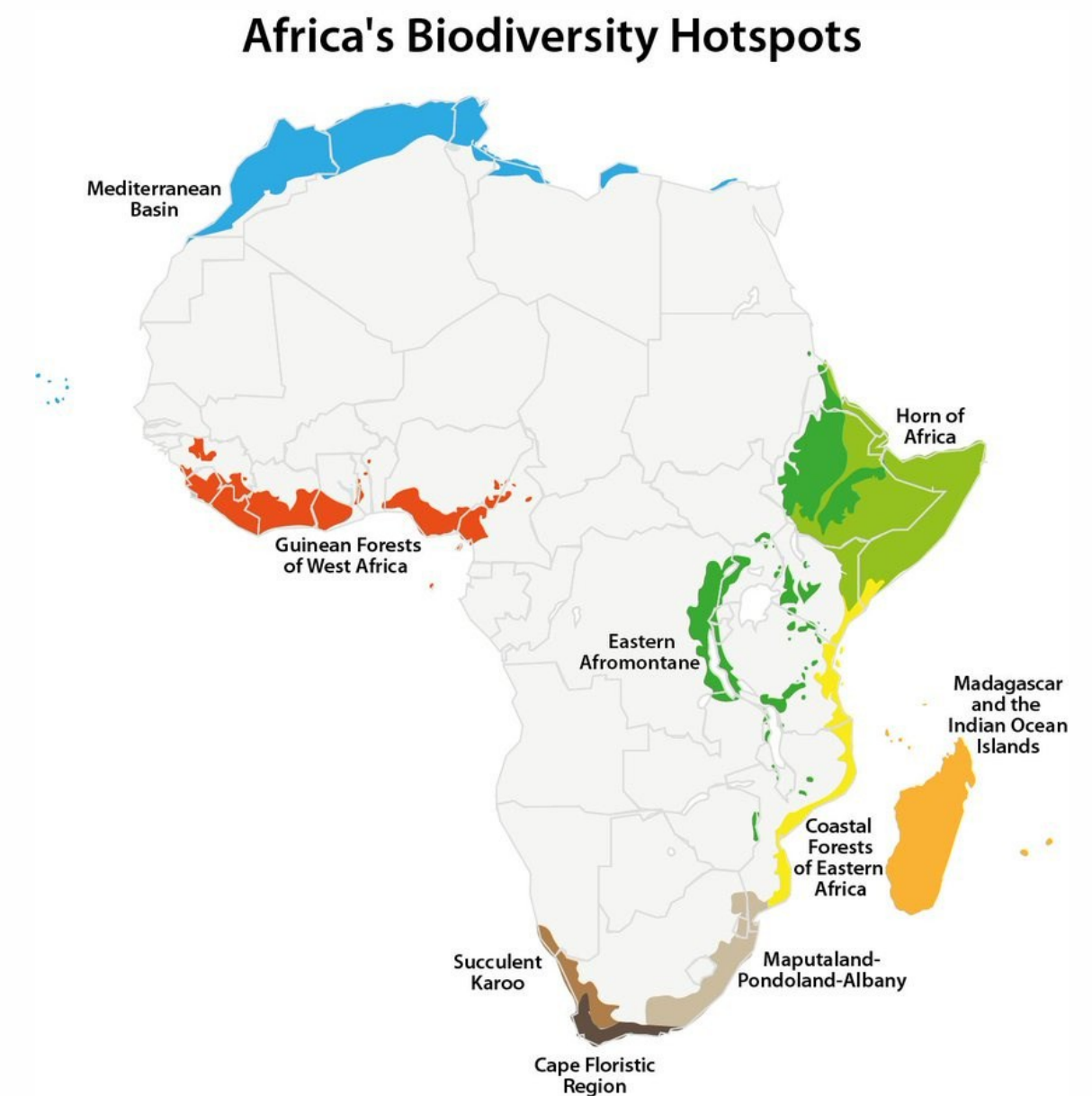
Context

World Meteorological Organization (WMO) 2023 report:

"Africa bears an increasingly heavy burden from climate change and disproportionately high costs for essential climate adaptation"

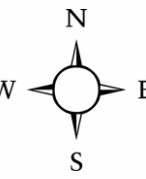
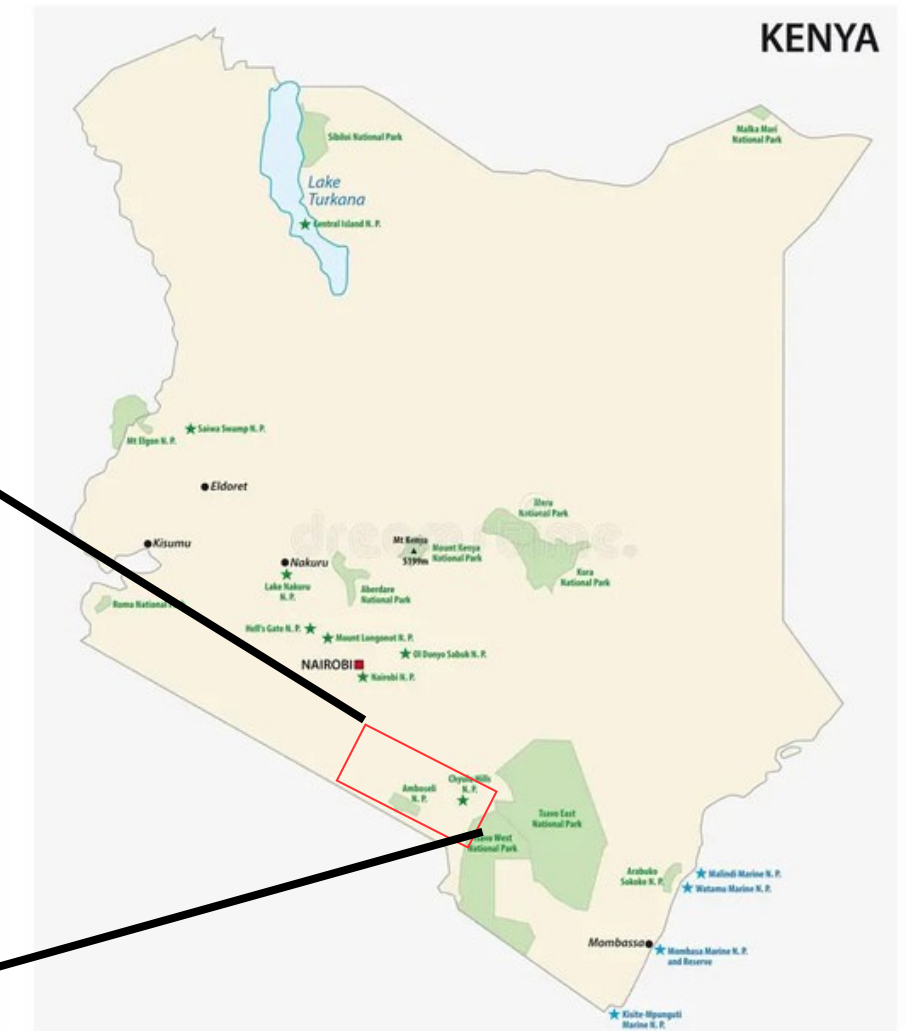
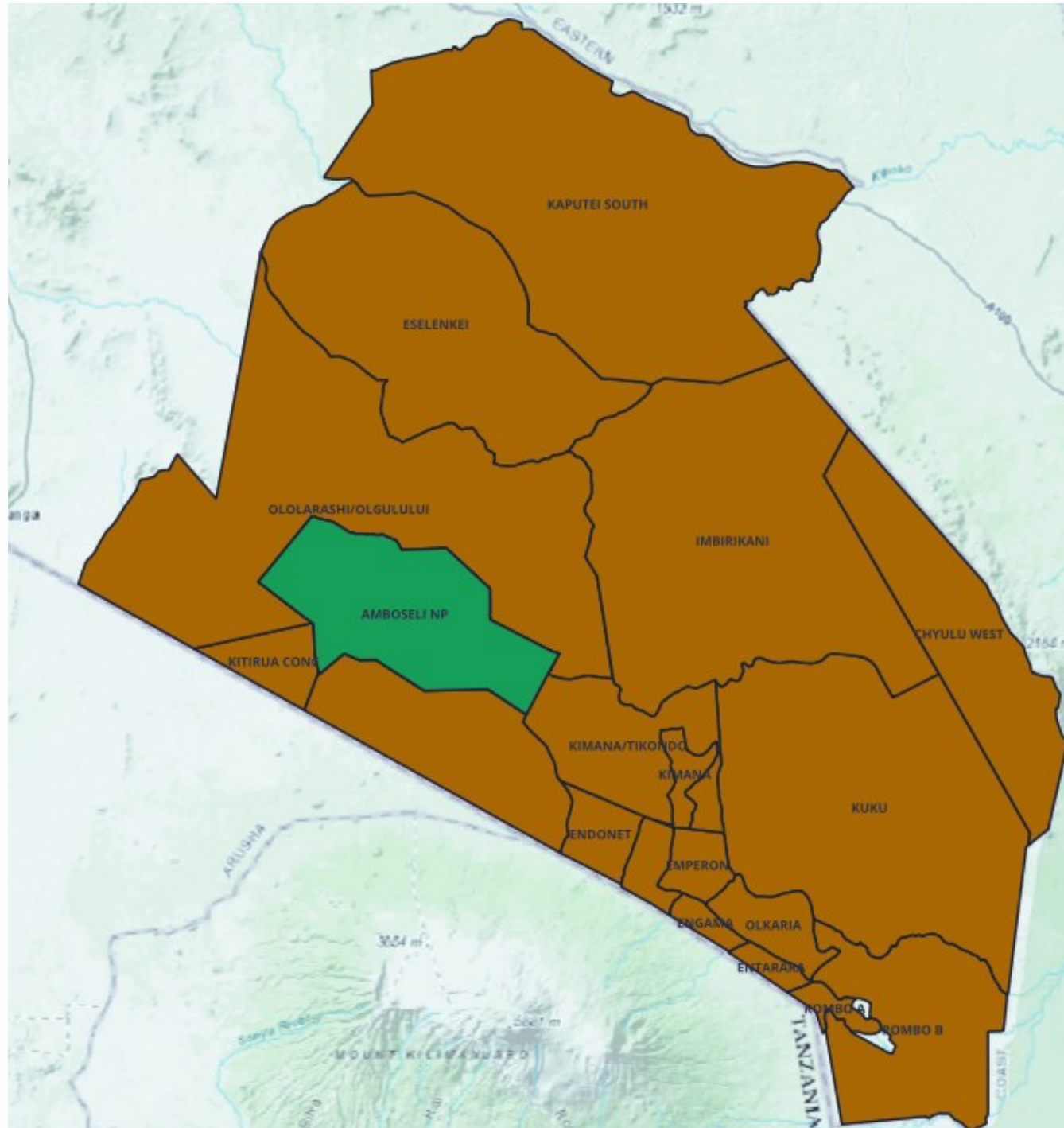
Drivers of biodiversity loss in Africa:

- Higher temperatures (Ahmadalipour & Moradkhani, 2020)
- Increased drought occurrences (Kamali et al., 2024)
- Changing rainfall patterns (Li & Chen, 2024)
- Rapid human population growth (UN DESA, 2023)



Source: Convention on Biological Diversity

Amboseli Ecosystem



National Park



Amboseli Ecosystem

Amboseli Ecosystem

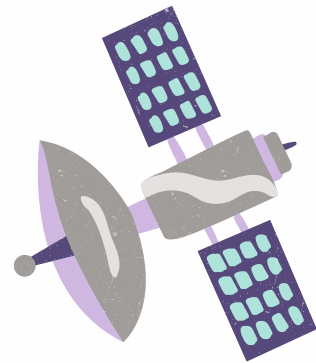
- Area size: approximately 5,700km²
- Semi arid and arid region
- Local community: Maasai people who are pastoralists



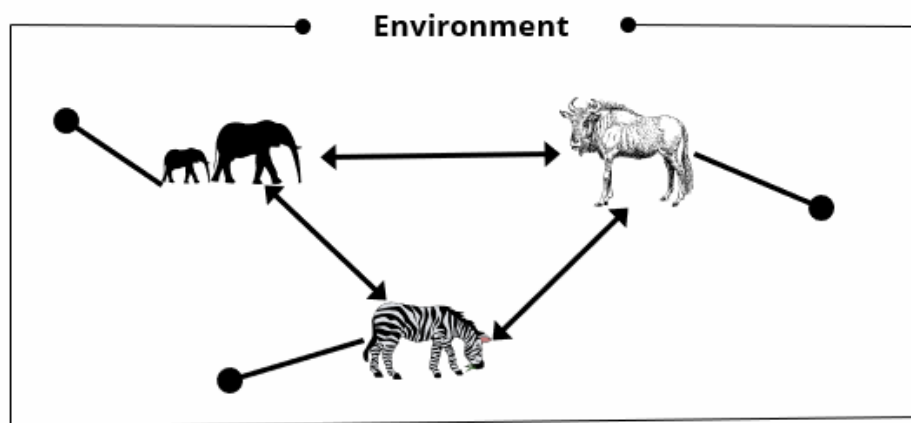
Mosaic Project team visiting Amboseli Ecosystem in 2024

Photos: Mosaic Project

Research Objectives



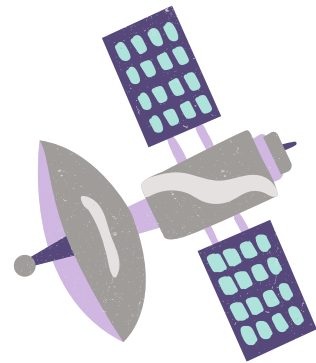
Identify environmental changes that affect animal distribution and health within the ecosystem and monitor these drivers using remote sensing



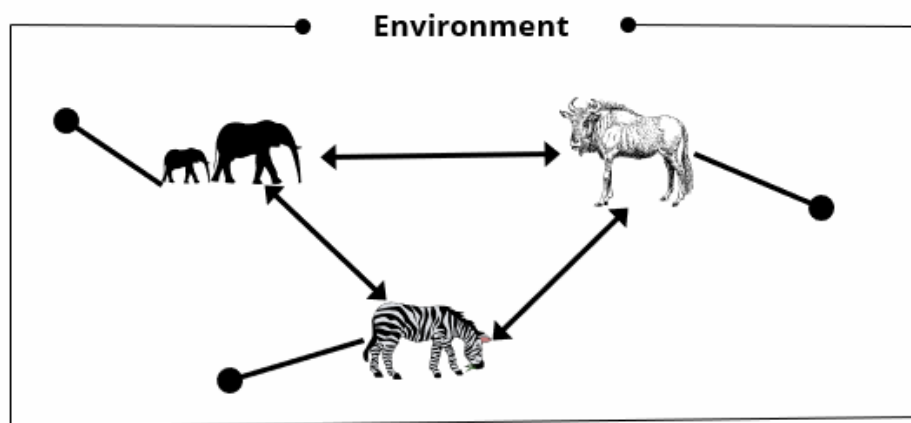
Develop a multi agent-based model to simulate the impacts of the environmental variables

Simulate future trends of animal distribution and health and generate insights for resource management by local communities.

Research Objectives

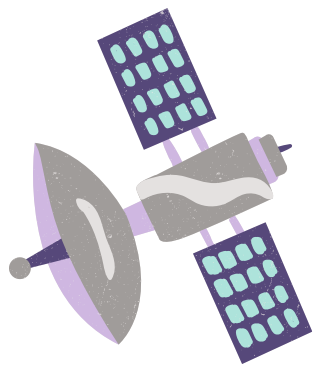


Identify environmental changes that affect animal distribution and health within the ecosystem and monitor these drivers using remote sensing

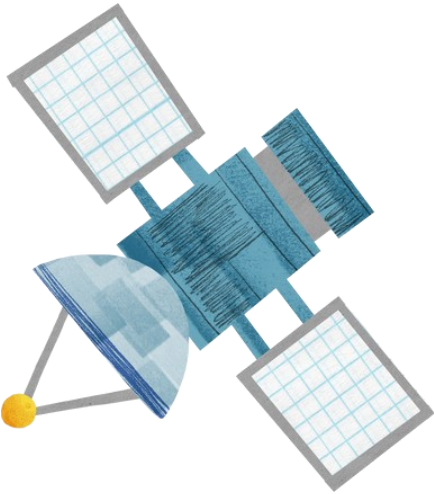


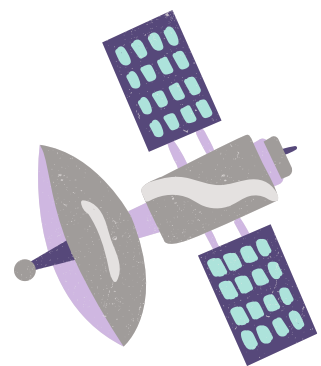
Develop a multi agent-based model to simulate the impacts of the environmental variables

Simulate future trends of animal distribution and health and generate insights for resource management by local communities.



Identify environmental changes that affect animal distribution and health within the ecosystem and monitor these drivers using remote sensing

Indicators	Raw Data	Model input data	Collection methods
Animal population and location	Aerial Count Analysis	Location and population size	 
Phenology	Sentinel 2	NDVI, EVI, MSAVI	
Water sources	Sentinel 2	NDWI	
Human settlement	Sentinel 2/ Global Human Settlement Layer	NDBI	
Barriers	Sentinel 2	Fences, roads, Pipeline	
Wildfires	Sentinel 2, MODIS, FIRMS	burned zones	
Poaching	Survey/Literature	-	 
Predators	Survey/Literature	danger zones	



Identify environmental changes that affect animal distribution and health within the ecosystem and monitor these drivers using remote sensing

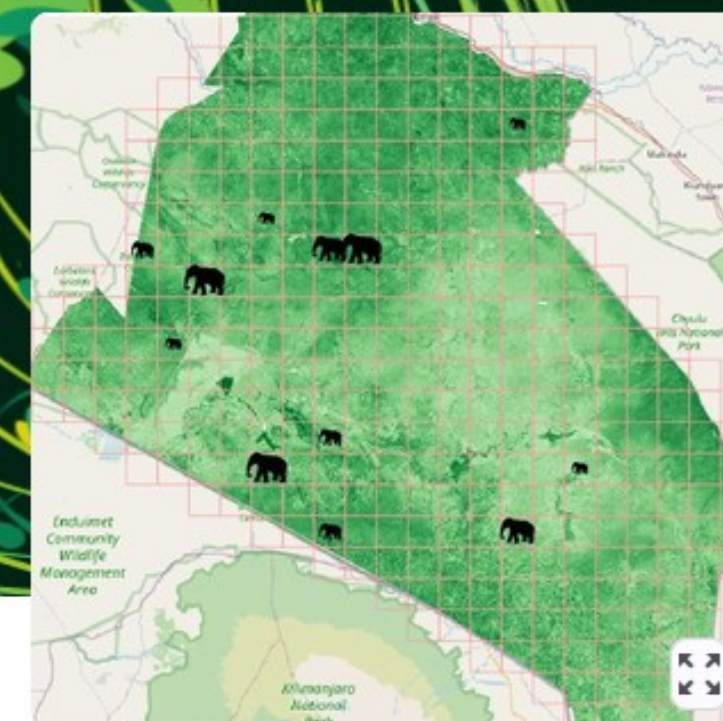
[Catalogue](#)[Visualiseur](#)[Applications](#)[Services](#)[← Retour](#)[★ Ajouter aux favoris](#)

Collection: A spatial dataset of large herbivore distributions and their environmental, climatic, and anthropogenic drivers in the Amboseli...

[Accéder à la réutilisation](#)[réutilisation](#)

Publié il y a 7 mois

The dataset provides a spatially harmonized integration of grid-based animal aerial count observations and environmental covariates for the May 2024 survey period in the Amboseli ecosystem :



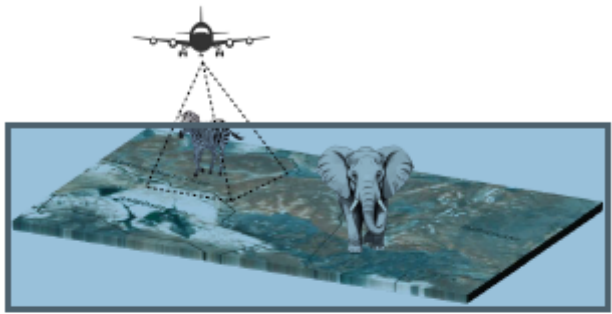
DOI

DOI : 10.18167/GEODE/9390

Develop a multi agent-based model

a) Animals Aerial Count & Telemetry data

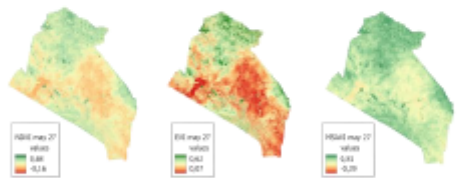
- Animal Population ⁴
- Geo-location
- Animal movement ecology



b) Enviromental Variables Dataset

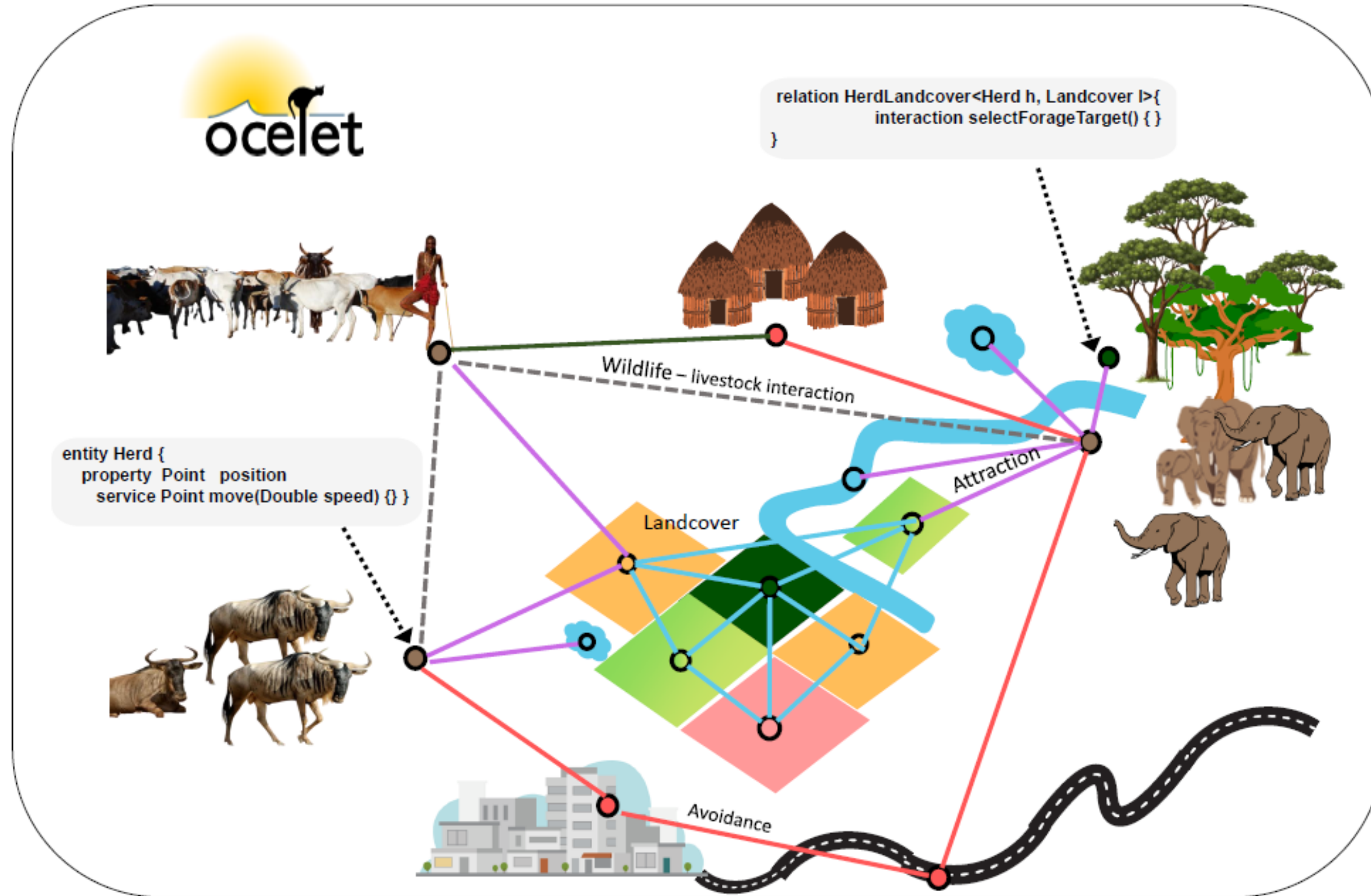
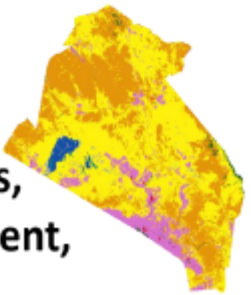
- Aggregated dataset for Amboseli ecosystem in May 2024 ⁵

Spectral Indices



Land Cover Classification

+ Water sources,
Human settlement,
Elevation,
Roads and barriers,
Rainfall, Temperature.

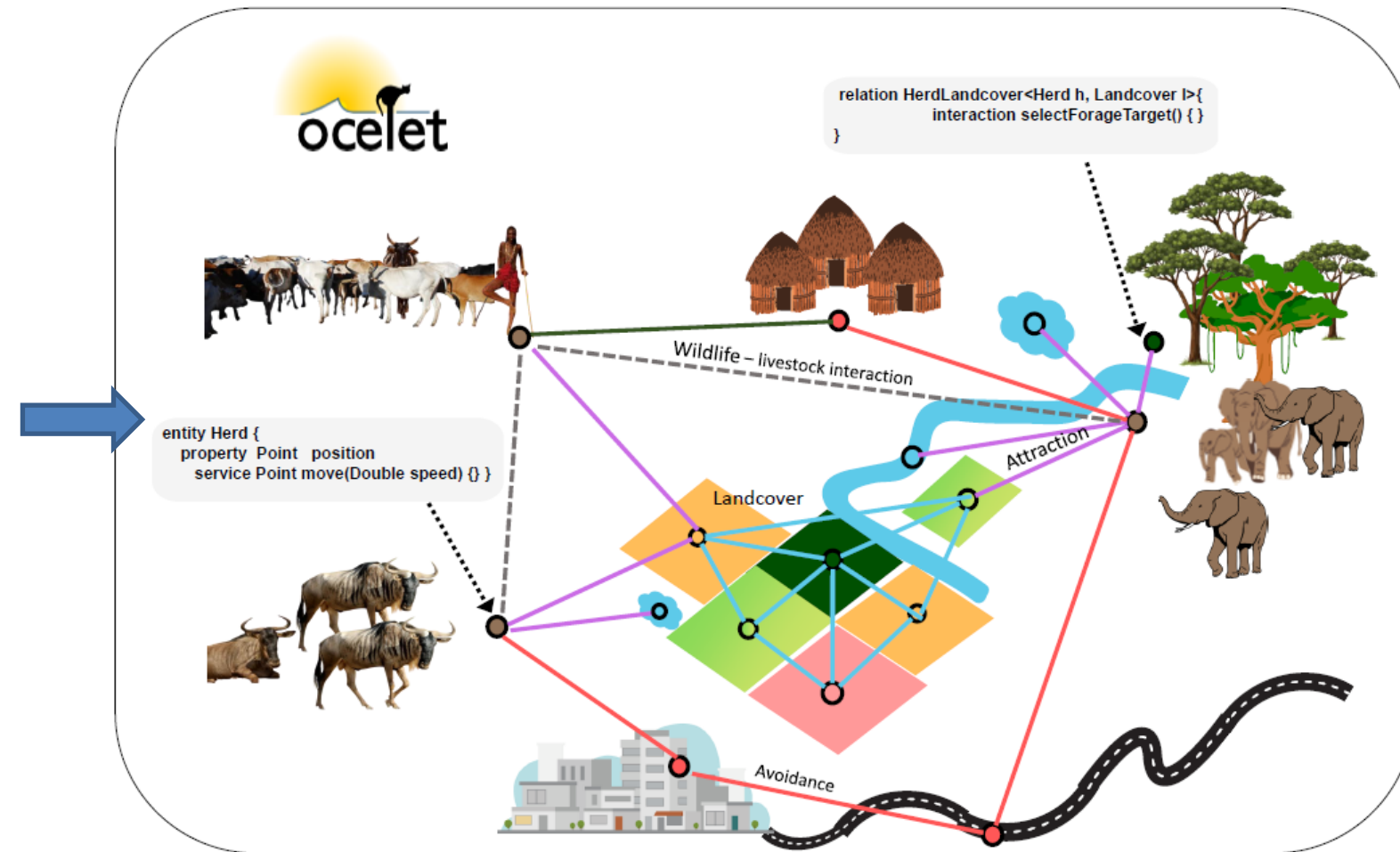
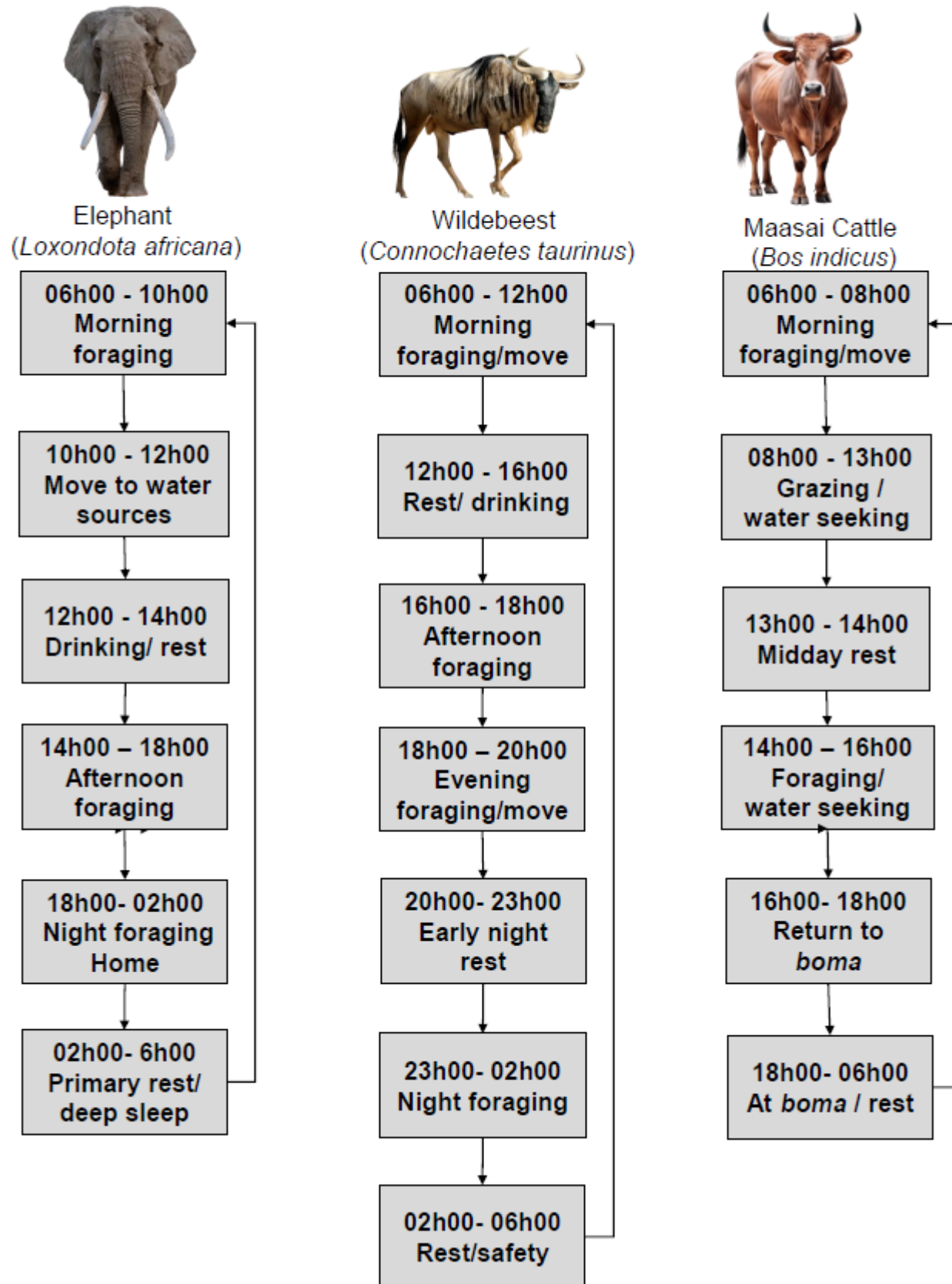


Develop a multi agent-based model

Species	Movement Speed & Daily Distance	Home Range	Spacing (Intra-Herd & Inter-Herd)	Activity Budget	Habitat Selection & Spatial Use	Special Parameters
African Elephant	Dry: 0.3–2.0 km/h (bachelors 1.9; ♀ 0.7) Wet: 0.2–1.6 km/h (both 0.5)	♂3,170 km ² (KDE) – 32,110 km ² (MCP) Expands dry season, contracts wet season (Amboseli-specific)	♀ family herds vs. ♂ bachelor herds (Matriarchal units; no numeric buffer reported)	75% foraging; rest AM/PM 74% encamped / 26% exploratory (HMM)	Avoid towns (4 km), roads (500 m) ♀ stay in Kenya; ♂ range into Tanzania	Musth ♂: less foraging (mate-search) Shift to cooler hours + mud-bathing (thermoregulation)
	<i>Gara et al., 2016; Wato et al., 2018</i>	<i>Ngene et al., 2017</i>	<i>Ngene et al., 2010</i>	<i>Wyatt & Eltringham, 1974; McClintock & Michelot, 2018 ; Wall et al., 2014</i>	<i>Harris et al., 2008; Gara et al., 2016; Ngene et al., 2017</i>	<i>Poole, 1989; du Plessis et al., 2021; Shannon, 2008</i>
Blue Wildebeest	Rest <55 m/h; Forage 55–300 m/h Mixed 300–1,100 m/h; Travel >1,100 m/h Average 21.0 km/day	Core (Amboseli NP) 392 km ² ; Dispersal 3,000 km ² Foraging range: 2.12 km ² (wet) – 8.98 km ² (late dry)	Evasion zone 1–4 m; Neutral zone 6–10 m Herd size 12–35 (fission-fusion)	Forage dawn/dusk; rest midday & night Min. 33% active foraging at night	Restricted to surface water; avoid woody habitat Prefer grass shoots <3 cm	Sprint 22 m/s Turn angle 88° (low risk) – 121° (high risk) Drinks q2–3d (≤80 km/5d w/o water)
	<i>Owen-Smith & Traill, 2017; Stabach et al., 2022</i>	<i>Msoffe et al., 2019; Owen-Smith & Traill, 2017</i>	<i>Chao & Levin, 2007; Owen-Smith et al., 2015</i>	<i>Owen-Smith & Traill, 2017; Kavwele et al., 2025</i>	<i>Stabach et al., 2016</i>	<i>Jeschke & Tollrian, 2007; Dröge et al., 2019; Curtin et al., 2018</i>
Plains Zebra	Transit 1.1 km/h; Grazing 0.3 km/h Night 0.77 (open) / 0.54 (woodland) km/h Day 0.45 (open) / 0.59 (woodland) km/h	Resident: 80–250 km ² Migratory: 300–400 km ² (wet) / 400–600 km ² (dry) Annual total (migration routes): up to 1,000 km ² +	Harems (stable) + bachelor herds; fission-fusion Intra-herd <6 body lengths; Inter-herd boundary >100 m	Family bands: 41.8% feed (+20% w/ foals), 18.5% rest, 10.9% move Bachelors: 27% vigilance, 21% move, 18.4% feed	Max 15 km radius from permanent water Prioritize forage quantity / biomass	Directional persistence β: 0.42 (encamped) vs 2.210 (traveling)
	<i>Brooks & Harris, 2008; Fischhoff et al., 2007</i>	<i>Klingel, 1969</i>	<i>Rubenstein, 2010; Thaker, 2010; Tong et al., 2015</i>	<i>de Vos et al., 2020</i>	<i>Western, 1975; Groom & Harris, 2010</i>	<i>Prima et al., 2022</i>
Maasai Cattle	10.2 km/day (9.6 wet, 10.4 dry)	No fixed range; central-place foragers around temporary bomas (relocated every few weeks)	Intra-herd width 50 m; Inter-herd boundary >100 m MCF buffer >1,000 m (0.1% vs 25.5% incidence at 100 m)	69.5–72.2% of daylight hrs grazing ↑ walking time in dry season (find patches)	Human-managed; bomas ideally 7–9 km from water Avoid wildlife overlap in wet season	Movement & activity schedule set by the herder (Human-controlled, not ecologically driven)
	<i>Raizman et al., 2013</i>	<i>VanderWaal et al., 2017</i>	<i>Butt et al., 2009; VanderWaal et al., 2017; Barnard et al., 1989</i>	<i>Odadi & Rubenstein, 2015; Butt, 2010</i>	<i>Western & Dunne, 1979; Mwasi & Fisher, 2018</i>	<i>VanderWaal et al., 2017; Butt, 2010</i>
Maasai Giraffe	12.1 km/day (mean)	Avg. 122 km ² (♂157.2, ♀ 114.6) Up to 205.2 km ² (pan-African est)	Intra-herd assoc. <500 m; Feeding spacing 9 m Zero territoriality (overlap ≠ social bond)	53% foraging (↑ to 57% dry season) (Nubian giraffe used as proxy)	Tolerate bomas, avoid populated towns Aggregate near riverine in late dry season	Water-independent (diet / dew) Weaker bonds & smaller groups near bomas
	<i>Brown et al., 2023</i>	<i>Knüsel et al., 2019; Brown et al., 2023</i>	<i>Bond et al., 2019, 2021; Shorrocks & Croft, 2009</i>	<i>Gitau et al., 2024</i>	<i>Knüsel et al., 2019; Stommel et al., 2025</i>	<i>Stommel et al., 2025; Bond et al., 2021</i>
Thomson's Gazelle	Up to 16 km/day (or every other day)	42–65 km ² (wet) – 142 km ² (dry) Landscape scale 1,600 km ²	♂territories 200 m diameter (temporary) Nomadic fission-fusion ♀ herds	12 h lying/resting; 7–9.25 h grazing 3.5–5.5 h moving; 24h polyphasic bouts	Pull dynamic: follows wildebeest/zebra (16–32 day lag); Optimal patch 20 g/m ²	Balances predator vigilance vs feeding competition
	<i>Estes, 1997</i>	<i>Martin, 2000; Estes, 2012</i>	<i>Walther, 1972 ; Fryxell & Berdahl, 2018</i>	<i>Walther, 1973</i>	<i>Anderson et al., 2024; Fryxell & Berdahl, 2018</i>	<i>Fryxell & Berdahl, 2018</i>

(Ayoub Ikhibi, 2026)

c) Daily Time budget



Calibration / Validation

- Pattern-Oriented Modelling (POM), Telemetry data and 1km animal aerial count

e) Output

Species mobility mapping

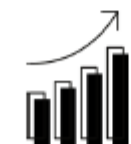
- **Movement maps** (trajectories, points of contacts)
- **Connectivity loss** (movement corridors, barrier effects)

Environment variables impacts on species

- **Health maps**(disease risk)
- **Risk hotspots** (resource scarcity, human pressure)

Future trends on animal distribution

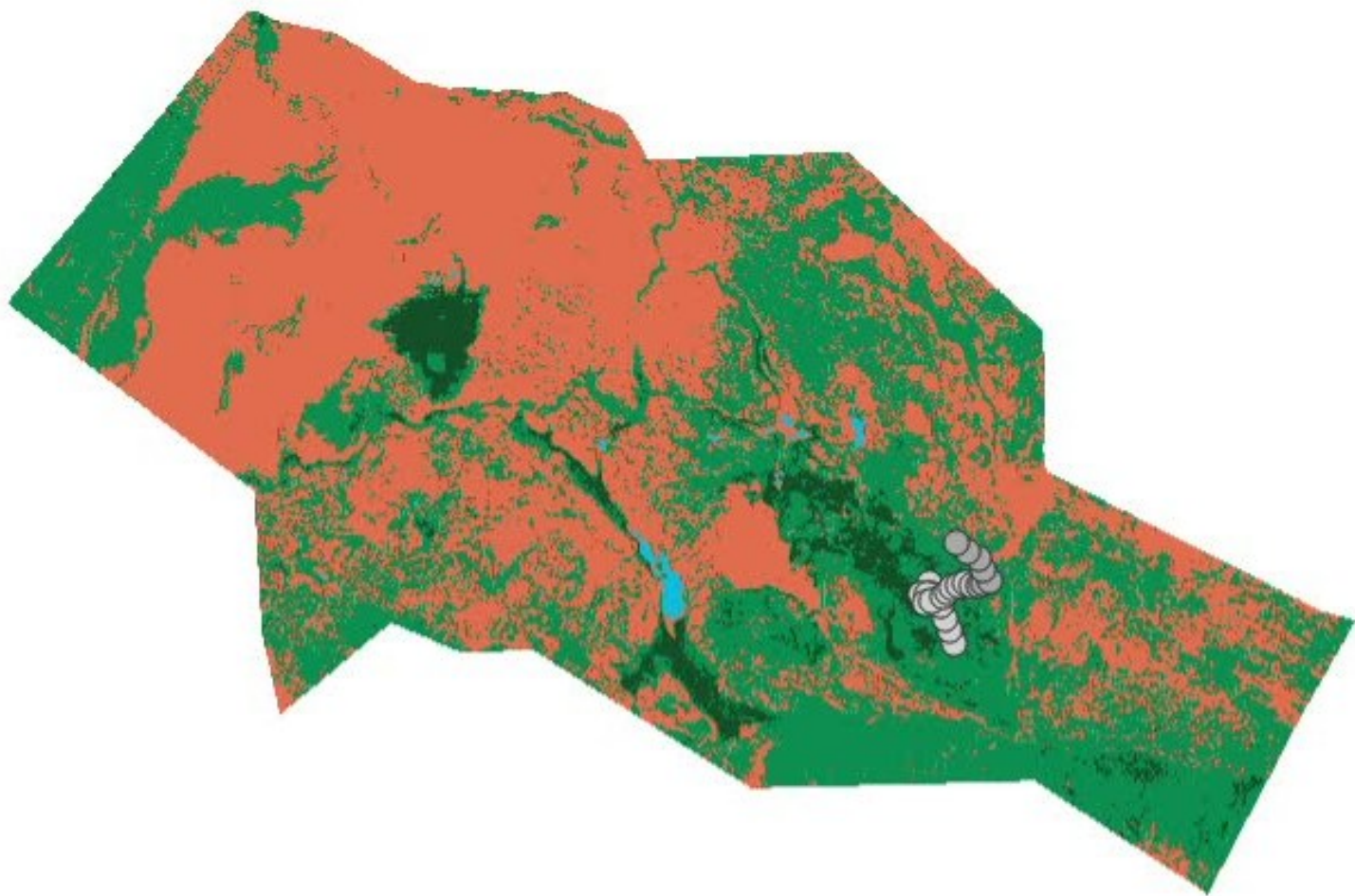
Scenario projections



Develop a multi agent-based model – preliminary results

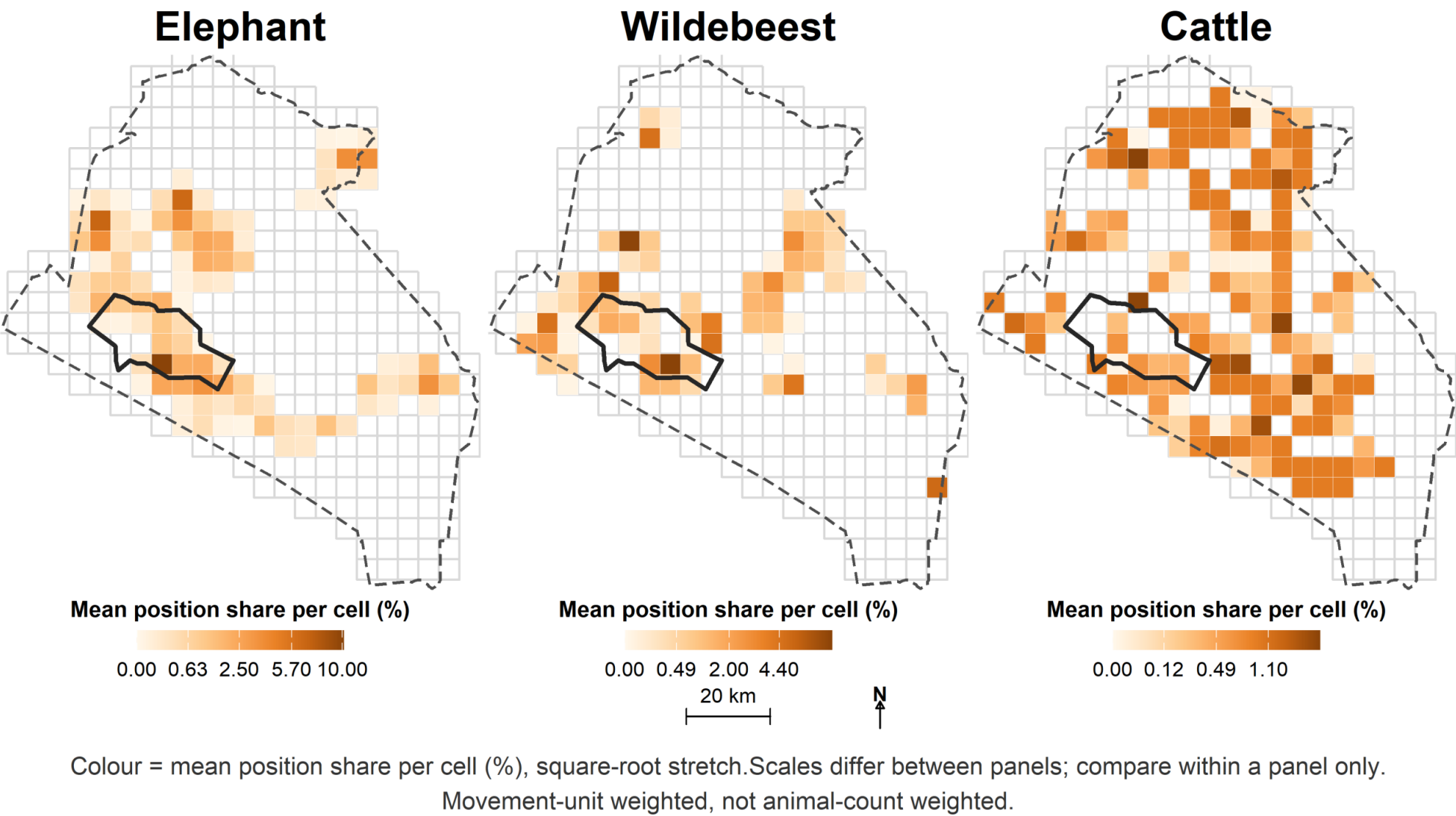
21-25 May 2024

- Roads/bare land
- Shrubs/grassland
- Woodlands
- Water



Species-specific simulated space use

Amboseli ecosystem | 21–25 May 2024 | mean across 20 stochastic simulations



Elephant Model

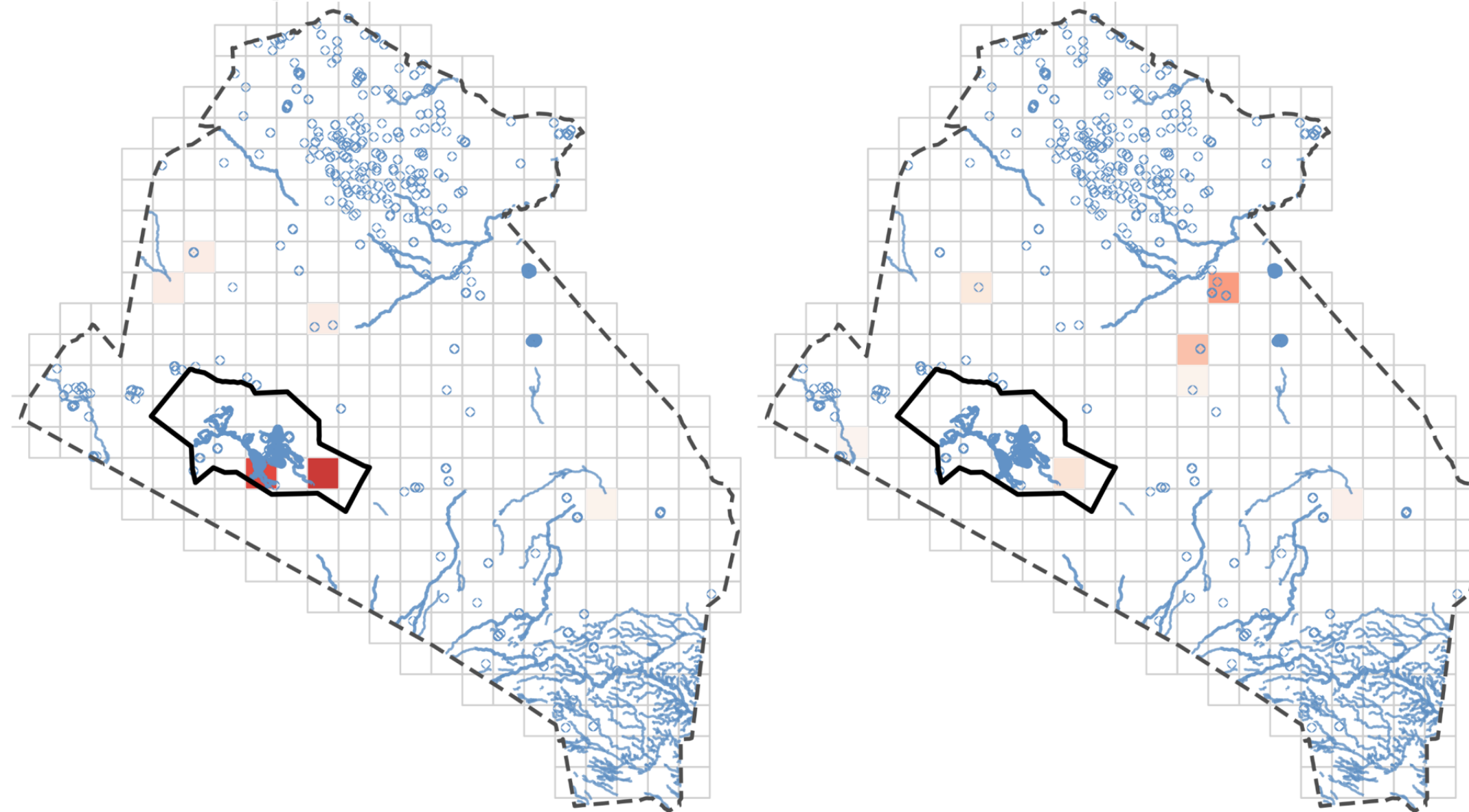
Develop a multi agent-based model – preliminary results

Wildlife–livestock local shared-water exposure opportunity

Amboseli ecosystem | 21–25 May 2024 | same hour, same source, local access ≤ 500 m

Elephant × Cattle

Wildebeest × Cattle



Cross-simulation
combinations (%)

0 10 20 30 40 50 60 70 80

Map features

□ Amboseli National Park □ Amboseli ecosystem □ Water sources □ 5 × 5 km aerial count grid

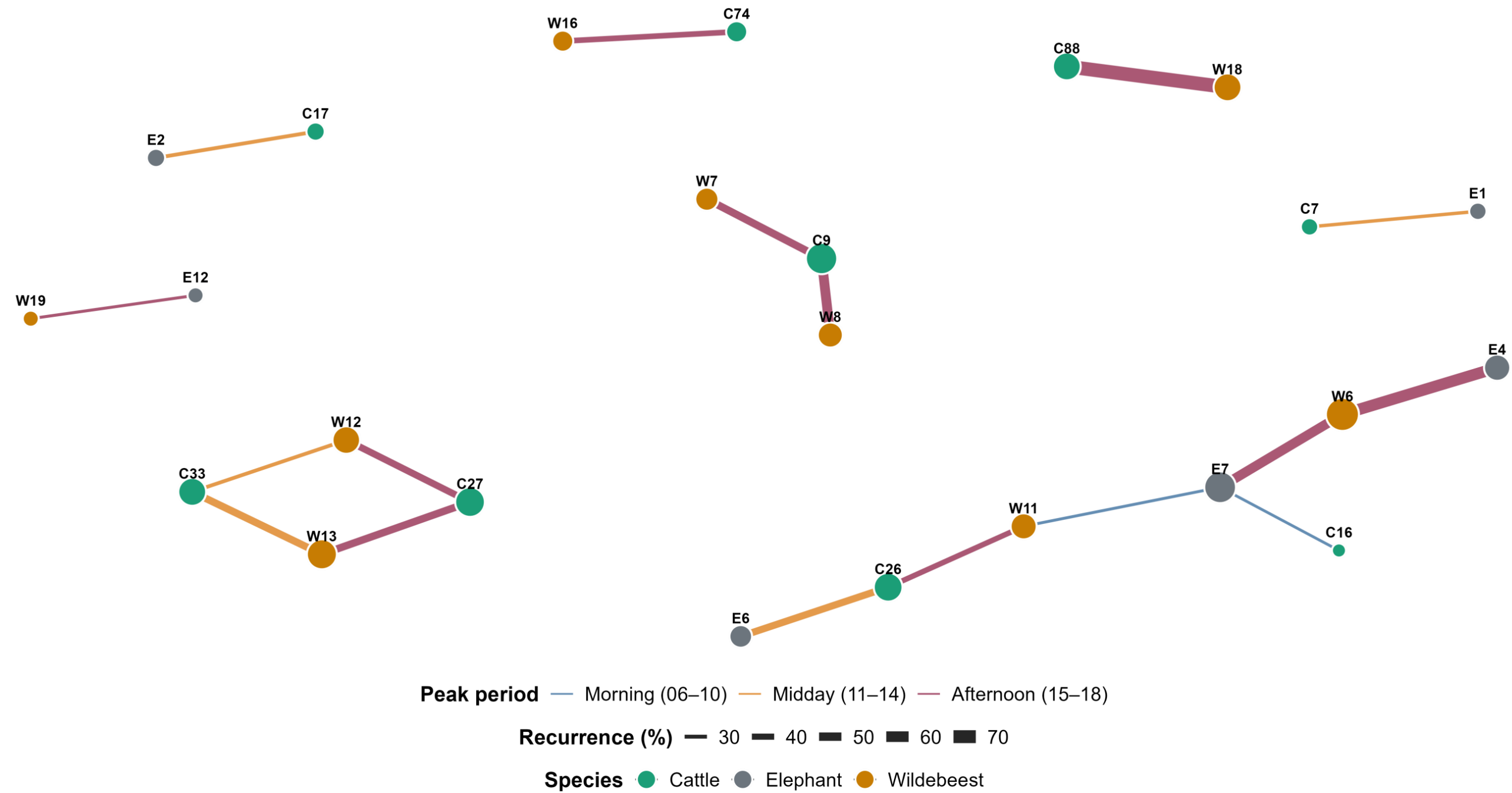
Colour = % of 400 cross-simulation combinations with ≥ 1 shared-water event in that cell.

Same hour, same source, access points ≤ 500 m apart.

Develop a multi agent-based model – preliminary results

Recurrent multi-host proximity network

21–25 May 2024 | same-hour proximity ≤ 250 m | edges recurring in $\geq 25\%$ of 400 cross-simulation combinations

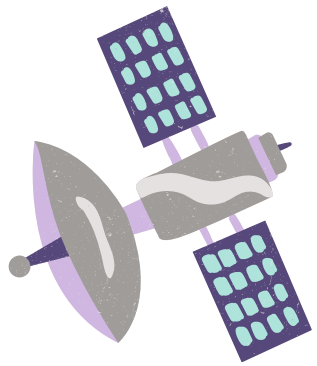


24 movement units and 17 retained edges in 8 components; the largest spans three species (7 units, 6 edges).

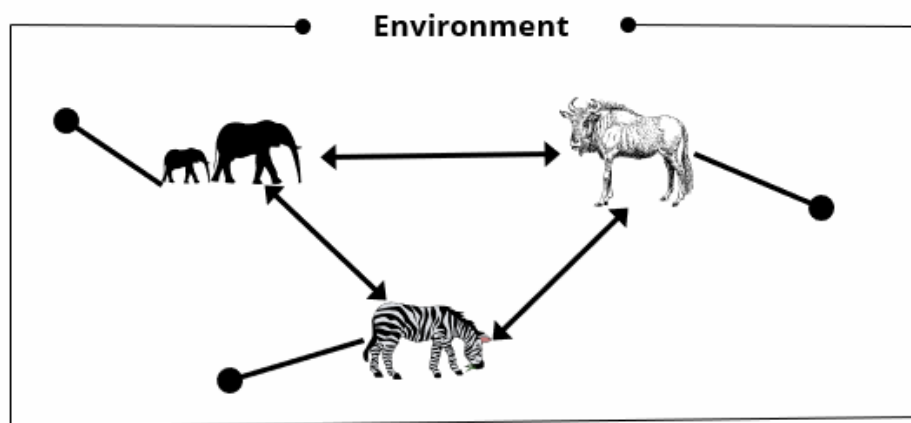
Node fill: grey = elephant (E), orange = wildebeest (W), green = cattle (C).

Edge width = recurrence across 400 cross-simulation combinations; colour = peak proximity period; node size = summed edge recurrence.

Conclusions / Perspectives



Remote sensing + ancillary data: to monitor environmental changes and impacts on animal distribution over large regions



●— Animal - Environment interaction ↔ Animal - Animal interaction

+ spatial modelling: to explore the complexity of multi-host networks

Perspectives: - dry season simulations + integration of other species
- Validation against observed wildlife and livestock movement

Thank You!

