AI for Wildlife Conservation

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AI & Multiagent Systems Research for Social Impact

Wildlife Conservation

Public Health

Public Safety and Security

Optimize Our Limited Intervention Resources

Lesson #1:Conservation & AI researchers both benefit from collaboration

Domain Impact & AI Innovation Go together: Incentives for collaboration

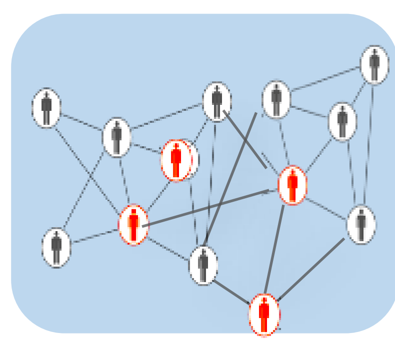
Green security games

Wildlife Conservation

Multiagent Systems Research

Stackelberg security games

Public Safety & Security



Social Networks & Bandits

Public Health

Lesson #2:

AI4SI only possible with interdisciplinary partnerships, with NGOs (non-profits)

Empower non-profits to use AI tools; avoid being gatekeepers to AI4SI technology

LOS ANGELES LGBT CENTER

S.P.Y safe place for youth

my friend's place

armman

ASHOKA TRUST FOR RESEARCH IN ECOLOGY & THE ENVIRONMENT

Wildlife Conservation Society

WWF

Air Shepherd The Lindbergh Foundation

Swasti THE HEALTH CATALYST

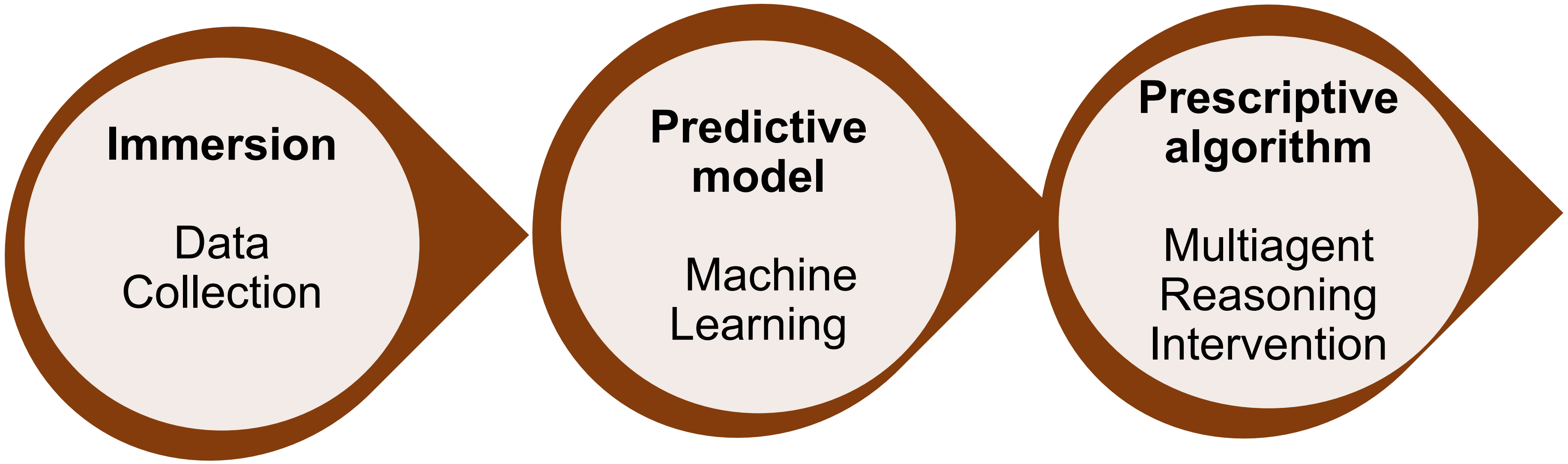
Wildlife Conservation Trust

SMART

everwell

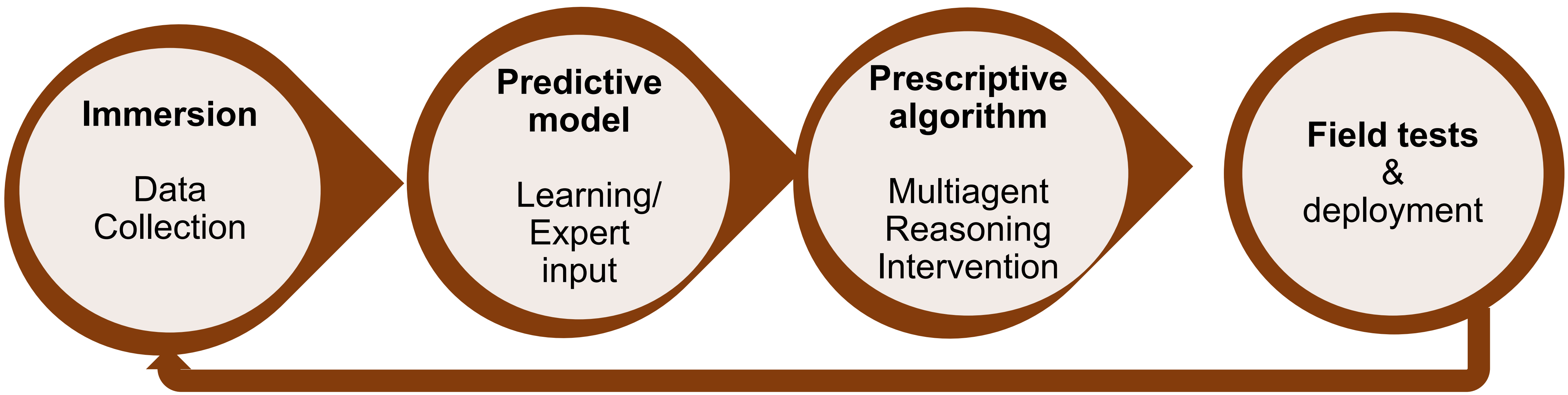
KhushiBaby

Lesson #3:
Data-to-deployment pipeline: Partner interactions throughout the pipeline



Lesson #3:
Data-to-deployment pipeline

Field test & deployment: Social impact is a key objective



Outline: AI for Wildlife Conservation

- *Background: How I got into this area*
- *Anti-poaching prediction and foot patrols*
- *Future directions: Data limitations, drones*
- *Google AI for Social Good workshops*
- *Future directions: Human-wildlife conflict*

- Cover papers from AAMAS, AAAI, IJCAI, NeurIPS…
- PhD students & postdocs highlighted
- Collaboration with Andy Plumptre

AI researcher: theory/simulations in the lab…Until 2006…

11 July 2006: Mumbai

ARMOR Airport Security: LAX(2007)
Game Theory direct use for security resource optimization?

Erroll Southers

LAX Airport, Los Angeles

LAX Checkpoint

Surveillance

Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games

Adversary

Defender

	Terminal #1	Terminal #2
Terminal #1	4, -3	-1, 1
Terminal #2	$\boxed{-5, 5}$	2, -1

Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games

Adversary

Defender

	Terminal #1	Terminal #2
Terminal #1	4, -3	$\boxed{-1, 1}$
Terminal #2	-5, 5	2, -1

Date: 6/1/2021

Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games

Stackelberg: Defender commits to randomized strategy, adversary strategic response

Security game: Played on targets, payoffs based on calculated losses

Optimization: Not 100% security; increase cost/uncertainty to attackers

Adversary

Defender

	Terminal #1	Terminal #2
Terminal #1	4, -3	-1, 1
Terminal #2	-5, 5	2, -1

ARMOR at LAX
Basic Security Game Operation [2007]


Kiekintveld


Pita

	Target #1	Target #2	Target #3
Defender #1	2, -1	-3, 4	-3, 4
Defender #2	-3, 3	3, -2	….
Defender #3	….	….	….

Mixed Integer Program

Pr (Canine patrol, 8 AM @Terminals 2,5,6) = 0.17

Canine Team Schedule, July 28

	Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
8 AM		Team1			Team3	Team5		
9 AM			Team1	Team2				Team4
…	…	…	…	…	…	…	…	…

ARMOR: Optimizing Security Resource Allocation [2007]

First application: Computational game theory for operational security

January 2009

•January 3rd	*Loaded 9/mm pistol*
•January 9th	*16-handguns,*
	1000 rounds of ammo
•January 10th	*Two unloaded shotguns*
•January 12th	*Loaded 22/cal rifle*
•January 17th	*Loaded 9/mm pistol*
•January 22nd	*Unloaded 9/mm pistol*

Deployed Security Games Systems…
Getting out of the lab & into the field!

ARMOR

2007-

Erroll Southers testimony
US Congress subcommittee

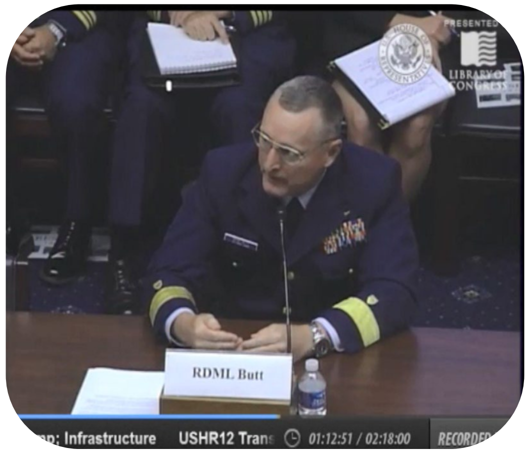
IRIS

2009-

TSA testimony
US Congress subcommittee

PROTECT

2011-



Coast Guard testimony
US Congress subcommittee

Estimated > $100 Million savings in decade of deployment (Winterfeldt et al)

World Bank Global Tiger Initiative
How I got into AI for Wildlife Conservation

Visiting Uganda & Meeting Andy Plumptre

Date: 6/1/2021

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Poaching of Wildlife in Uganda
Limited Intervention (Ranger) Resources to Protect Forests

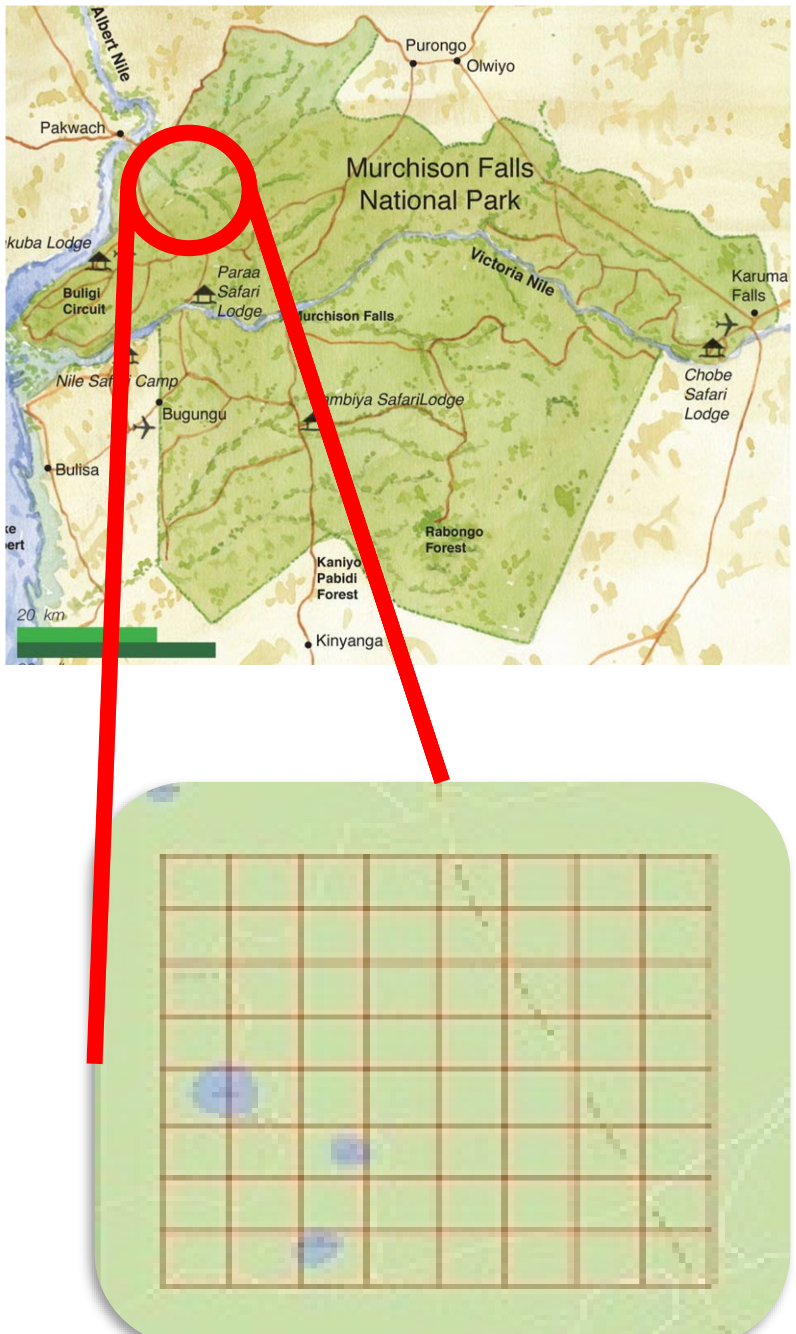
Snare or Trap

Wire snares

Stackelberg Security Games?

(IJCAI 2015)

Fang



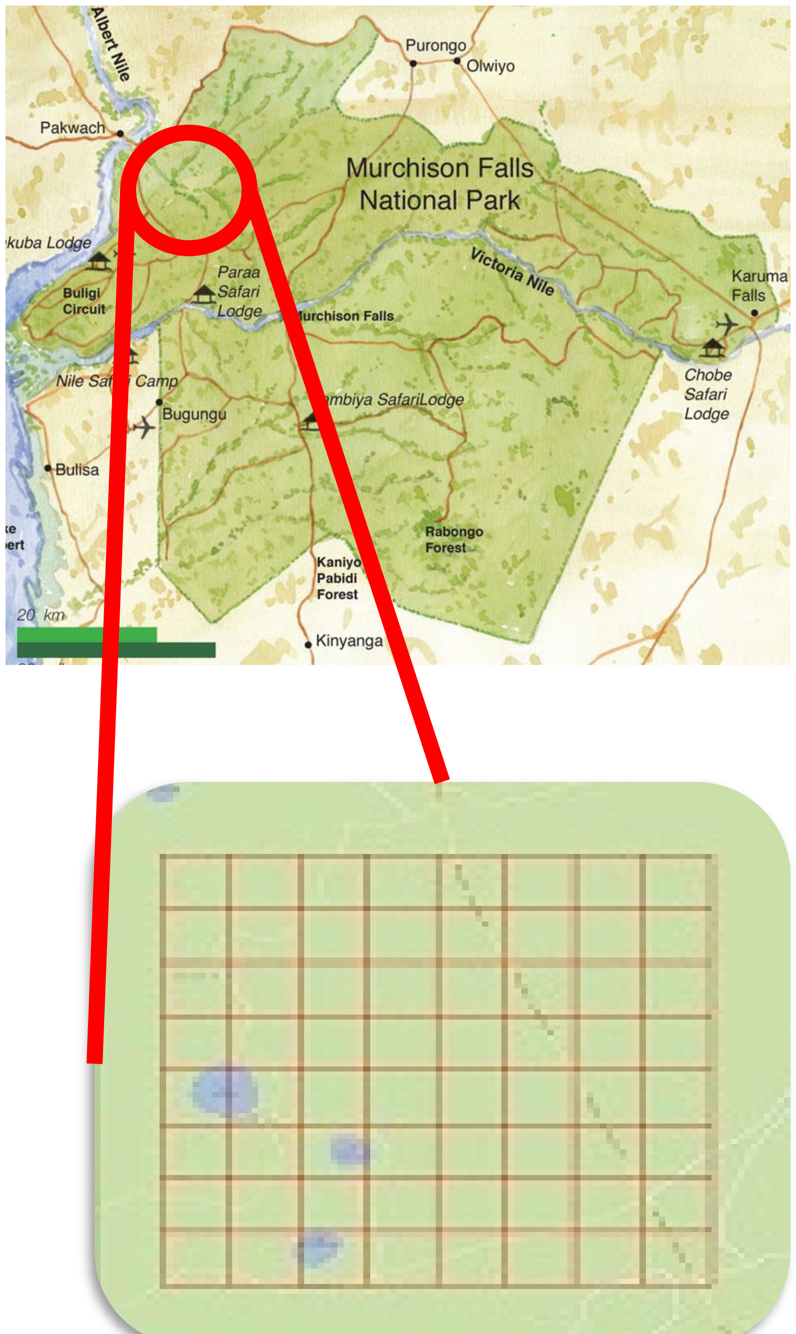
➢ ***Stackelberg security games (SSG)***

	Area1	Area2
Area1	4, -3	-1, 1
Area2	-5, 5	2, -1

Green Security Games Combine Stackelberg Security Games and Machine Learning

(IJCAI 2015)

Fang



- ***Not fully strategic adversaries***
- ***Boundedly rational poachers, past poaching data***
- ***Learn adversary response model at targets "i"***

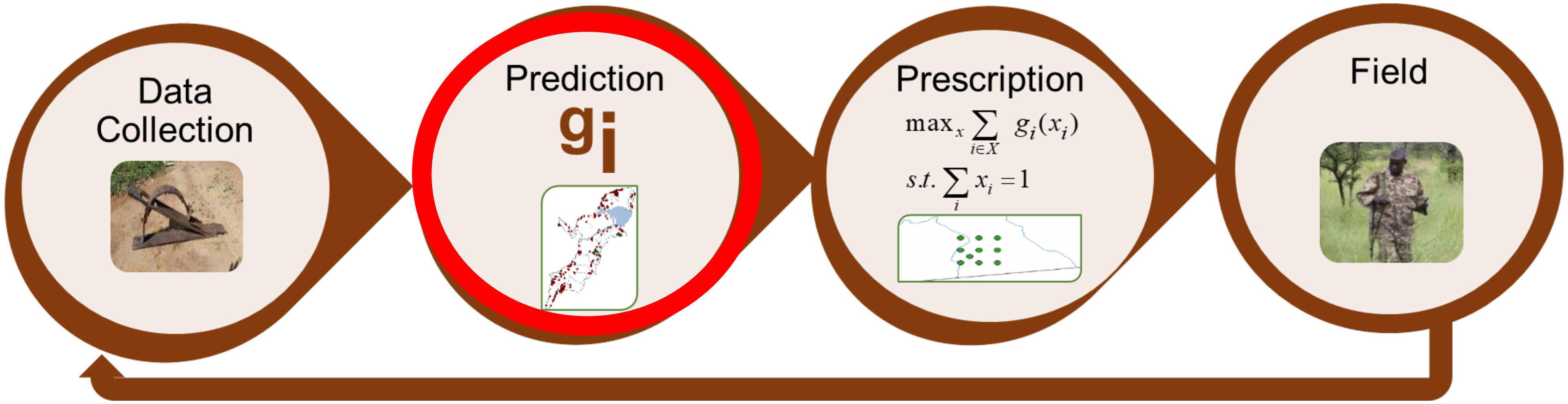
	Area1	Area2
Area1	4, -3	-1, 1
Area2	-5, 5	2, -1

Date: 6/2/2021

Learning Adversary Response Model: Uncertainty in Observations

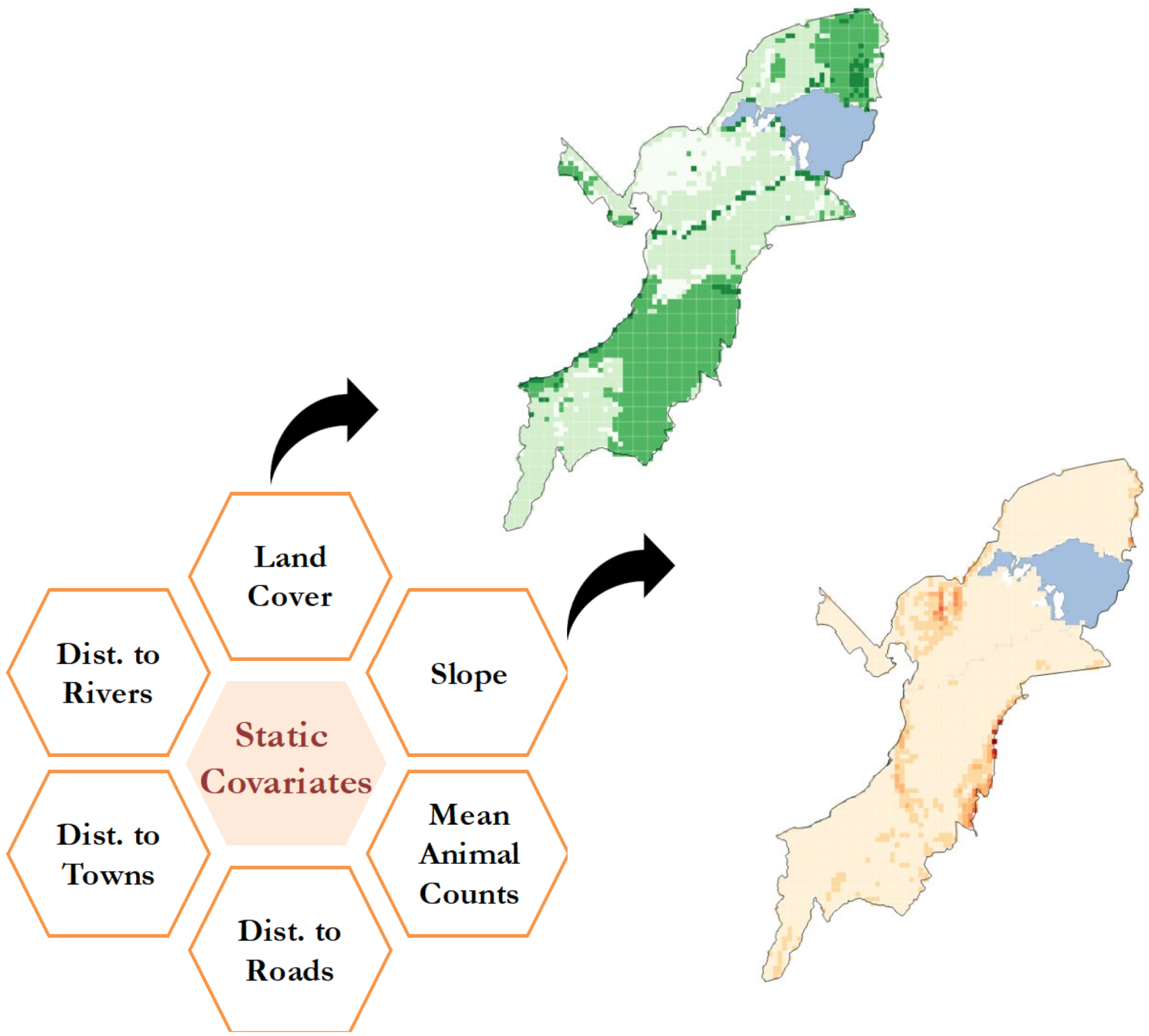

Nguyen

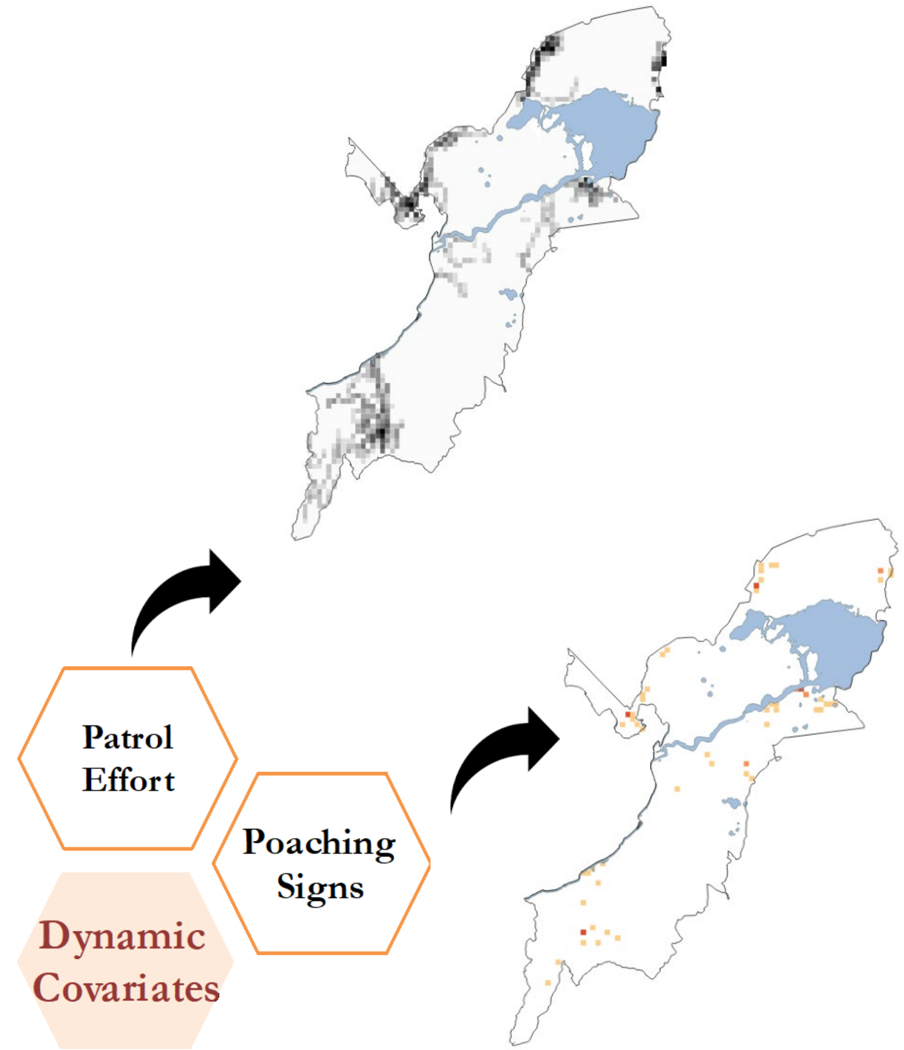

Gholami



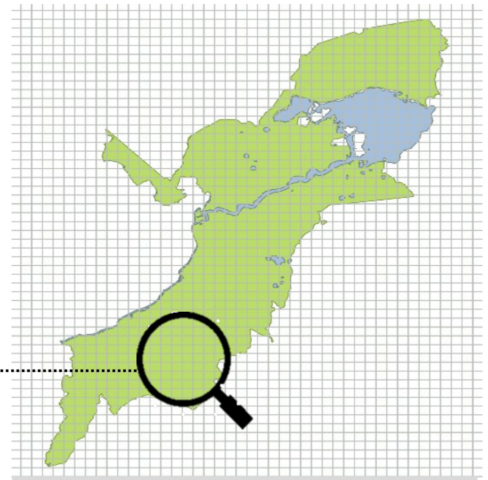
Datasets Predictive Covariates (Features)
14 years of Past Poaching Data from Uganda

Gholami

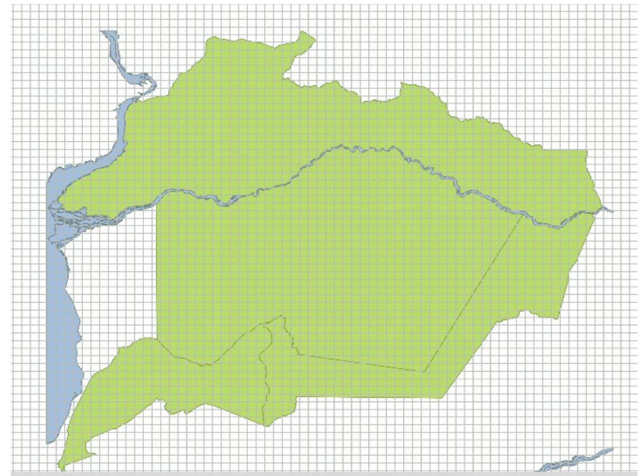




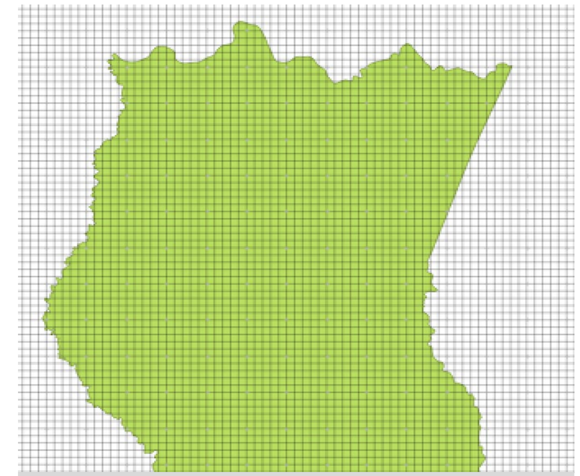
Spatiotemporal Data Processing



Queen Elizabeth Park
(Uganda, 2520 sq. km)



Murchison Fall Park
(Uganda, 3892 sq. km)



Mondulkiri Park
(Cambodia, 2668 sq. km)

- Discretize space into grid (e.g., 1km×1km)
- Discretize time into small time steps (e.g. 3 Month)

Predictive Covariates

Time Step 1: Jan-Mar 2011

Animal Density

Forest Cover

0.5, 0.6, …, 0.1	0.25, 0.16, …, 0.9	0.4, 0.6, …, 0.2
0.3, 0.8, …, 0.15	0.55, 0.8, …, 0.2	0.7, 0.6, …, 0.7
0.7, 0.3, …, 0.55	0.8, 0.3, …, 0. 35	0.2, 0.35, …, 0. 95

$\propto$

Snare Detections

Snare detected

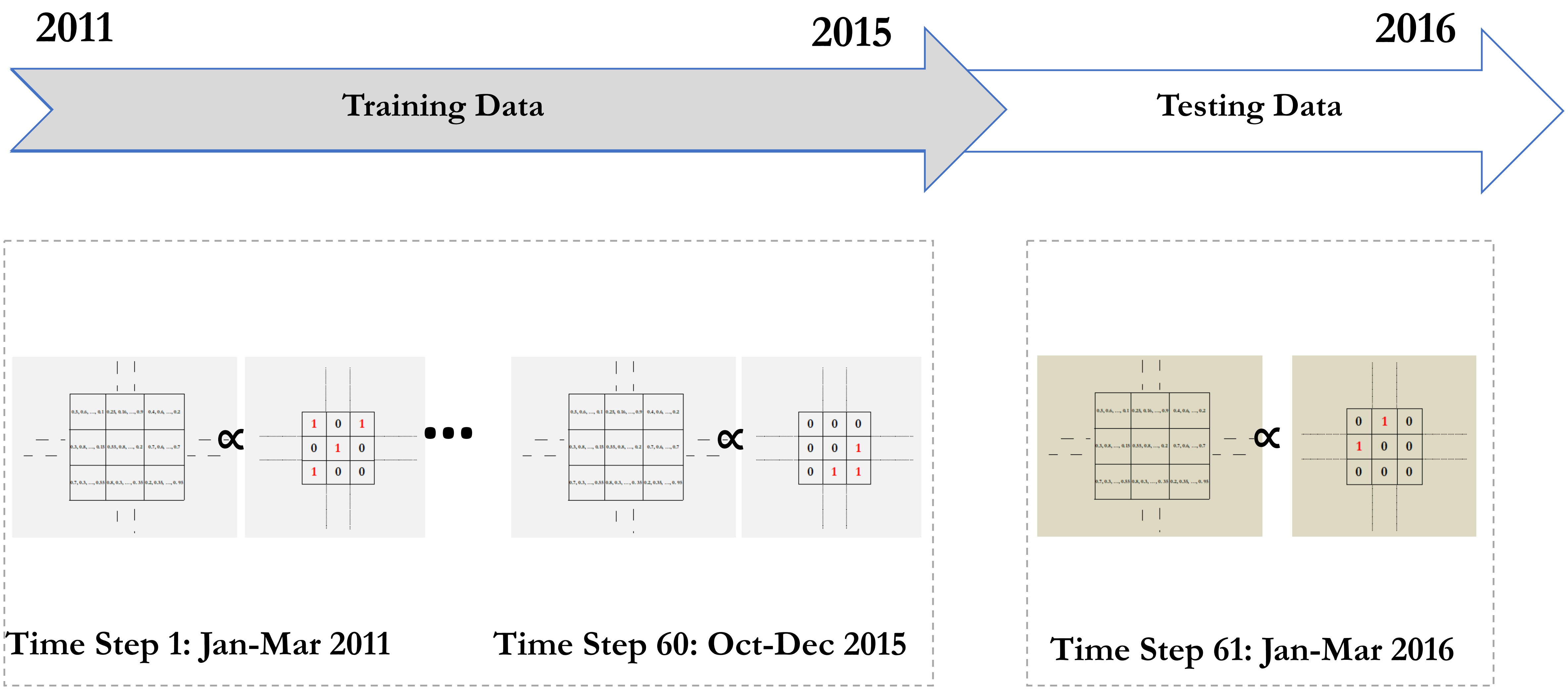
Snare not detected

1	0	1
0	1	0
1	0	0

Spatiotemporal Dataset Generation


Gholami

Data: Predictive Covariates + Snare Detections



Positive and Unlabeled Data

Gholami

Assumptions:

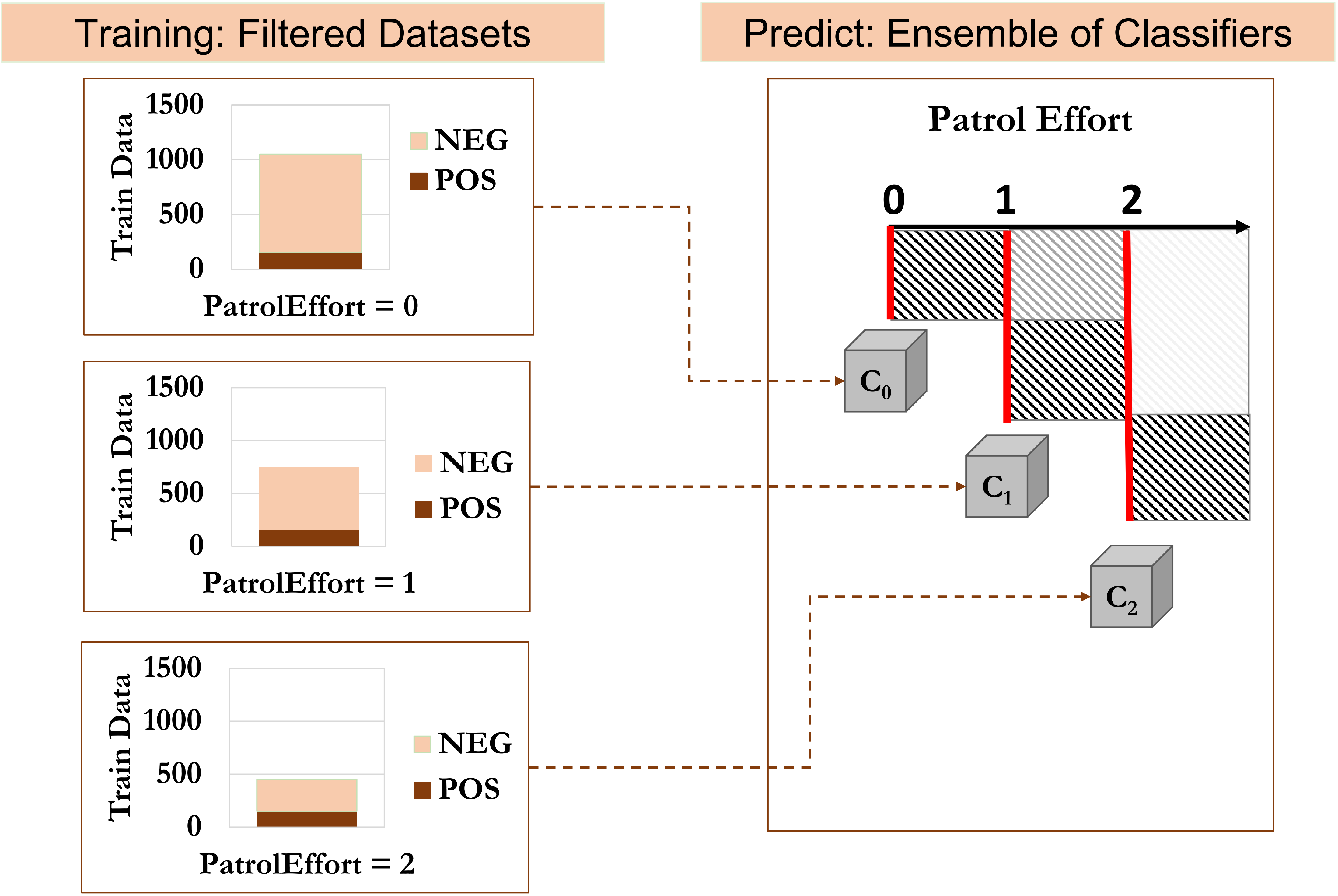
- Negative attack records are **uncertain & uncertainty** is related to **patrol effort**

Patrol Effort: 1.5 km
Record: No Attack (NEG)

Patrol Effort: 1.9 km
Record: Attack (POS)

Adversary Response Modeling
Imperfect Observation Ensemble Model

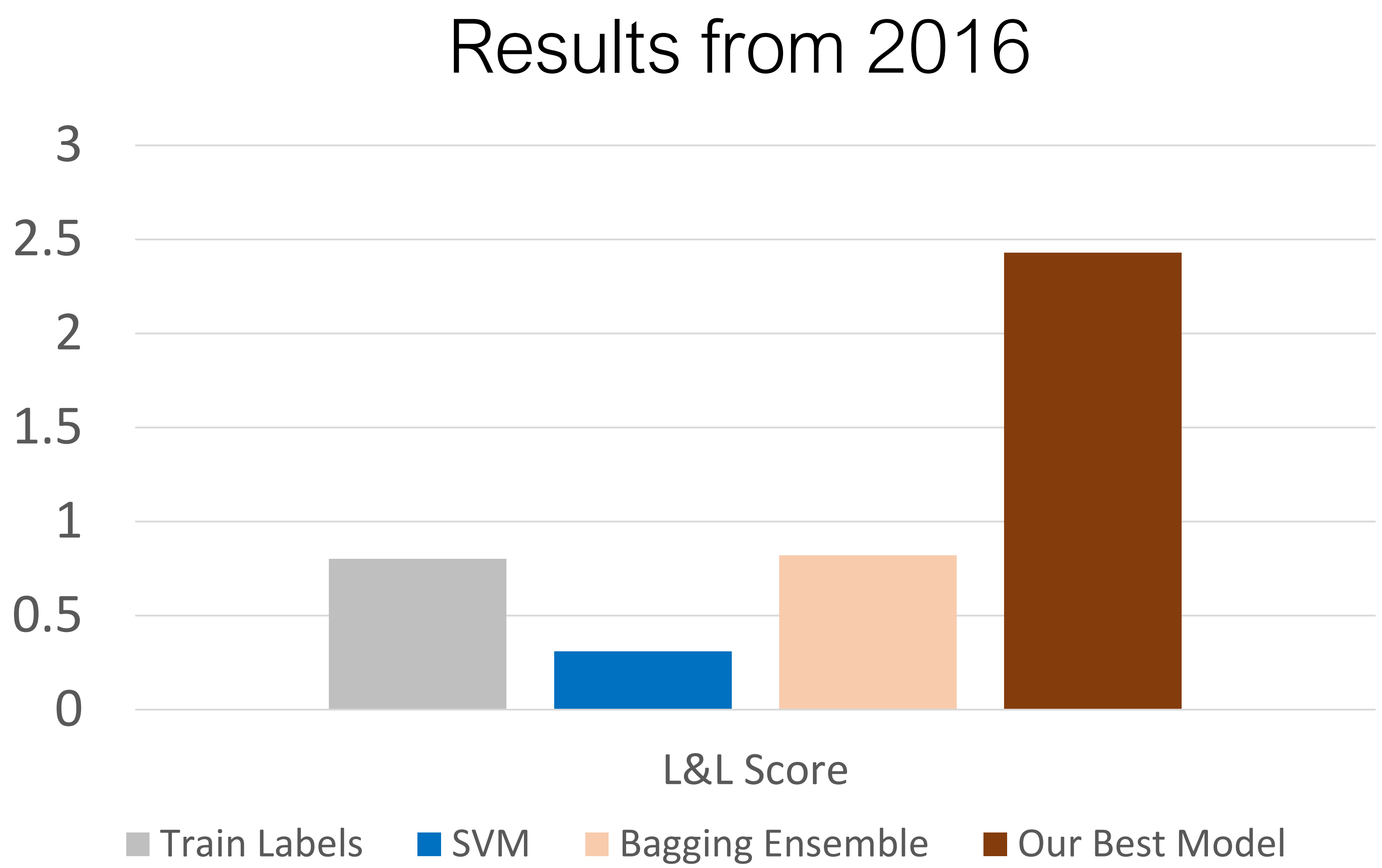

Gholami



PAWS: Protection Assistant for Wildlife Security
Queen Elizabeth National Park Predictions


Gholami

Poacher Behavior Prediction



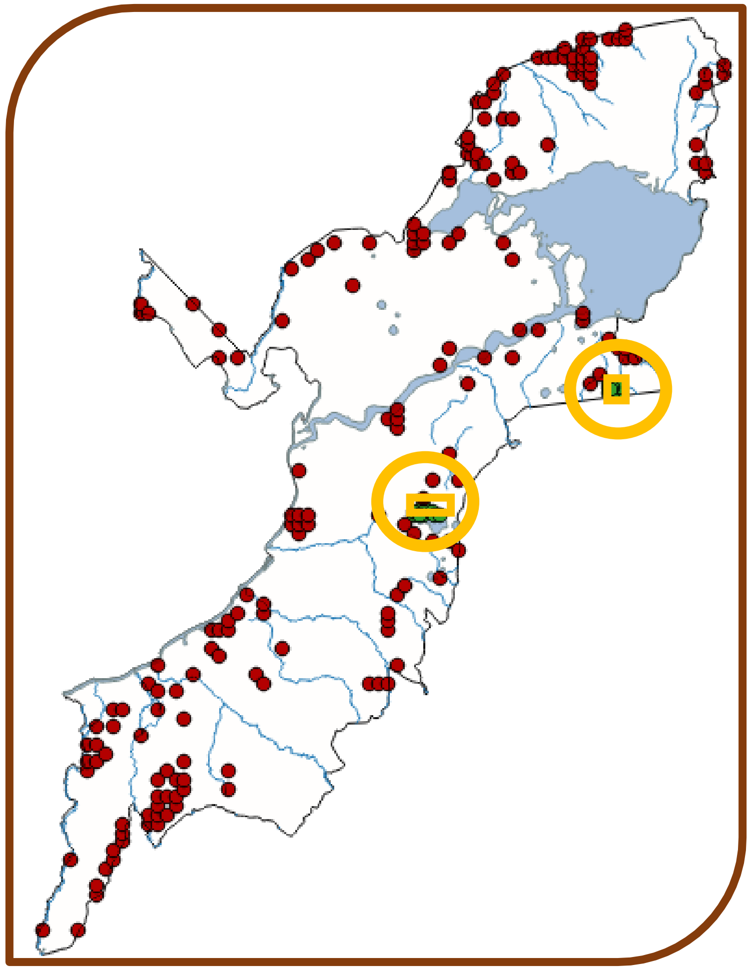
PAWS: First Pilot in the Field

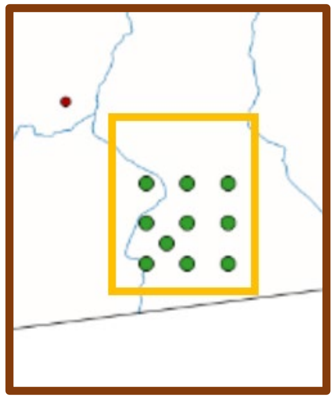
(AAMAS 2017)

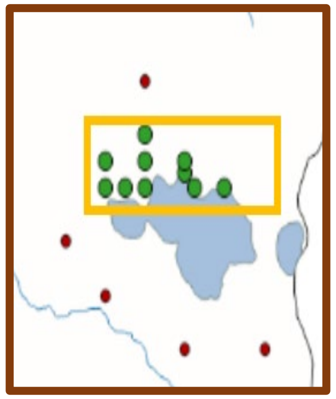
Ford

Gholami

- Two 9-sq.km areas, infrequent patrols







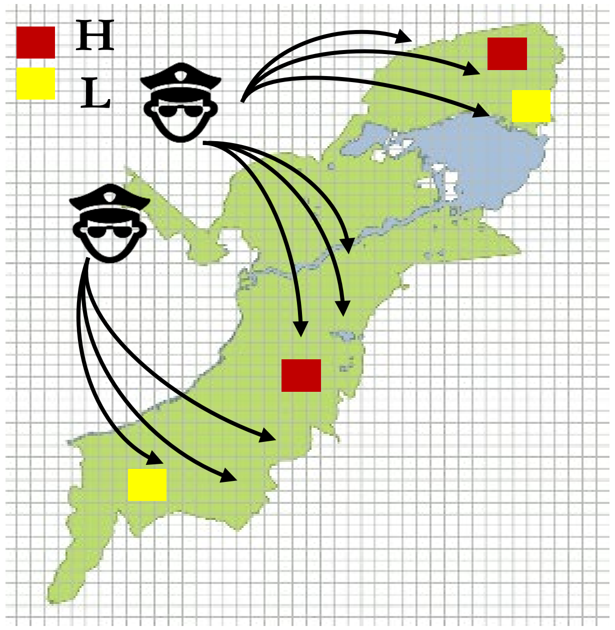
- Poached elephant
- 1 elephant snare roll
- 10 Antelope snares

PAWS Predicted High vs Low Risk Areas: 2 National Parks, 24 areas each, 6 months

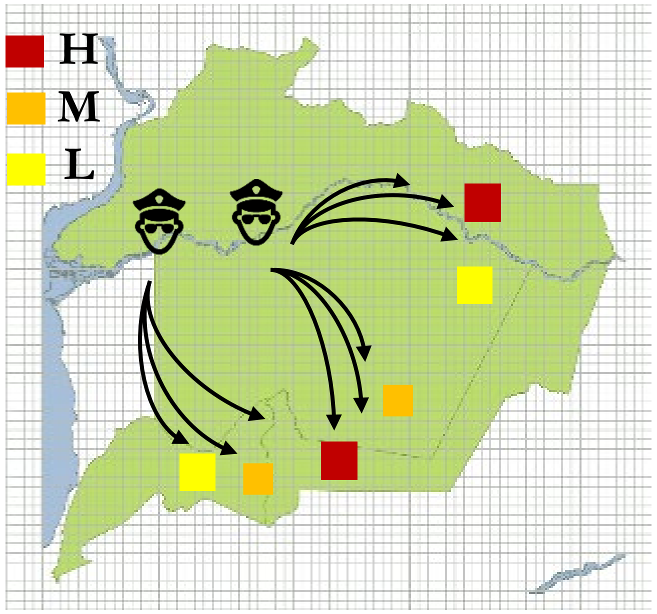
(ECML PKDD 2017, ICDE 2020)

Ford

Gholami

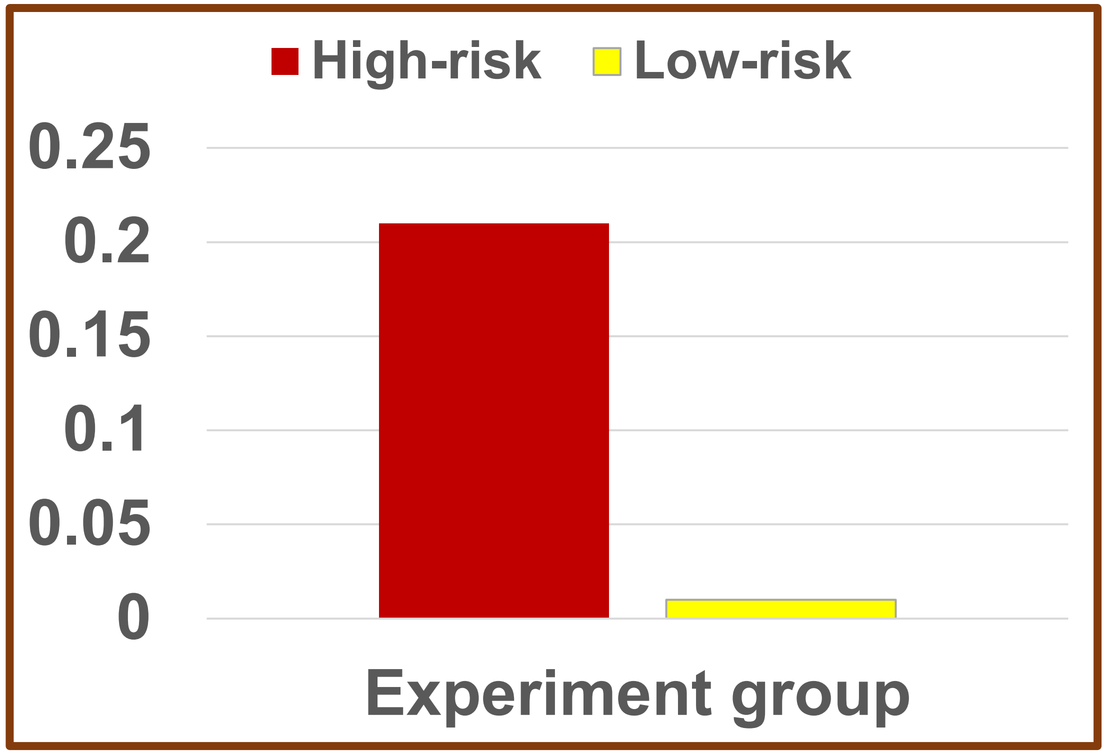


Queen Elizabeth National Park

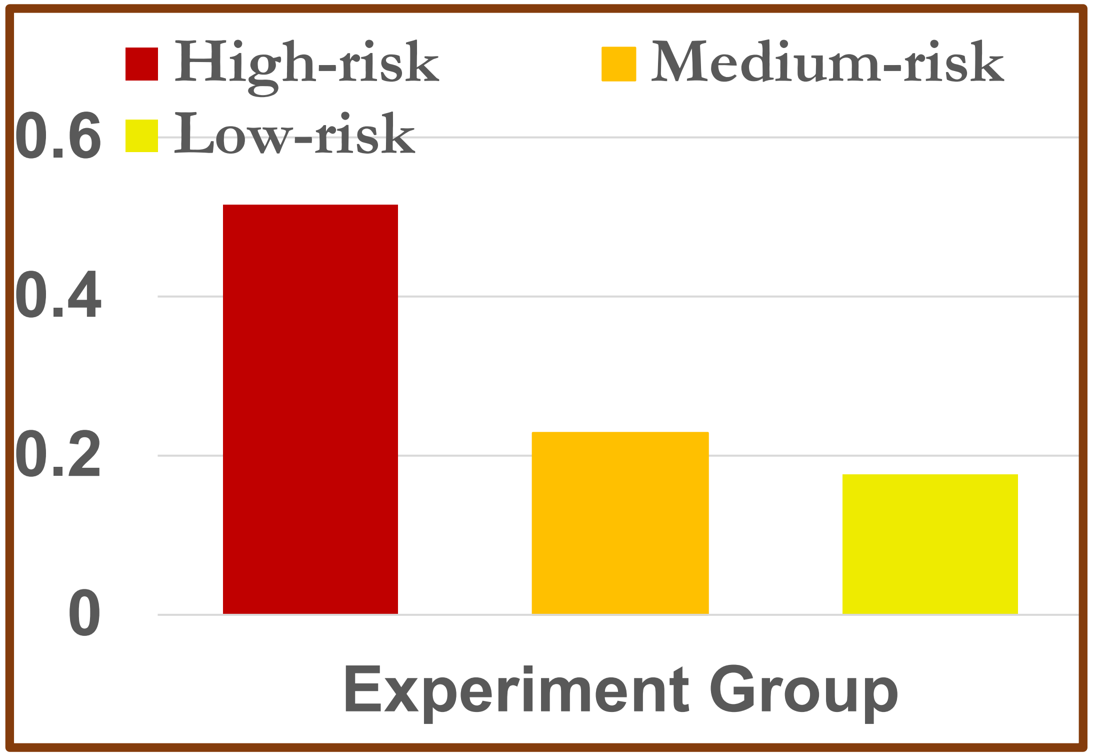


Murchison Falls National Park

Snares per patrolled sq. KM



Snares per patrolled sq. KM



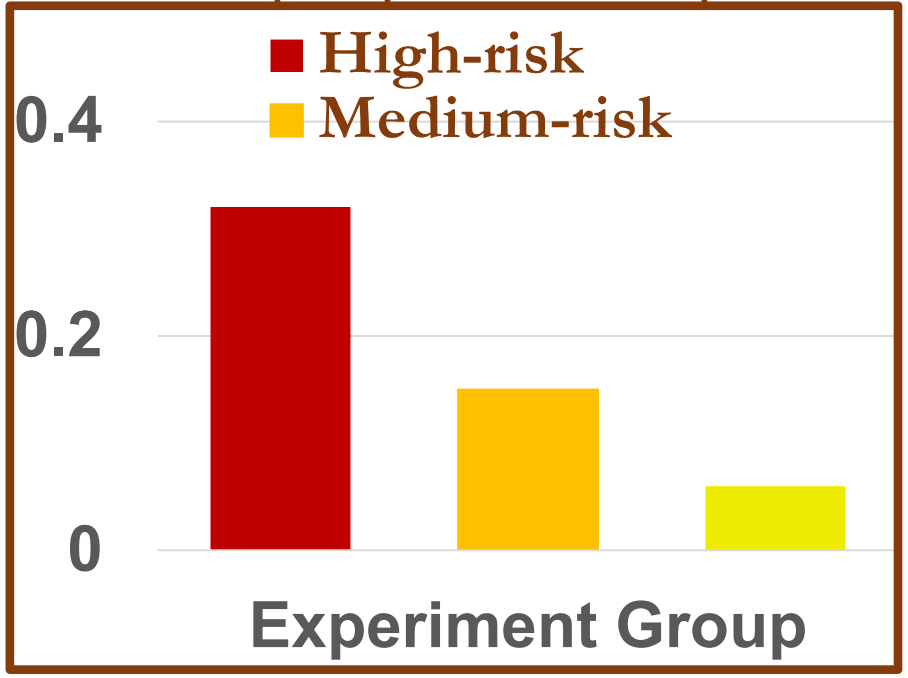
PAWS Real-world Deployment
Cambodia: Srepok Wildlife Sanctuary [2018-2019]

PAWS Real-world Deployment
Cambodia: Srepok Wildlife Sanctuary

(ICDE 2020)

Xu

Snares per patrolled sq. KM



2019: *521 snares/month*

vs

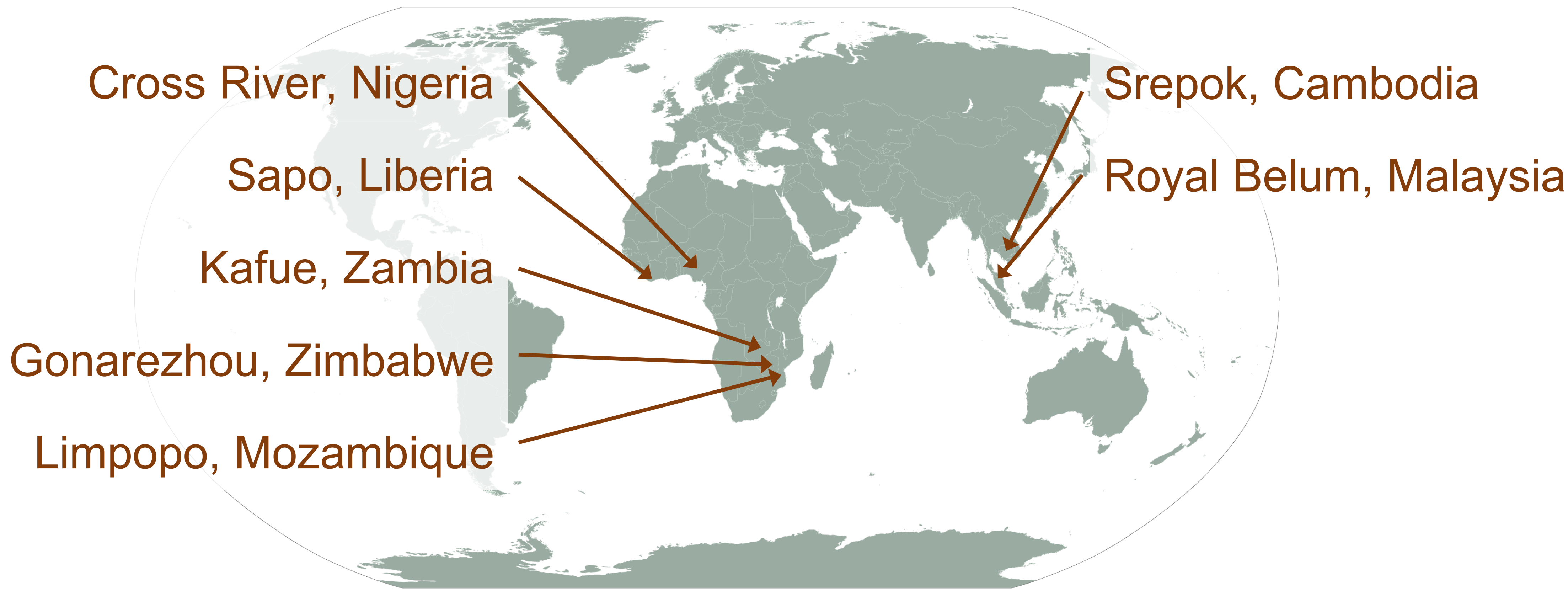
2018: *101 snares/month*

2021 PAWS

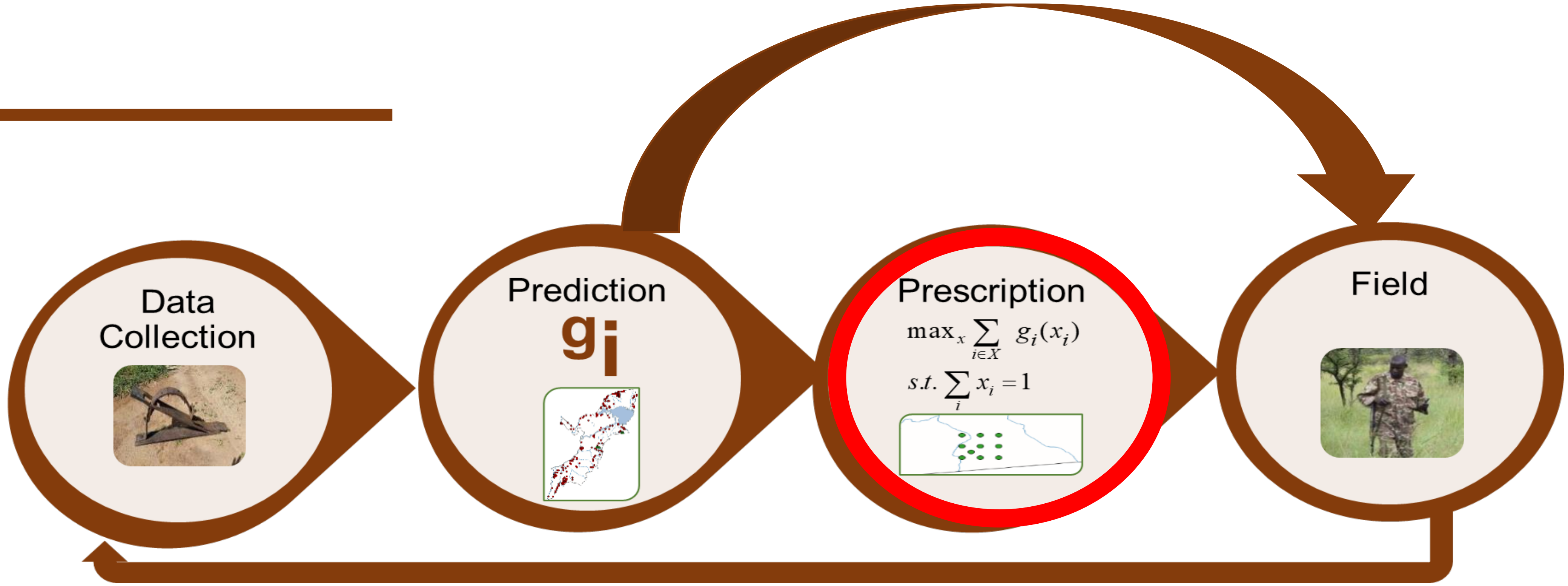
1,000 snares in March

PAWS GOES GLOBAL with SMART platform!!

Protect Wildlife
800 National Parks
Around the Globe



Prescription Phase to Improve Recommendations



	Area1	Area2
Area1	4, -3	-1, 1
Area2	-5, 5	2, -1

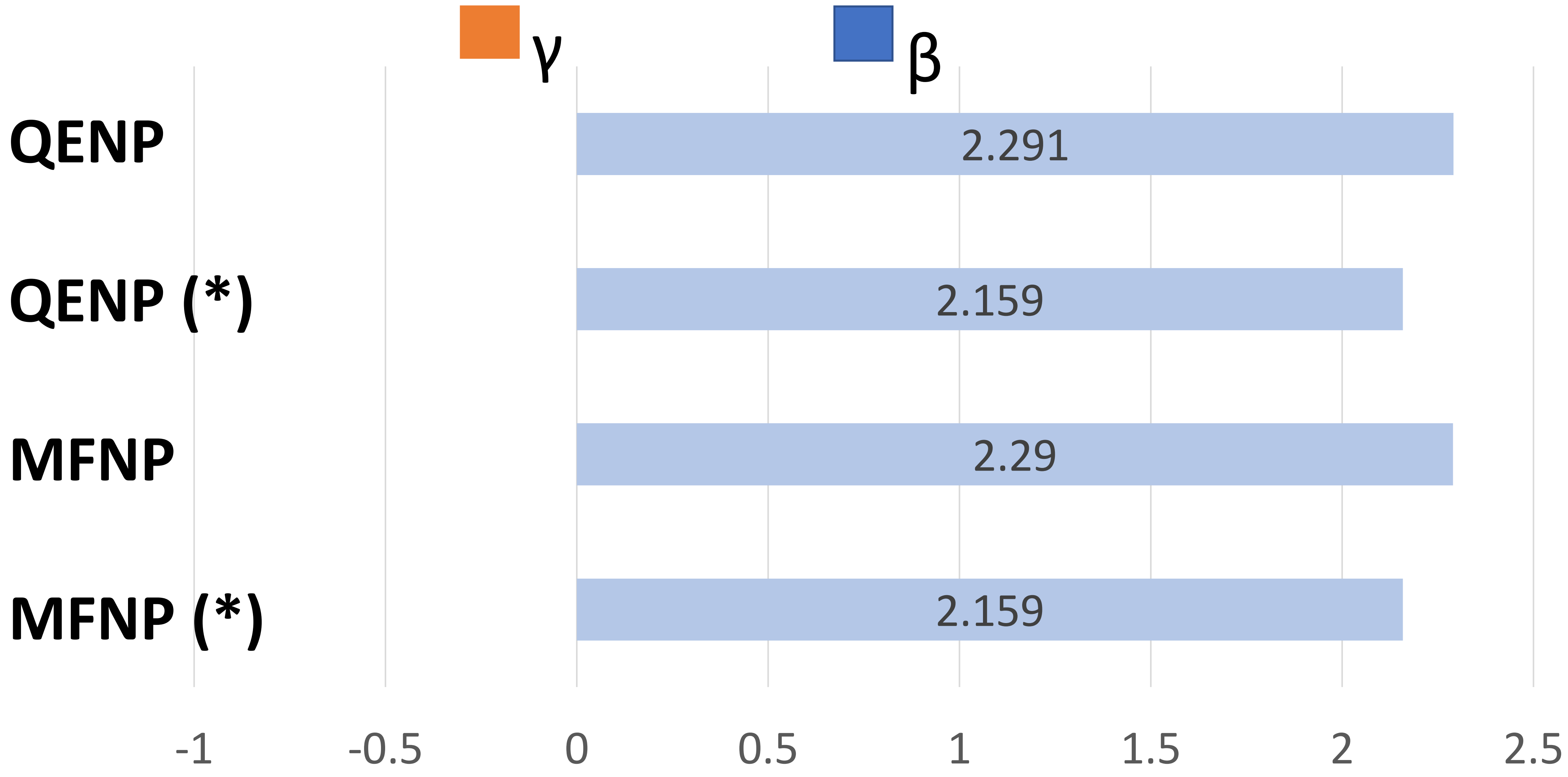
Is Adversary observing & Reacting to Patrols?
Evidence from the Field Justifies Stackelberg Assumption


Xu


Perrault

- Logistic regression model

$$a_i + \gamma \cdot \mathtt{past\_effort} + \beta \cdot \mathtt{current\_effort}$$



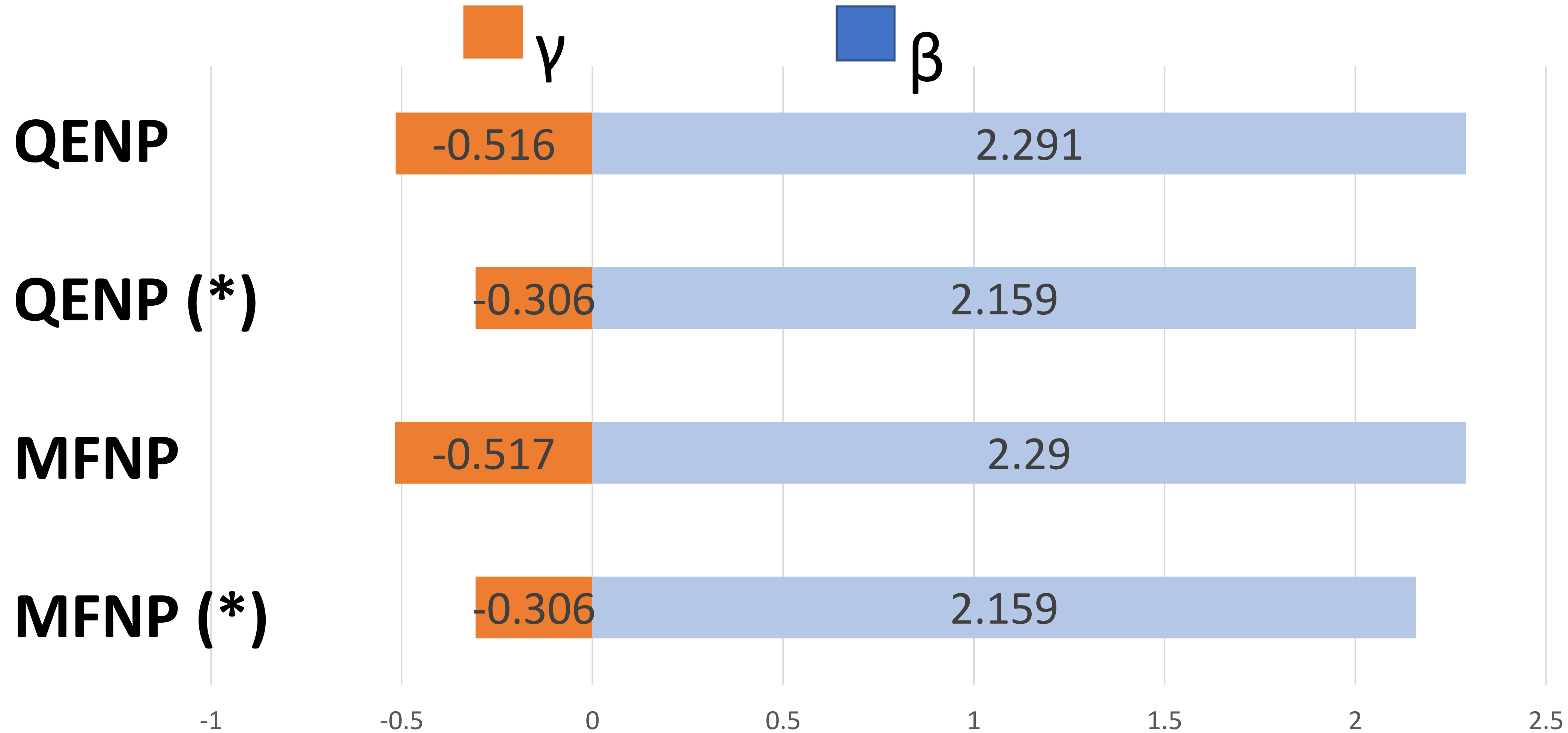
Demonstrating Deterrence:
Evidence from the Field Justifies Stackelberg Assumption *(UAI 2021)*

Xu

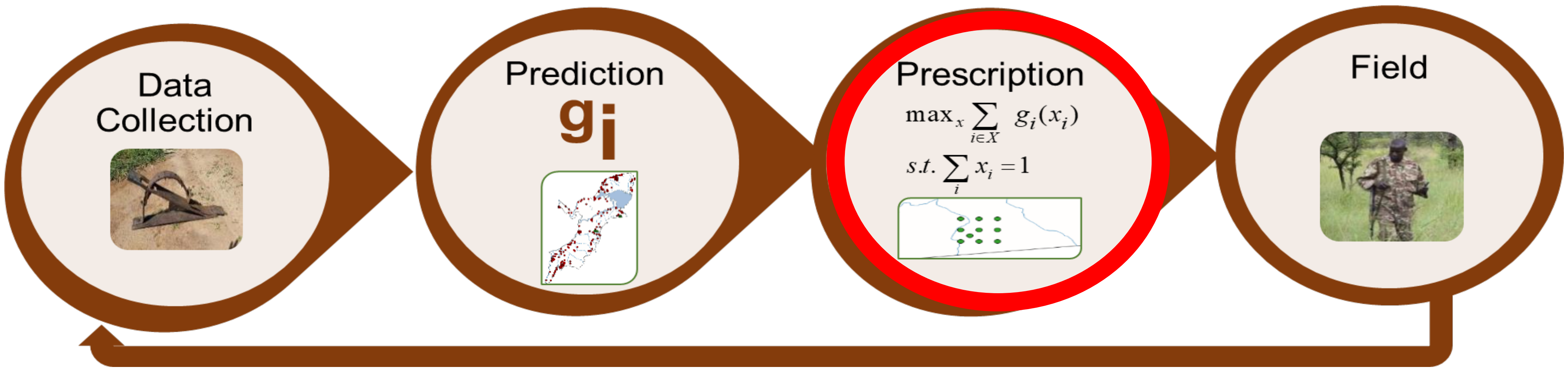
Perrault

➢ Is adversary observing & reacting to patrols? Logistic regression model

$$a_i + \gamma \cdot \texttt{past\_effort} + \beta \cdot \texttt{current\_effort}$$



New Challenges in Solving Games to Prescribe Patrols



	Area1	Area2
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Patrol Routes in Complex Terrain: Solving Security Game with Learned Adversary Model

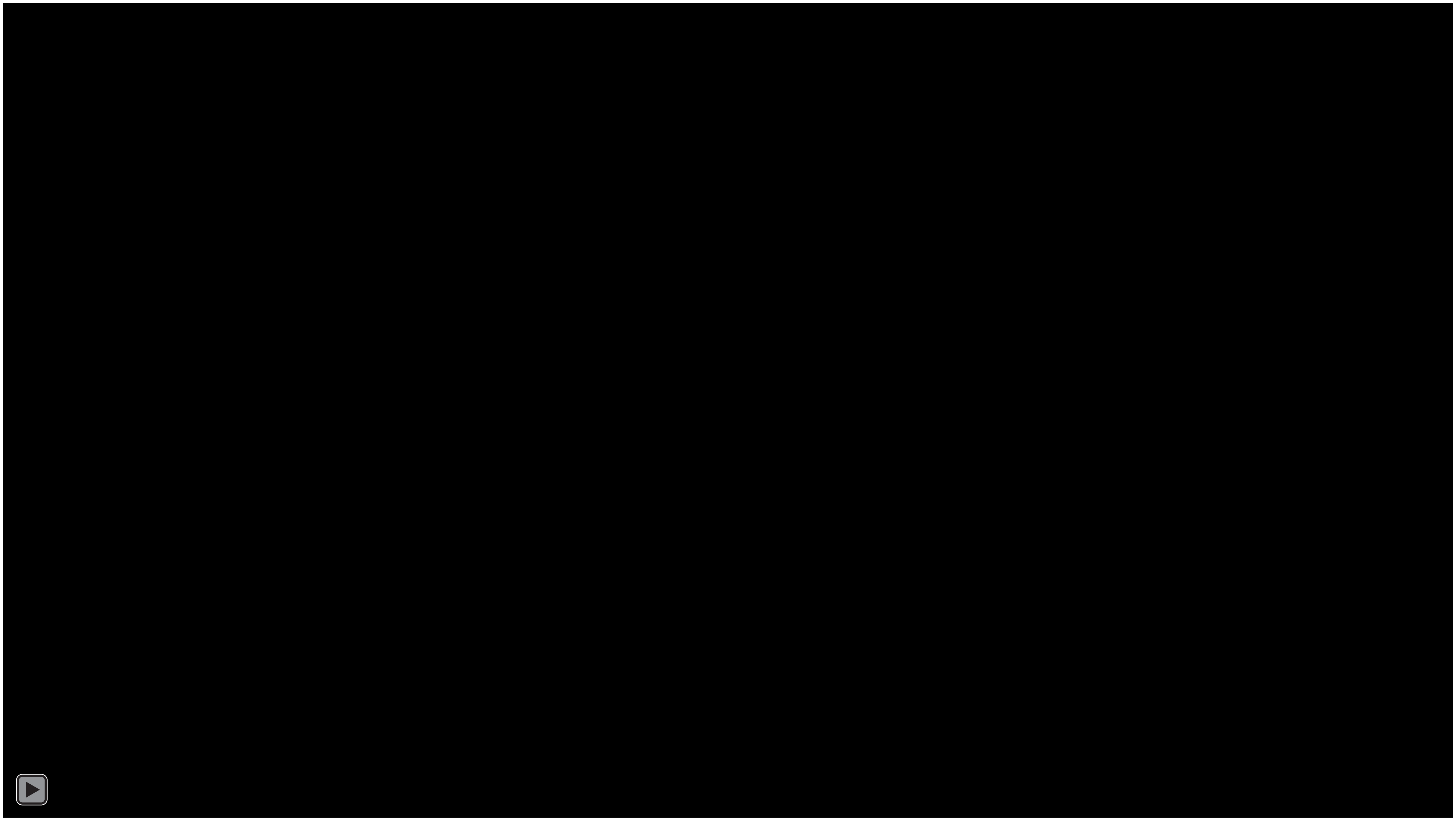
- Solving Stackelberg security game with learned adversary model

  → Difficulty of generating routes: many constraints on patrols

Malaysia:
Tamen Negara

Panthera

PAWS: Protection Assistant for Wildlife Security



Challenge: Uncertainty in Deterrence-Based Patrol Planning

(UAI 2021)


Xu


Perrault

$$a_i + \gamma \cdot \texttt{past\_effort} + \beta \cdot \texttt{current\_effort}$$

Uncertainty in exact parameter value

➡ **Robust planning**

evaluated in terms of **regret**: how well we could have done

Patrol in time T affects adversary behavior in time $T + 1$

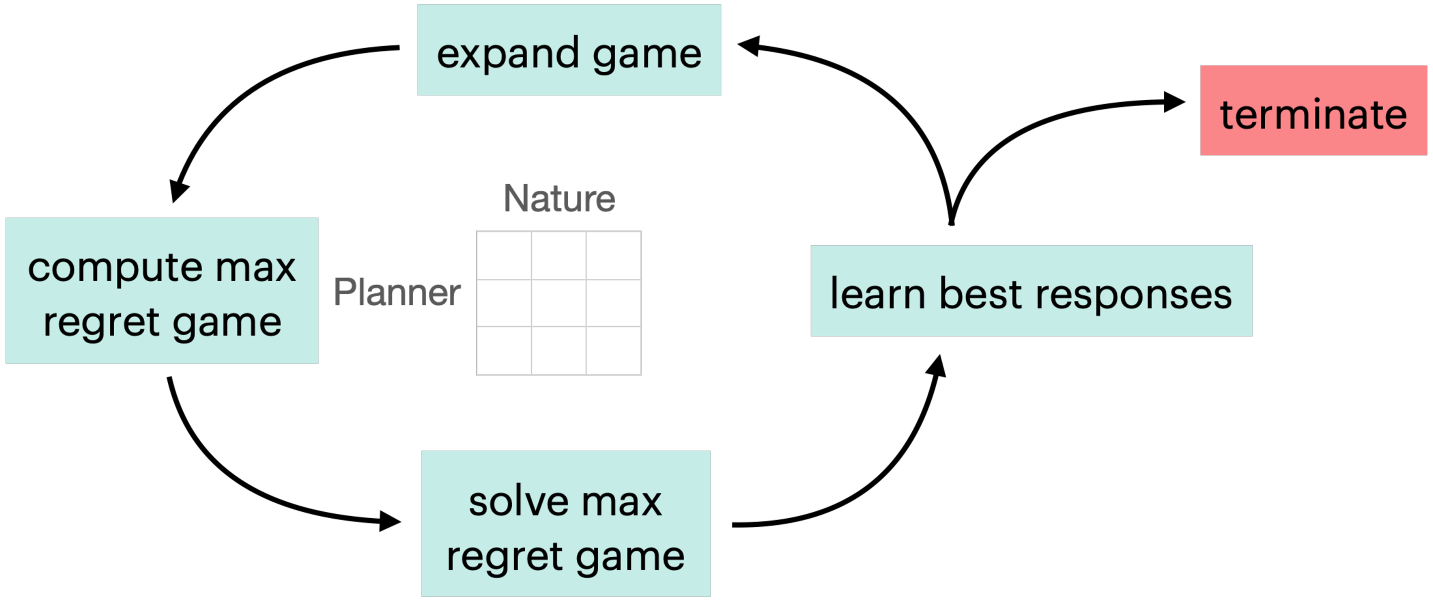
➡ **Sequential decision making**

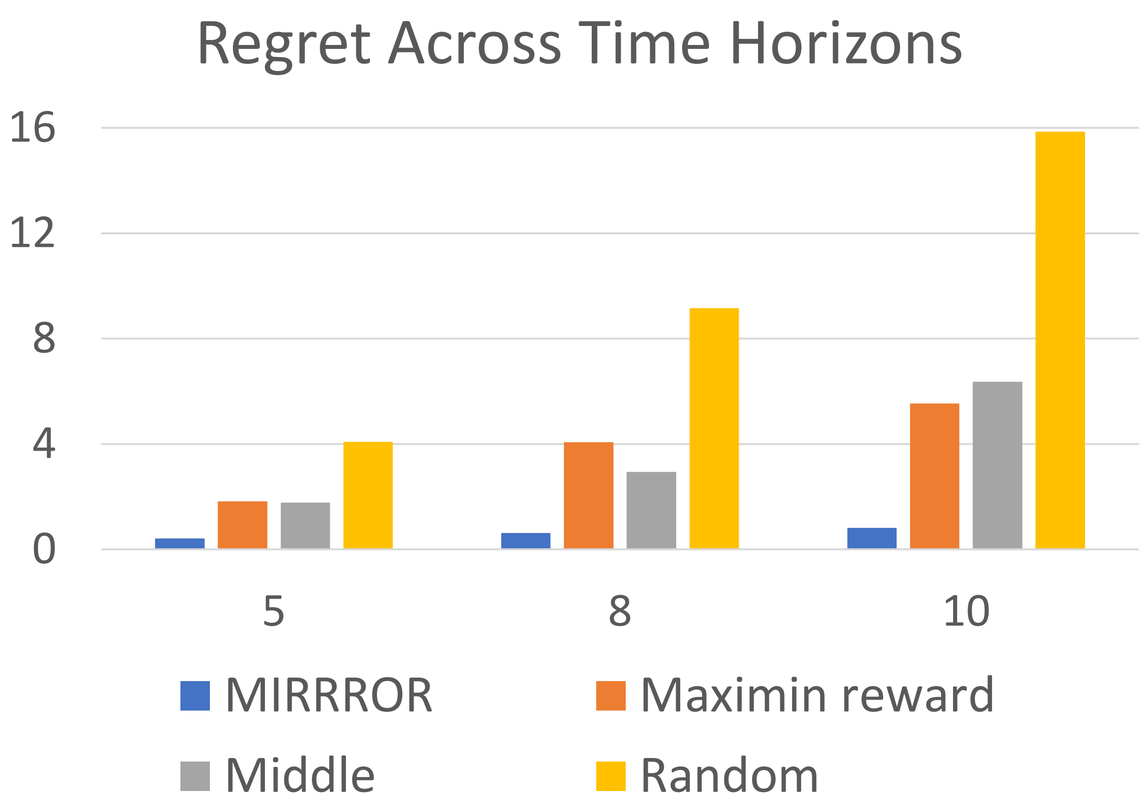
MIRROR: Deterrence-Based Patrol Planning
Simulation Results (UAI 2021)

Xu

Perrault

- Game-theoretic interaction between planner and nature
- Iteratively solve for equilibrium then learn best response
- Final strategy is guaranteed to minimize max regret





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Direction #2:
Data Scarce Parks

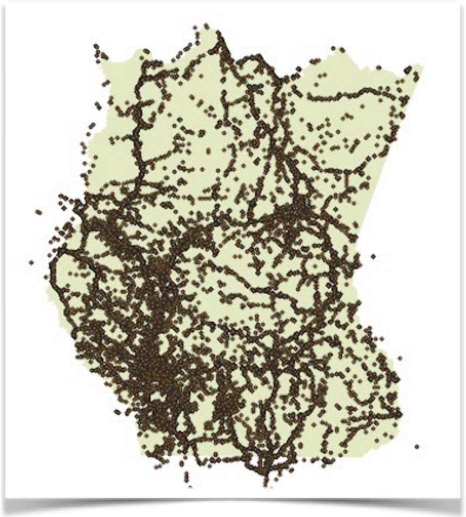
Xu

exploitation

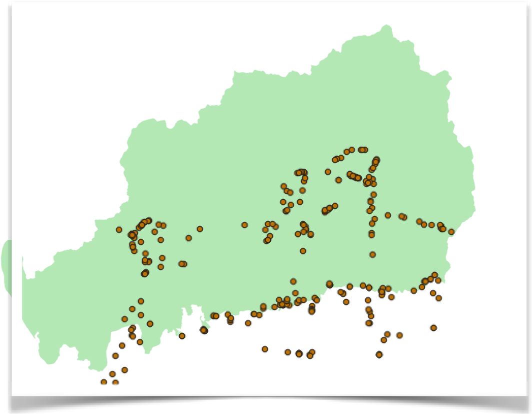
Data-rich parks: build predictive models to plan patrols

Data-scarce parks: conduct patrols to detect illegal activity and collect data to improve the predictive model

exploration



Srepok, Cambodia
43,269 patrol observations
2013 – 2018



Royal Belum, Malaysia
824 patrol observations
June – August 2018

LIZARD: Multiarmed Bandit
LIpschitZ Arms with Reward Decomposability (AAAI 2021)

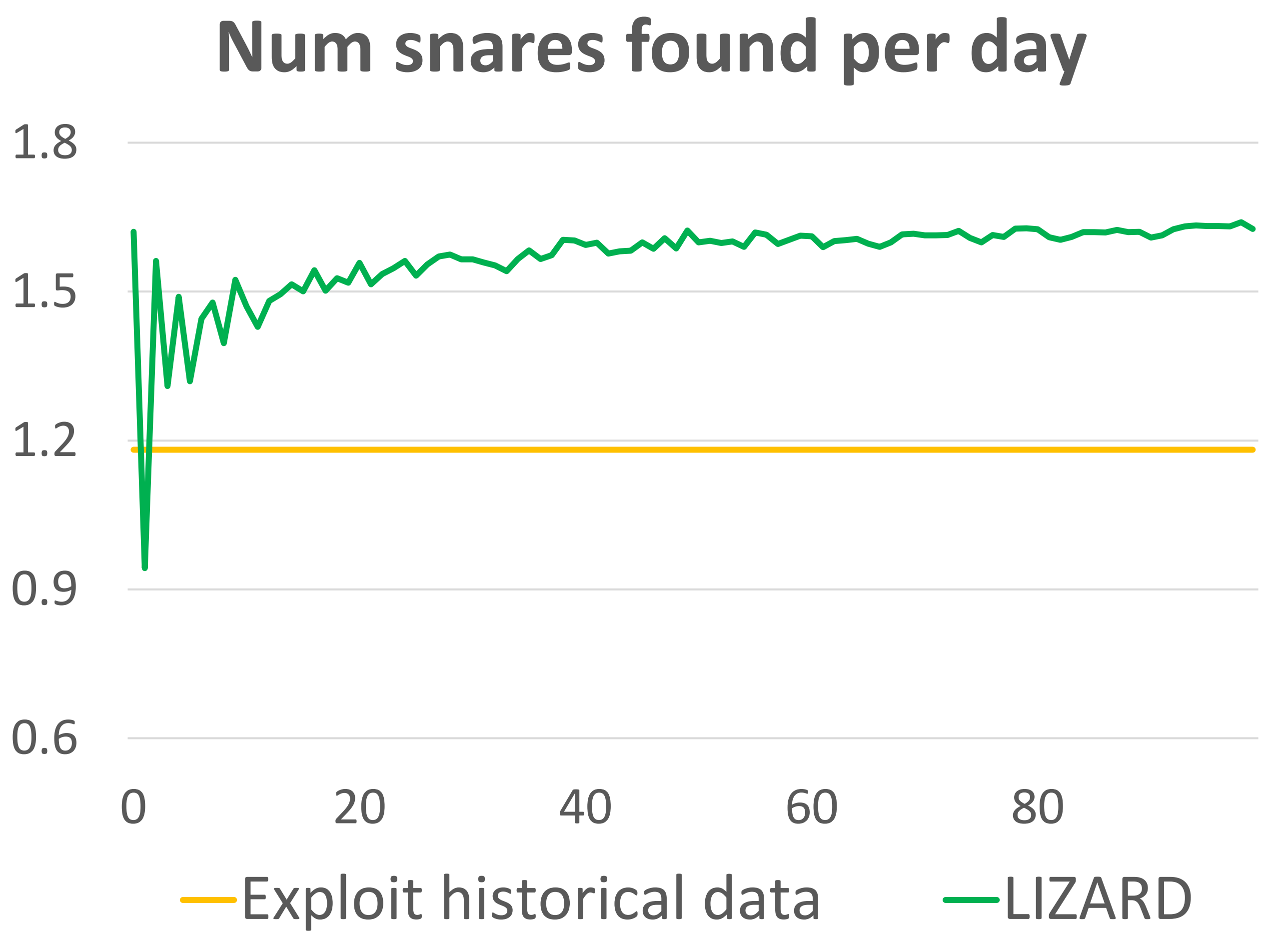
Xu

- Input: N Targets with features, T Time Horizon
- Stochastic adversary, who places snares at targets
- Patrolling algorithm: Specify patrol effort in each target up to budget B
- Reduce regret wrt OPT, optimal patrol effort, for capturing snares

Lizard exploits decomposability, smoothness, monotonicity

LIZARD: Multiarmed Bandit SIMULATION
(AAAI 2021)


Xu



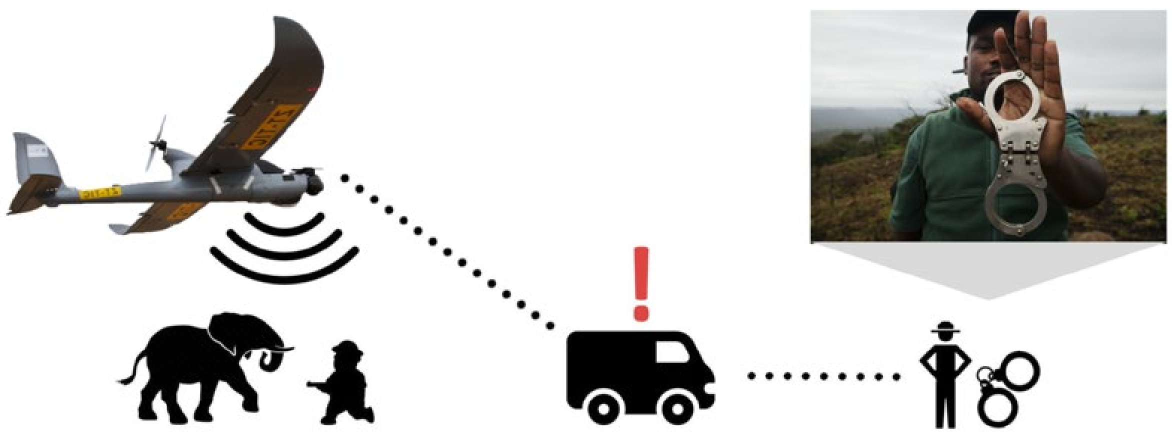
Proactively exploring areas with high uncertainty allows us to find more snares in the long run

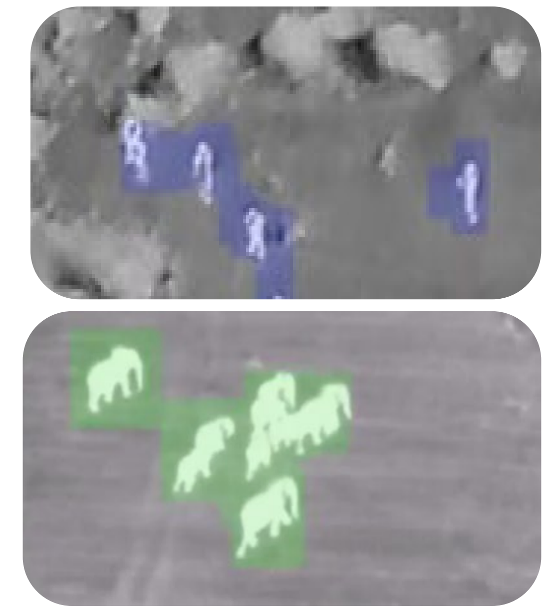
Green Security Games:
Integrating Real-Time “SPOT” Information

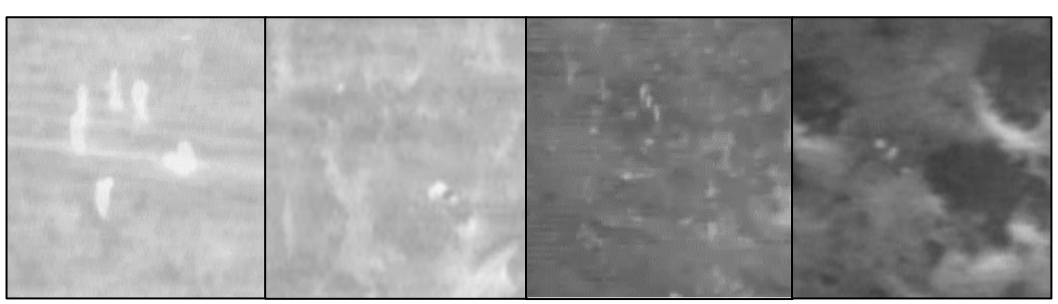
(IAAI 2018)

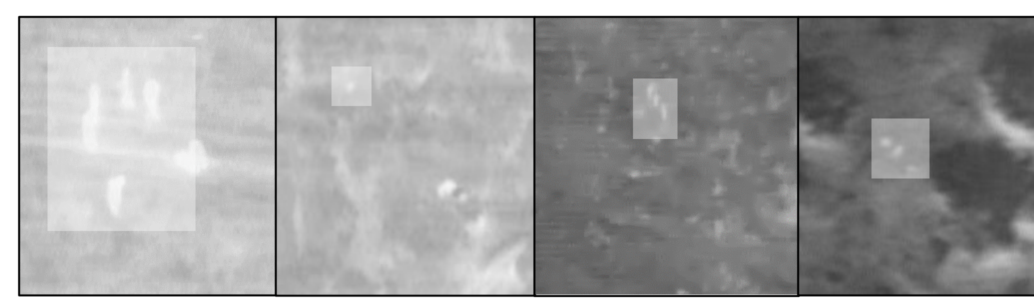
Bondi

Air Shepherd
The Lindbergh Foundation









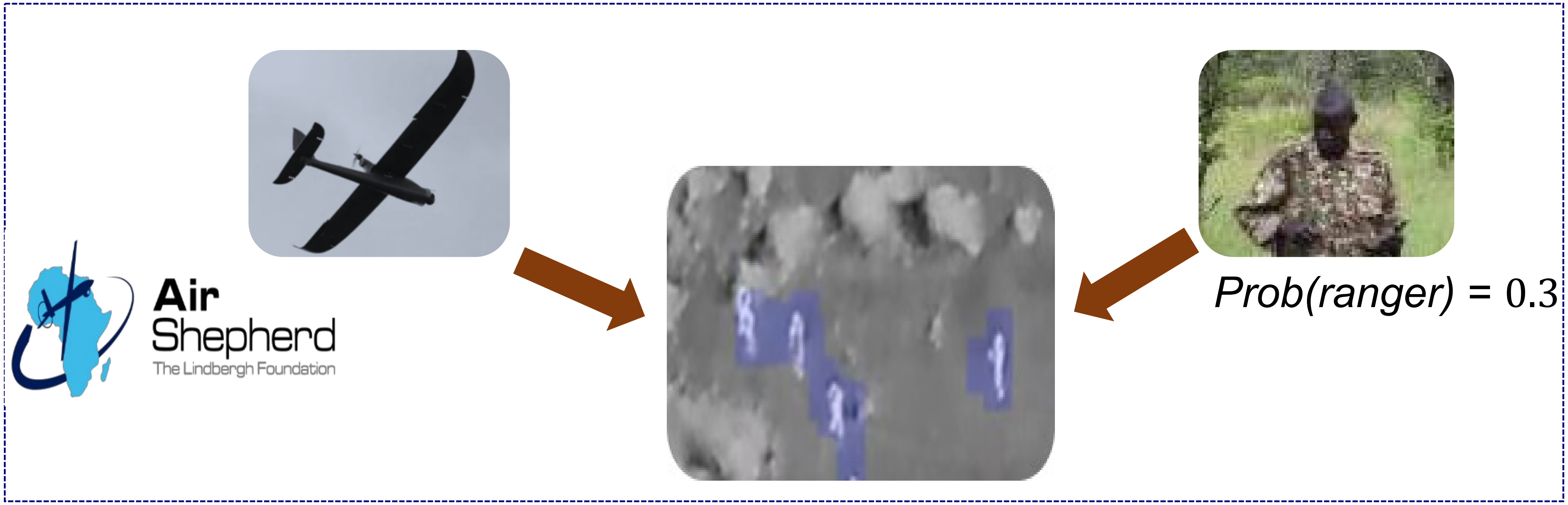
Goal: automatically find poachers

Drone Used to Inform Rangers

Xu

Bondi

- *Prob(ranger arrives)* = 0.3   [poacher may not be stopped]
- Deceptive signaling to indicate ranger is arriving



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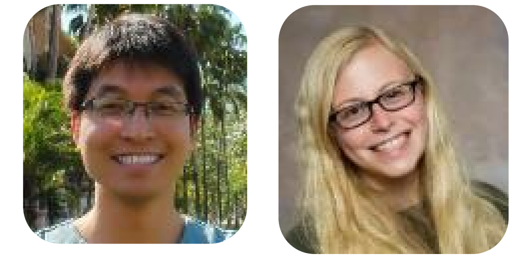
Drone Used to Inform Rangers

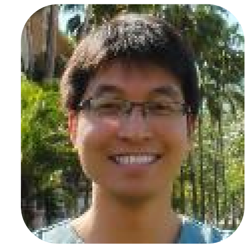


Xu Bondi

- *Prob(ranger arrives)* = 0.3 [poacher may not be stopped]
- Deceptive signaling to indicate ranger is arriving
- Must be strategic in deceptive signaling

Exploiting Informational Advantage Defender Knows Pure & Mixed Strategy

(AAAI 2018, AAAI 2020, AAMAS 2021)

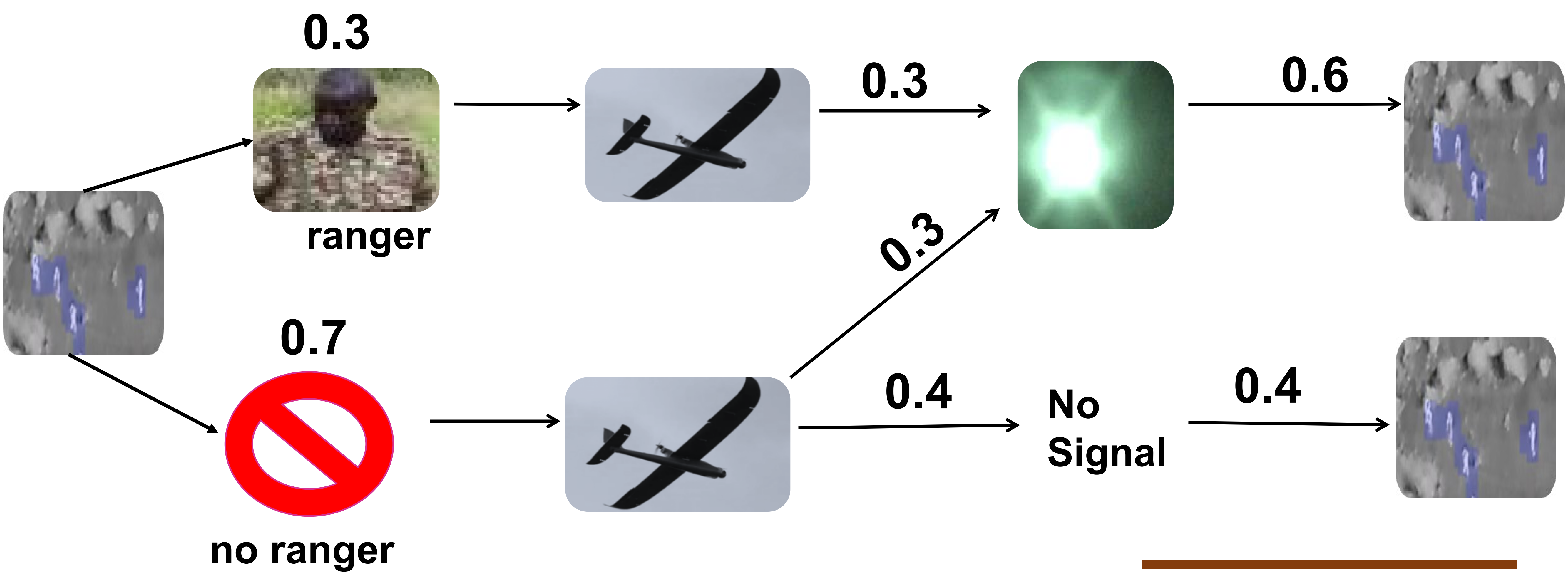


Xu

Bondi

Si-G Model: Stackelberg Security Games with Optimal Deceptive Signaling

- Poacher best interest to "believe signal" even if know 50% defender deception
- Recent work used RL for deception policy generation (AAMAS 2021)



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AI4SG Workshop - November 2019

- NGOs, Academics (AI, Policy, Sociology), Googlers
- 25+ Proposals submitted in 2 days
- Selected six projects as combination NGO+academics +Googlers

Google Research

AI4SG Workshop - November 2019

Partners

Public Health:

Conservation:

ASHOKA TRUST FOR RESEARCH IN ECOLOGY & THE ENVIRONMENT

Wildlife Conservation Trust

Education:

PRATHAM BOOKS storyweaver

Academic Partners:

IIT Madras, IIIT Delhi,

Singapore Management University, Nanyang Tech

Google Research India is based out of Bengaluru and will be part of and support Google's global network of researchers (Bloomberg)

Google funds six AI-based research projects in India

1 min read . Updated: 18 Feb 2020, 02:52 PM IST

IANS

Google Research India will provide each team with funding and computational resources in addition to supporting the efforts

Among the six projects are improving health information for high HIV/AIDS risk communities from team from IIT Delhi

INDIAN EXPRESS INDULGE

CULTURE ENTERTAINMENT SOCIETY FASHION FOOD TRAVEL LIFESTYLE

From healthcare to wildlife conservation, Google launches six AI research projects in India

Poona M Published: | 18th February 2020 12:59 PM

AI4SG Workshop – May 2021

orkshop on AI for Social Good

Home · Organizers · Application Details · 2019 Projects

AI for Social Good Workshop, Google

Deadline for proposal submission for workshop attendees : March 1, 2021

Google is excited to launch the second call for applications to join a collaborative NGO + academic AI for Social Good workshop.

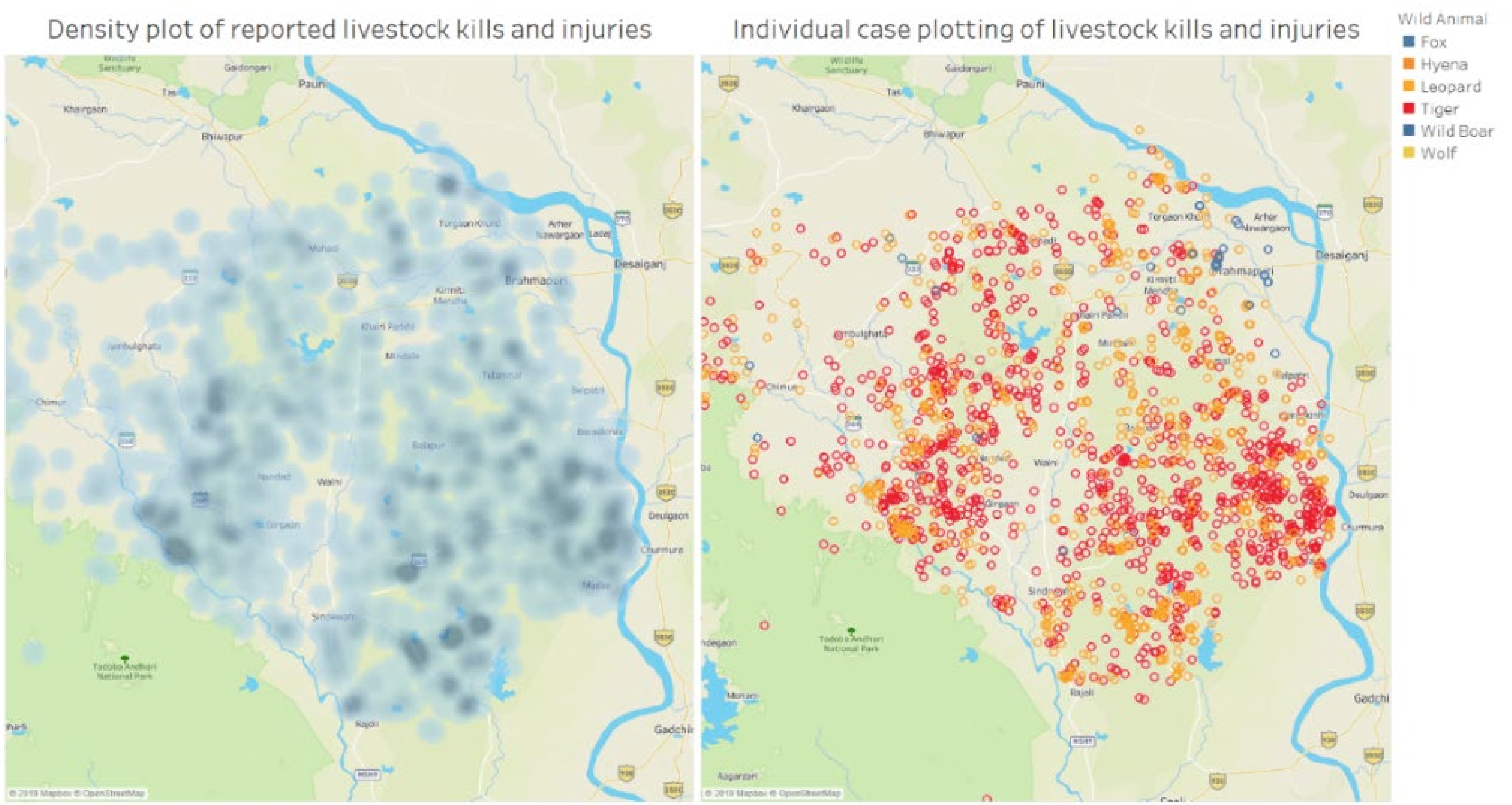
- 180 academics
- 180 NGOs
- 30 winners!
- $20K for NGO, $10K for researcher

Google Research

Wildlife Conservation Trust

- Most forest areas in India are multi-use, instead of being Protected Areas.
- Wild animals & humans co-habit
- High density of carnivores and herbivores – scope for conflicts with humans with loss of crops, cattle and lives

Conflict Map: Maharashtra

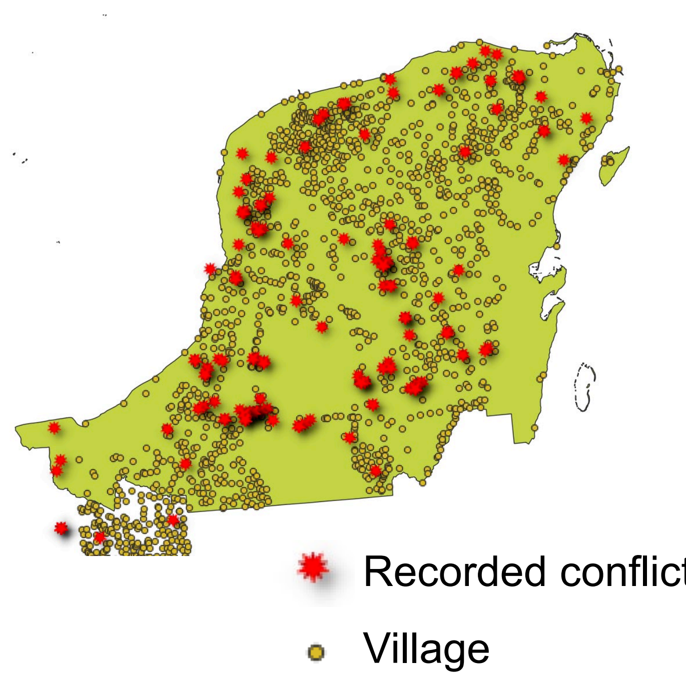


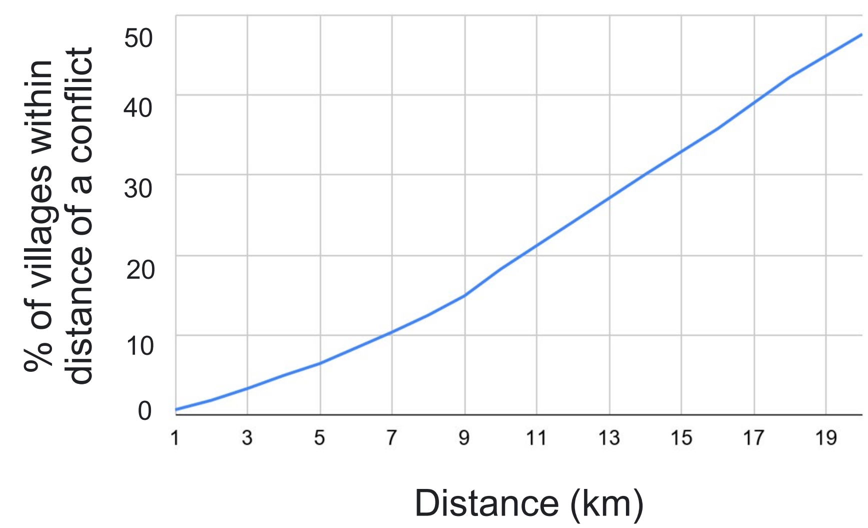
Given past data of conflicts, cultivated crops, village boundaries, animal movements can we predict conflict?

Google Research

Human-Wildlife Conflict: Mexico

- *Problem:* Livestock depredation by coyotes, pumas, and jaguars
- *Data:* Insurance reports from 2017–2019
- *Mitigation strategies:* Build electric fences, train ranchers



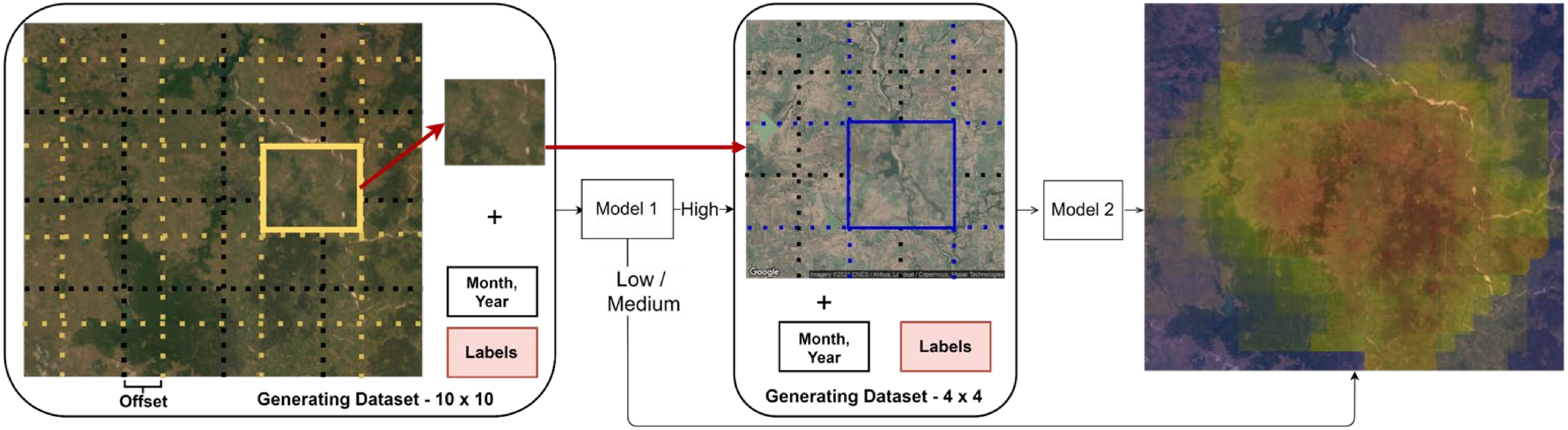


WWF

Conflicts in the Maya Forest, Mexico

Hierarchical solution

- Limited data - use offsets to create more training samples
- Two step classification - macro (bigger) and micro (smaller)
- 80.4% accuracy - with 76% precision and 76% recall for conflict areas.



Future: AI for Social Impact (AI4SG or AI4SI)

Achieving social impact & AI innovation go hand in hand

Empower non-profits to use AI tools; avoid being gatekeepers to AI4SI tech

Data to deployment: Not just improving algorithms, new AI4SI evaluation

Important to step out of the lab and into the field

Embrace interdisciplinary research -- social work, conservation

Lack of data is the norm, a feature; part of the project strategy

Key Collaborators on Papers Referenced
(In the order papers referenced)

Invitation to collaborate!

@MilindTambe_AI