Reviving the Ecosystem in Bushbuckridge Nature Reserve

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Outline

About Bushbuckridge Nature Reserve

- Location: North of Mpumalanga Province, near Kruger National Park, Approximately 7000 hectares.
- Co-managed by Mpumalanga Tourism and Parks Agency (MTPA) and Communal Property Associations (CPA).
- 100% land claimed by Sisonke CPA (95%) and Injaka Watervaal (5%).

Bushbuckridge Nature Reserve

Background

- The reserve's value as a catchment area and ecological corridor linking Blyde River Canyon and Kruger National Park.
- Challenges: Habitat loss, human-wildlife conflict, and increasing human settlements.
- Potential for eco-tourism, biodiversity conservation, and local community benefits.

Problem Statement and Objectives

- Used to be one of the province's well-operational and well-preserved natural reserves.
- What can be done to revive the ecosystem of Bushbuckridge Nature Reserve since there is currently no life or meaningful activity?
- **Objectives**
  - Restore and conserve the ecosystem.
  - Address human-wildlife conflict through innovative solutions.
- Design or develop a mathematical model to assist with presenting viable tools for controlling the ecosystem while human-wildlife conflict.

Strategies

1. **Population Models**
   - Develop mathematical models for population dynamics.
   - Monitor biodiversity and ecological health.
2. **Facility Layout Design**
   - Tourist Trails and Species interaction.
   - Enhance accessibility while minimizing environmental impact.
3. **Movement Population Models**
   - Simulate animal migration and habitat use.
   - Ensure connectivity between protected areas.
4. **Cost Optimization**
   - Budgeting for infrastructure and conservation programs.
   - Maximizing profit and employment while keeping costs down.

Population Model

- R_f - Reforestation rate
- r_V - Vegetation Growth Rate
- K_V - Vegetation Carring Capacity
- α - Grazing rate by prey
- ω - Vegetation loss rate due to deforestation, tree cutting, etc.
- R_2 - Prey re-introduction rate
- r_2 - Prey Growth Rate
- k_2 - Prey Carring Capacity
- β - Vegetation contribution to prey growth
- δ- Production rate on prey
- σ - Prey loss due to hunting
- γ - Efficiency of prey conversion into predator biomass
- μ - Predator Mortality rate
- R_1 - Predator re-introduction rate

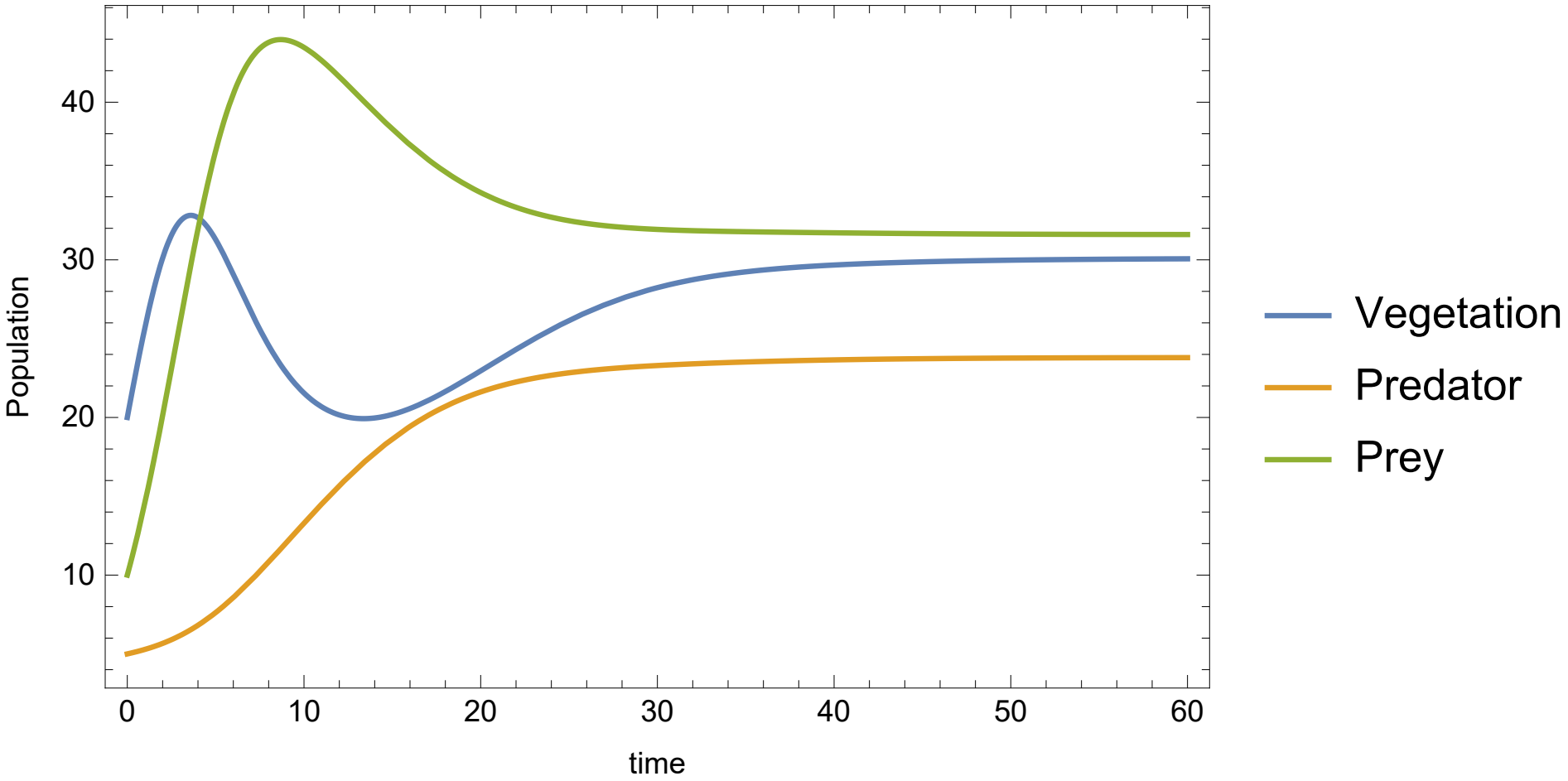
Population Models

$$\frac{dV}{dt} = R_f + r_V V\left(1 - \frac{V}{K_V}\right) - \alpha N_2 V - \omega V \tag{1}$$

$$\frac{dN_1}{dt} = R_1 + \gamma N_1 N_2 - \mu N_1 \tag{2}$$

$$\frac{dN_2}{dt} = R_2 + r_2 N_2\left(1 - \frac{N_2}{K_2}\right) + \beta N_2 V - \delta N_1 N_2 - \sigma N_2 \tag{3}$$

Population dynamics(Experimental data)



Facility Location Design

Aim: **Maximise Tourist Experiance**
Main Points:

- Potential Location (Zonation)
- Facilities
- Adaptability
- Proximity to tourist trail
- Community-wildlife balance

Maximizing Tourist Experiance

Decision Variables

$$X_{ij} = \begin{cases} 1 & \text{if facility } i \text{ is at location } j. \\ 0 & \text{Otherwise.} \end{cases}$$

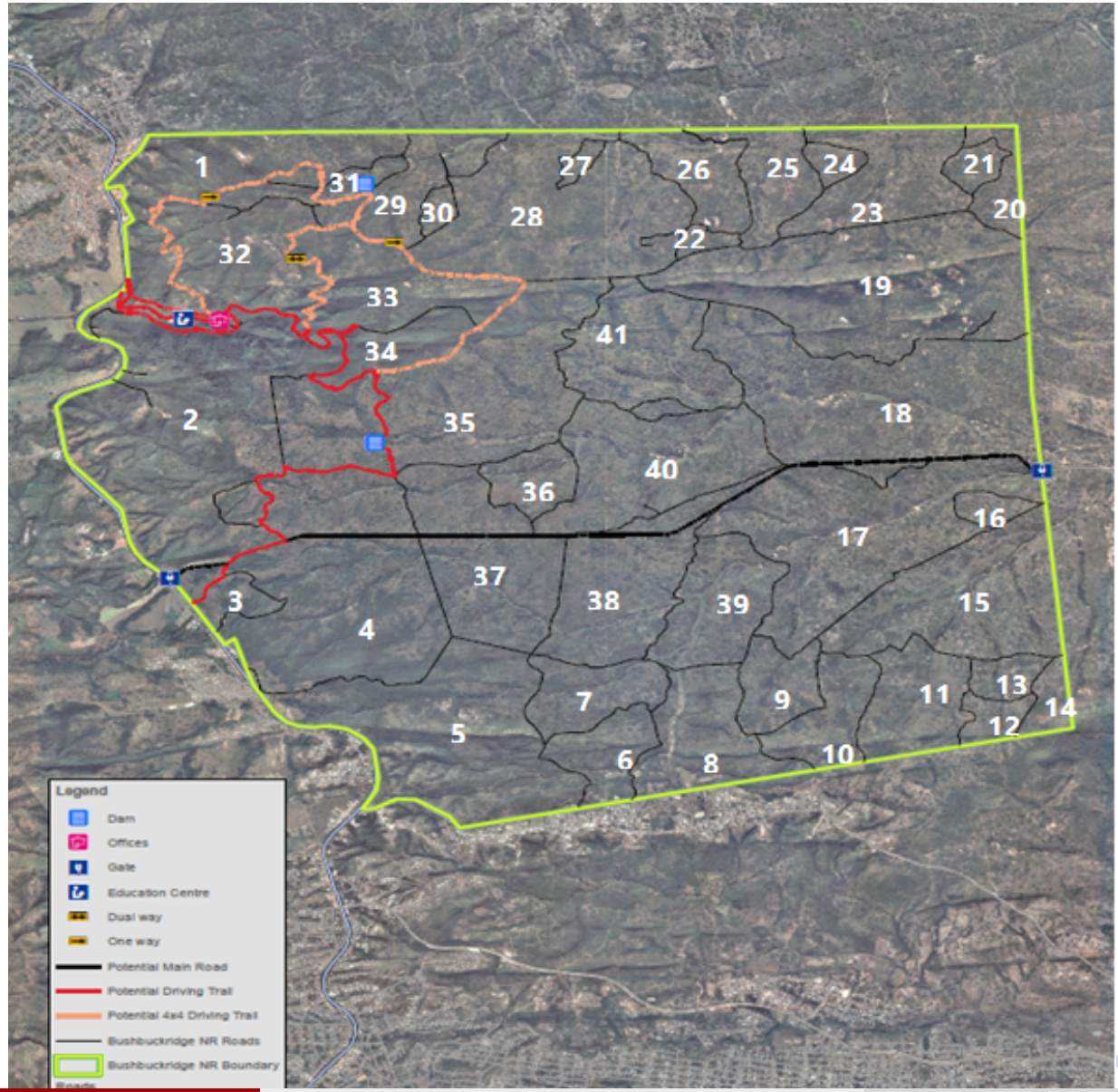
Parameters

- d_{ij} : Adaptability of "facility" i at location j.
- f_{ij} : Visibility factor from the trail if "facility" i is at location j.
- J_j : The set of adjacent local i to j.
- J_B : The set of all j next to the boundary.
- I_P : The set of all predators
- I_V : The set of all prey

Fixed Variables

- Tourist Trail
- Ancestral Gravesites

Locations(J)


1
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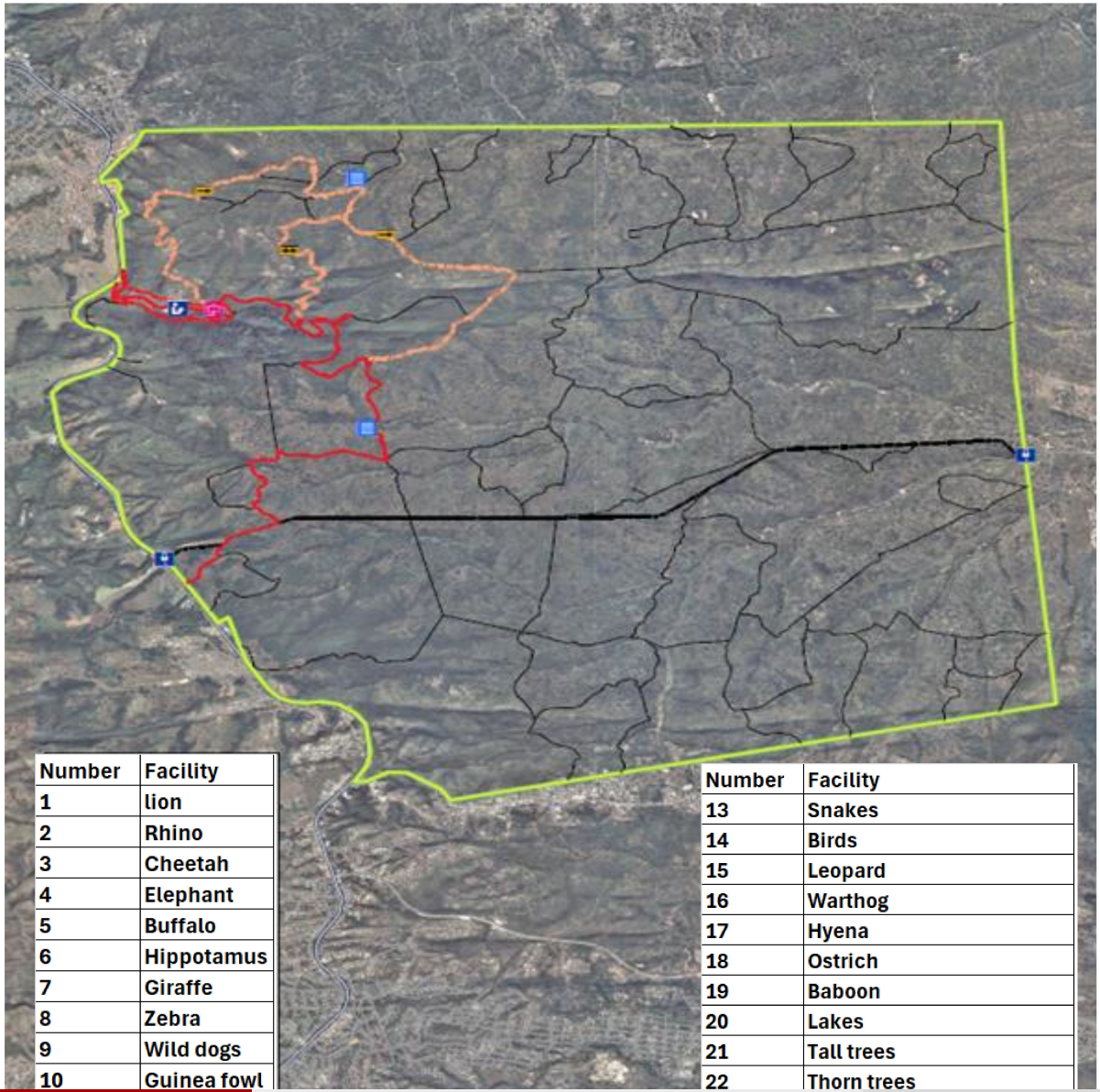
12
5
6
8
10
Legend
Dam
Offices
Gate
Education Centre
Dual way
One way
Potential Main Road
Potential Driving Trail
Potential 4x4 Driving Trail
Bushbuckridge NR Roads
Bushbuckridge NR Boundary

Facility(*I*)



Number	Facility
1	lion
2	Rhino
3	Cheetah
4	Elephant
5	Buffalo
6	Hippotamus
7	Giraffe
8	Zebra
9	Wild dogs
10	Guinea fowl

Number	Facility
13	Snakes
14	Birds
15	Leopard
16	Warthog
17	Hyena
18	Ostrich
19	Baboon
20	Lakes
21	Tall trees
22	Thorn trees

Maximizing Tourist Experiance

- **Objective Function**
  - Maximizing facility visibility and improve visitor experiance.
- **Constrained by:**
  - Each facility must have a location.
  - Each location can have a maximum of 2 facilities.
  - Office and accomodation should be sufficiently far enough from predators.
  - Hunting fields must be close enough to the community.
  - The community must be able to get medicinal plants and firewood.
  - Predator and prey cannot share the same location.
  - Baboon and cheetah should not share the same location.
  - The predators must not be at the boundary.

Maximizing Tourist Experiance

Mathematical modeling

$$\max_{X} \quad \sum_{i\in I}\sum_{j\in J}\sum_{k\in I}\sum_{l\in J} d_{ij} f_{kl} X_{ij} X_{kl}$$

Subject to

$$\sum_{j\in J} X_{ij} = 1, \quad \forall i \qquad \sum_{i\in I} X_{ij} \leq 2, \quad \forall j$$

$$\sum_{i\in I_P} X_{ij'} \leq 1 - X_{oj}, \quad \forall j \in J, j' \in J_i \qquad \sum_{i\in I_v}\sum_{j\in J_B} X_{ij} \geq 1$$

$$\sum_{j\in J_B} X_{Trees,j} \geq 1 \qquad X_{kj} + X_{lj} \leq 1, \quad k \in J_V, l \in J_P, \forall j$$

$$X_{cheetah,j} + X_{Baboon,j} \leq 1, \quad \forall j \qquad \sum_{i\in I_P}\sum_{j\in J_B} X_{ij} = 0$$

Maximizing Tourist Experiance

Linear Facility layout Design

$$\max_{X} \quad \sum_{i \in I} \sum_{j \in J} f_{ij} X_{ij}$$

Subject to

$$\sum_{j \in J} X_{ij} = 1, \quad \forall i$$

$$\sum_{i \in I} X_{ij} \leq 2, \quad \forall j$$

$$\sum_{i \in I_P} X_{ij'} \leq 1 - X_{oj}, \quad \forall j \in J, j' \in J_i$$

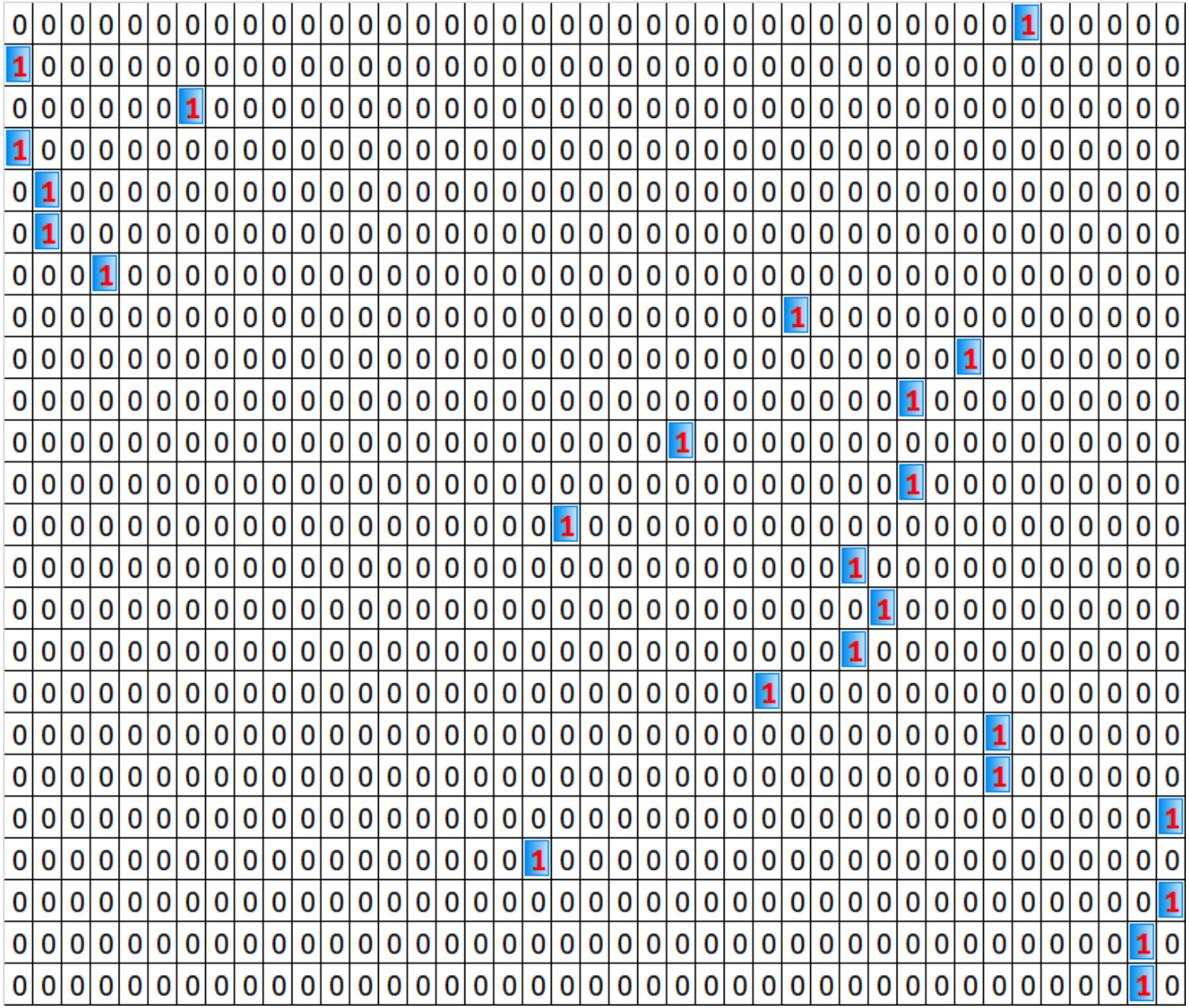
$$\sum_{i \in I_v} \sum_{j \in J_B} X_{ij} \geq 1$$

$$\sum_{j \in J_B} X_{Trees,j} \geq 1$$

$$X_{kj} + X_{lj} \leq 1, \quad k \in J_V, l \in J_P, \forall j$$

$$X_{cheetah,j} + X_{Baboon,j} \leq 1, \quad \forall j$$

$$\sum_{i \in I_P} \sum_{j \in J_B} X_{ij} = 0$$




Legend

Benefits to Stakeholders

1. **Biodiversity and Tourism**
   - Improving visitor experiance.
   - Identify best usage of space.
2. **Local Population**
   - Inform a fair and equitable discussion between the government and community
3. **Government**
   - Use tool to identify and redirect resources.
   - Reduce human-wildlife conflict and illegal activities (e.g., poaching) through better management and monitoring.

Conclusion

- Revitalizing Bushbuckridge Nature Reserve requires an integrated approach.
- Collaboration with local communities and scientific institutions is key.
- Sustainable eco-tourism can drive conservation and economic growth.
- Mathematical models and strategic planning will ensure long-term success.

Future Work

- Apply realistic data to population model
- Investigate optimal solution for non-linear facility layout design, incorporating realistic parameters.
- Consider other strategies.

THANK YOU!

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