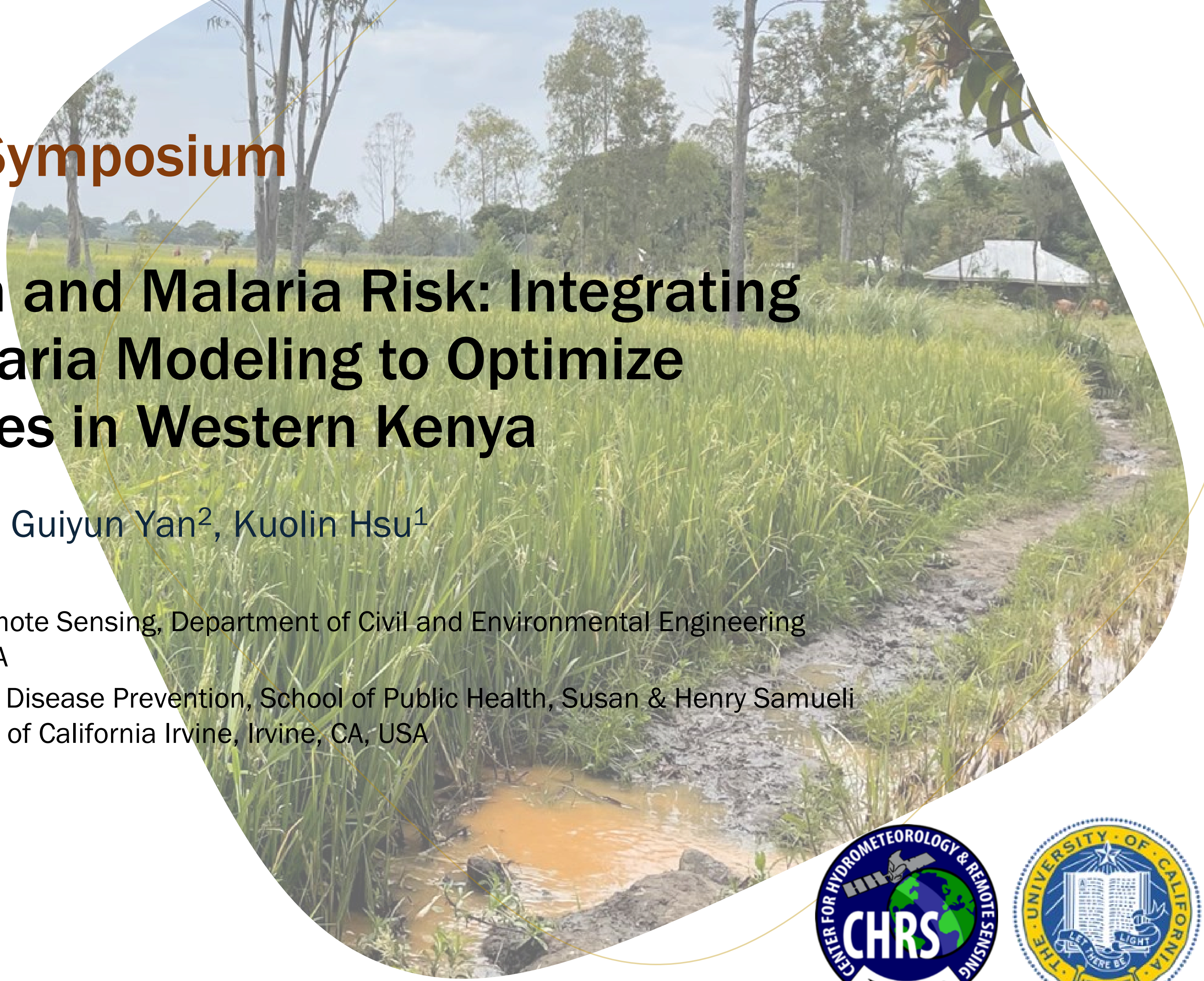
2024 IDM Annual Symposium

Balancing Irrigation and Malaria Risk: Integrating Hydrologic and Malaria Modeling to Optimize Agricultural Practices in Western Kenya

Ai-Ling Jiang[1], Ming-Chieh Lee[2], Guiyun Yan[2], Kuolin Hsu[1]

1. Center for Hydrometeorology and Remote Sensing, Department of Civil and Environmental Engineering University of California, Irvine, CA, USA
2. Department of Population Health and Disease Prevention, School of Public Health, Susan & Henry Samueli College of Health Sciences, University of California Irvine, Irvine, CA, USA



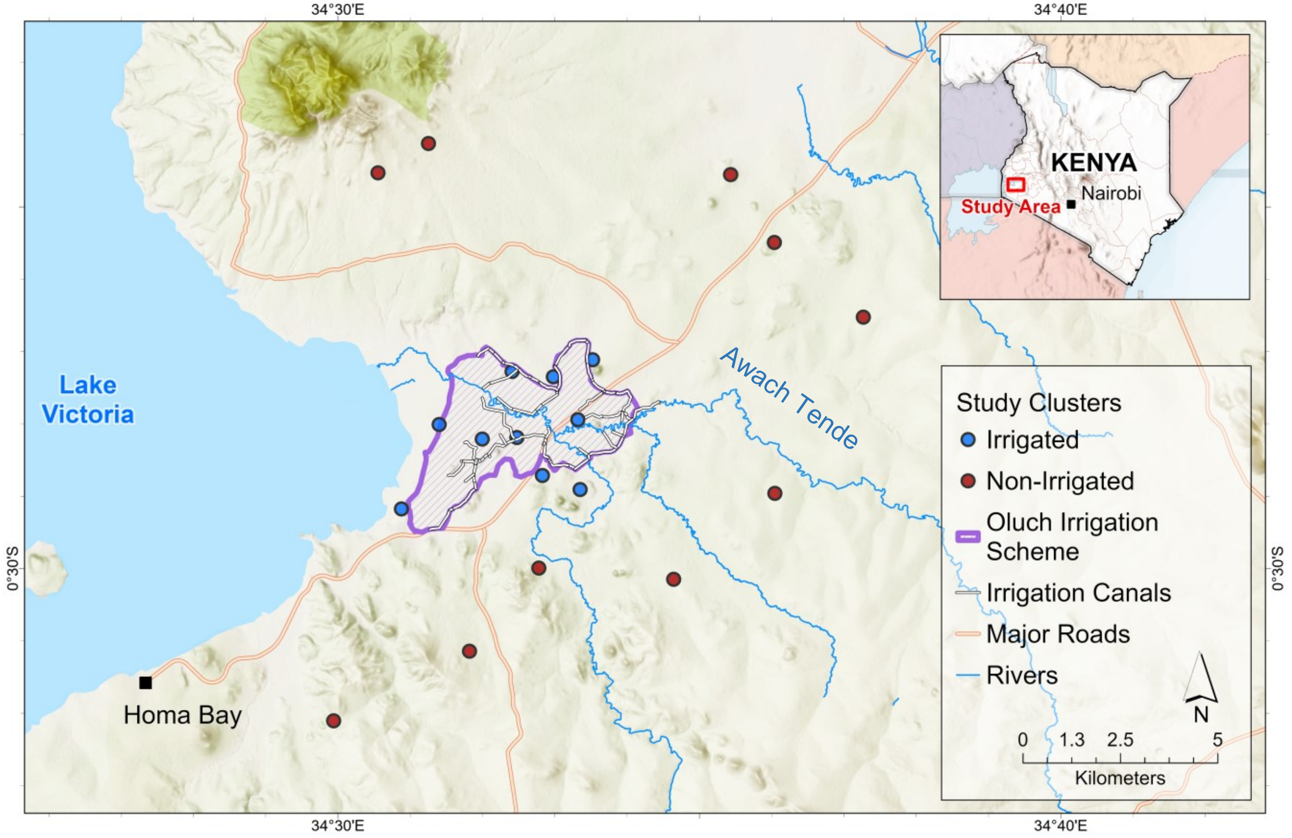
Oct 2nd, 2024

Dilemma between Food Security and Malaria Transmission

- To promote food security, numerous irrigation schemes have been developed in Africa
- Irrigation creates additional potential breeding habitats for malaria vectors
- It is vital to understand the impact of agricultural practices on malaria vectors and transmission risks

Study area: Oluch Irrigation Scheme, Homa Bay County, Kenya

- Oluch irrigation project was launched in 2007 to improve livelihoods of smallholder farmers



Crop Productivity Remains Low Despite Massive Irrigation Infrastructure

- Only half of the total land is irrigated
- Majority of farmers still grow maize and beans (Makone et al., 2021)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Why a Sh6 billion irrigation project is wasting away
By James Omoro | 6yrs ago
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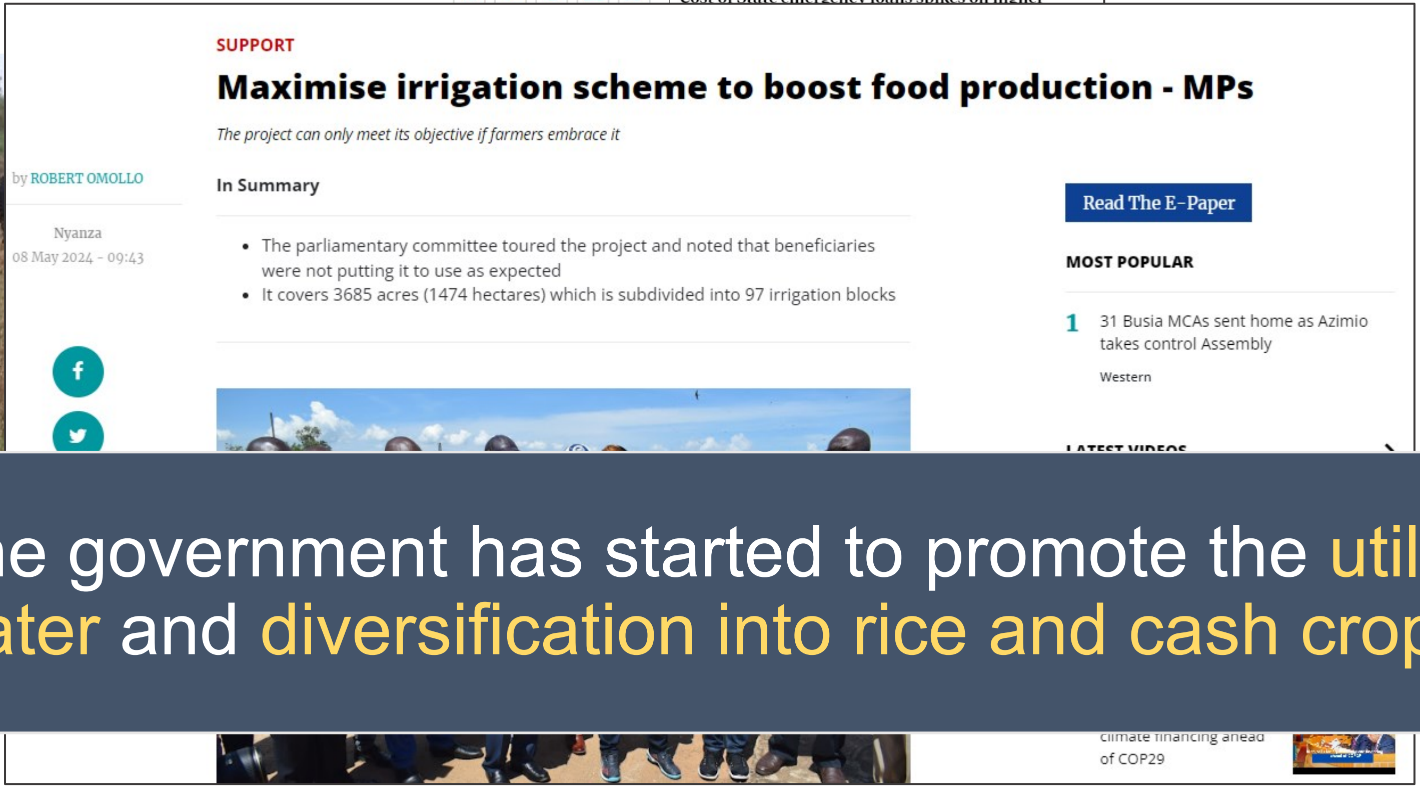
SUPPORT
Maximise irrigation scheme to boost food production - MPs
The project can only meet its objective if farmers embrace it
by ROBERT OMOLLO
Nyanza
08 May 2024 - 09:43
In Summary
- The parliamentary committee toured the project and noted that beneficiaries were not putting it to use as expected
- It covers 3685 acres (1474 hectares) which is subdivided into 97 irrigation blocks
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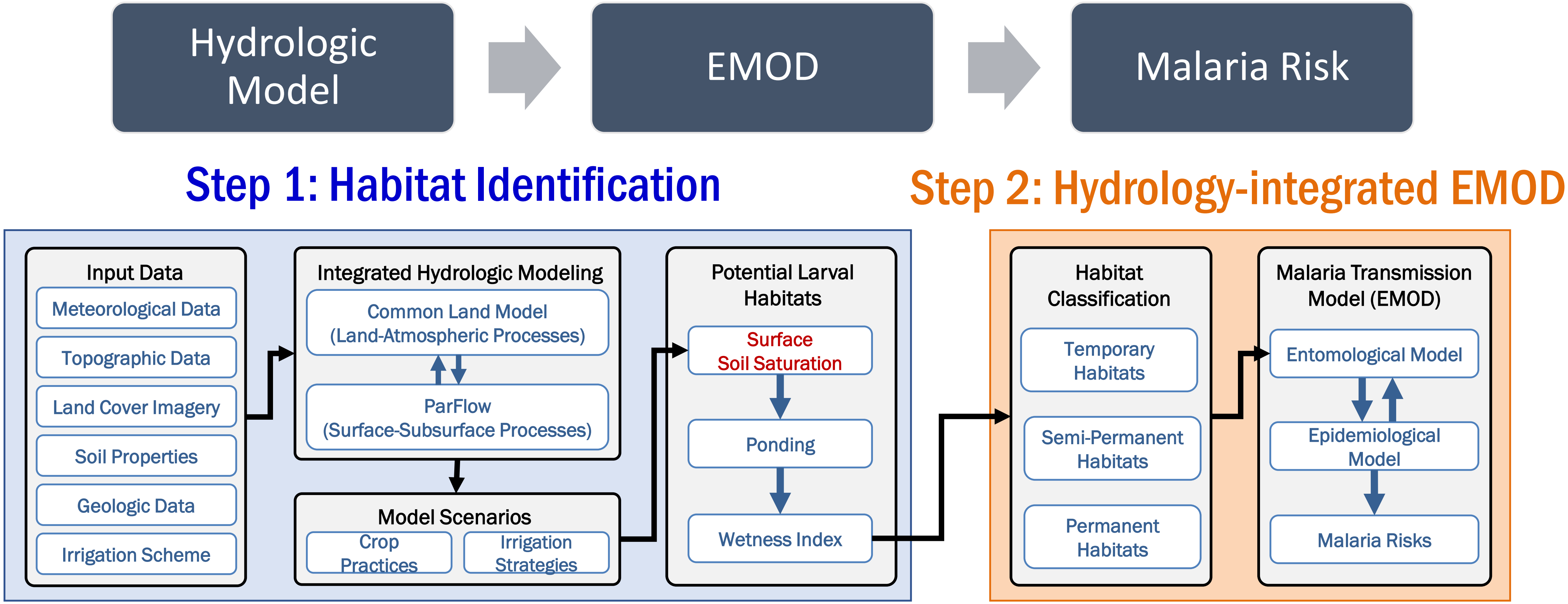
The government has started to promote the utilization of irrigation water and diversification into rice and cash crops

Research Questions

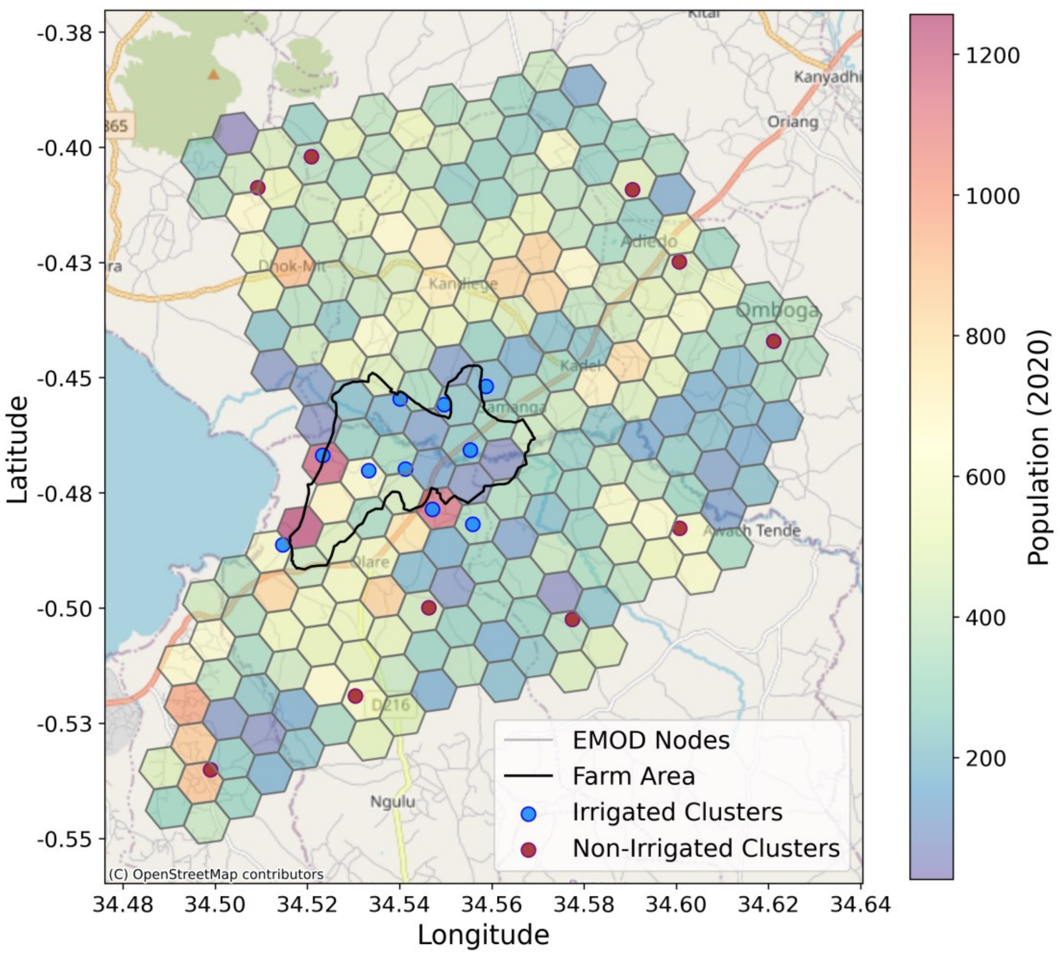
- How does the increasing irrigation coverage affect the availability and characteristics of potential larval habitats?
- How do different cropping practices affect malaria transmission intensity?
- What is the effectiveness of irrigation strategies in mitigating malaria risk?

Hydrology-Integrated Malaria Modeling Framework



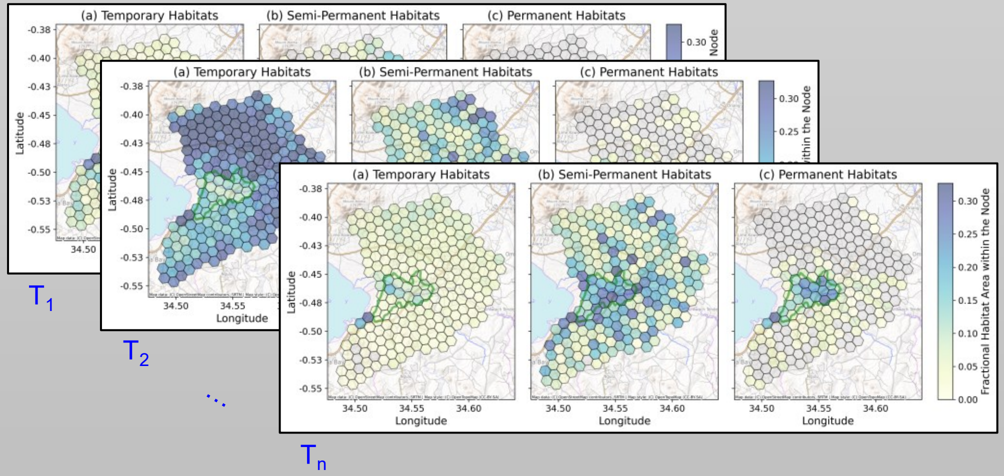
Jiang et al., 2023

Multi-Node Simulation

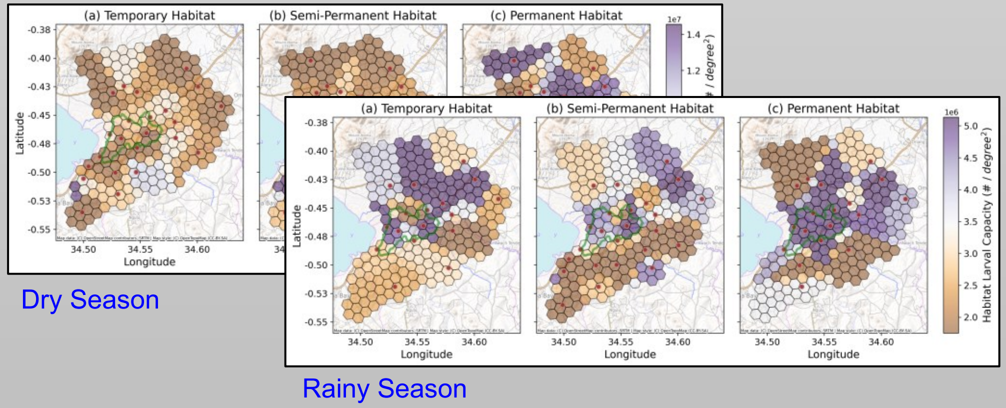


- 10-year simulation period
- 225 nodes (0.75km^2 each)
- Encompass 10 irrigated and non-irrigated clusters

Hydrologic Modeling Simulated Larval Habitats



Field Data Informed Habitat Larval Capacity

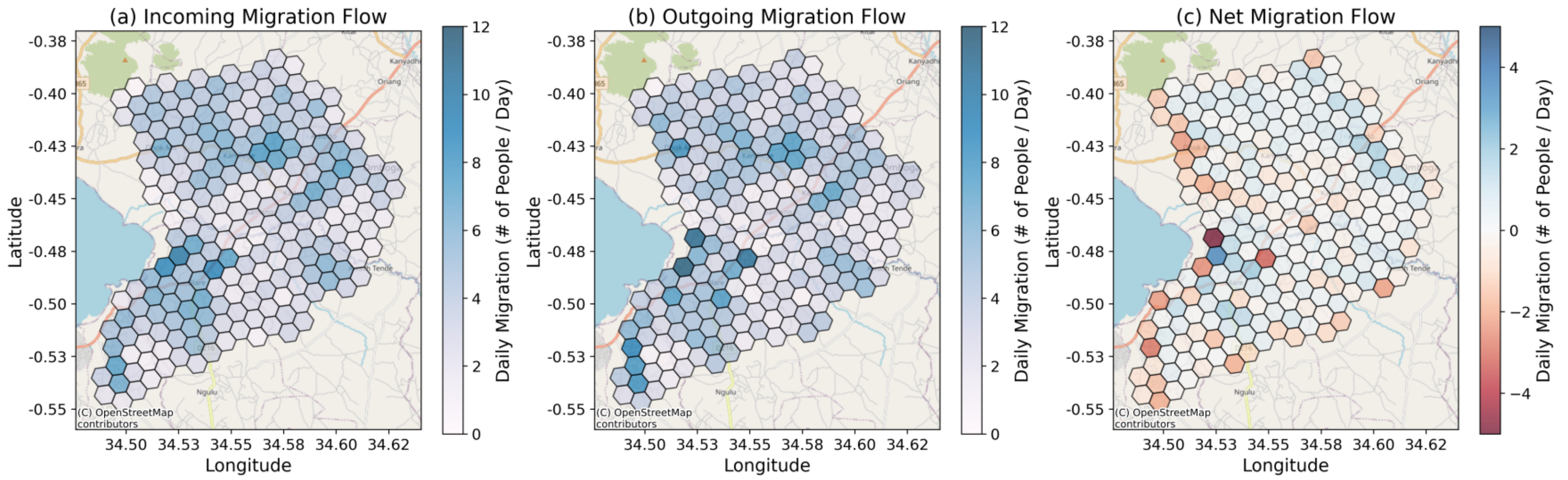


EMOD Malaria Model

Human and Vector Migration Considered

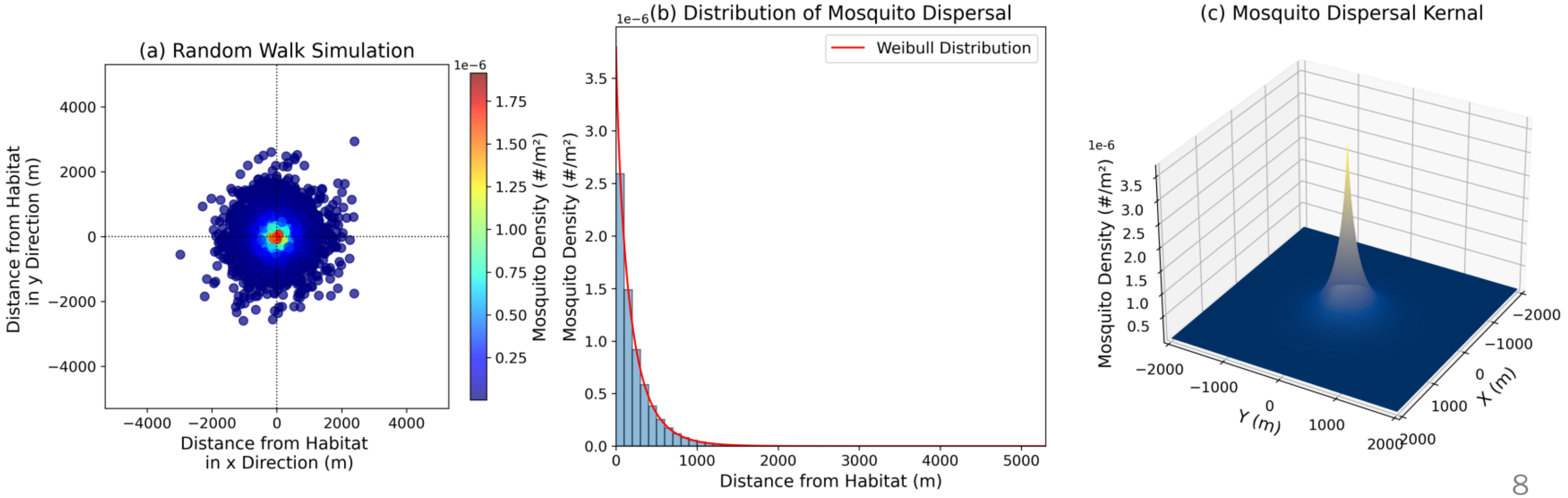
Human Migration

- Estimated by the Radiation Model (Simini et al., 2012; Lellis et al., 2021)
- Calibrated based on 1.65 overnight trips per person six month (Camlin et al., 2019)



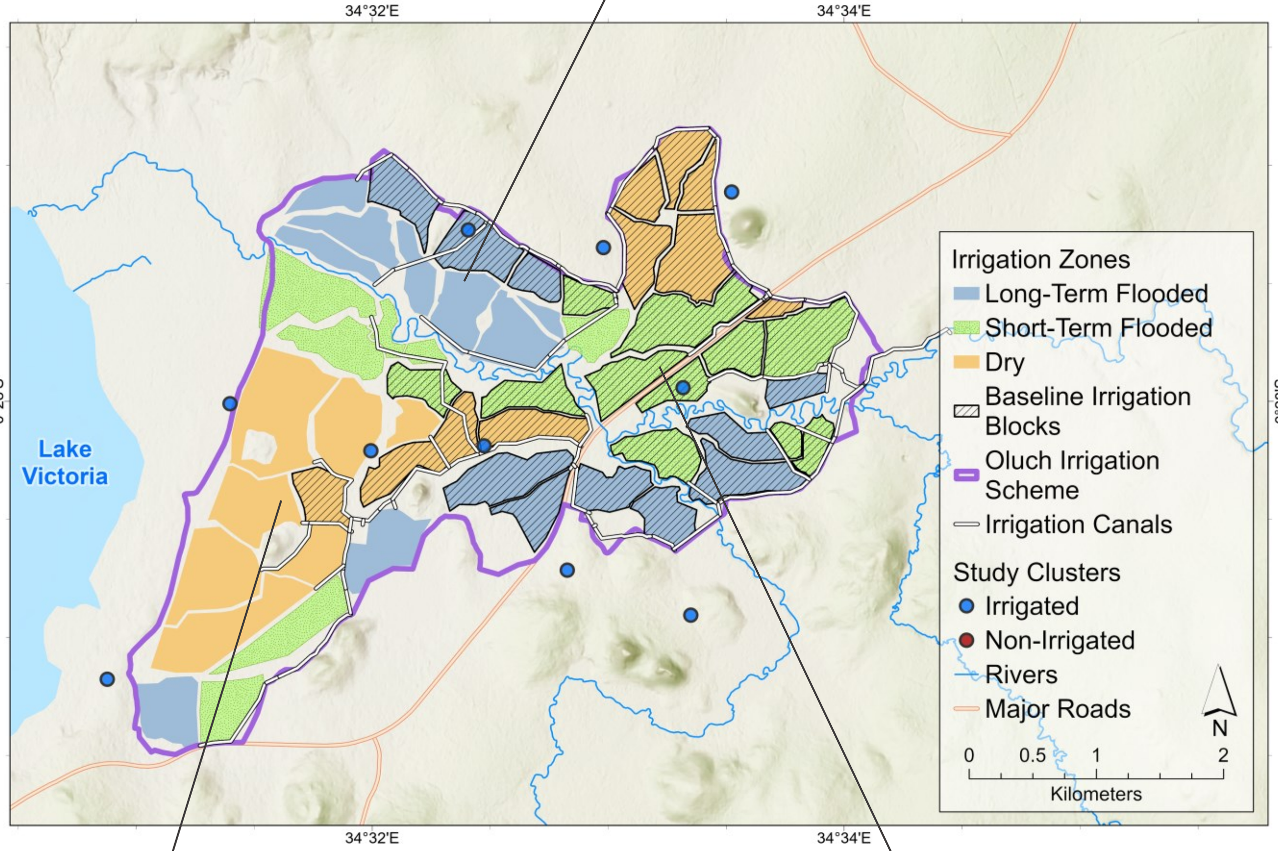
Vector Migration

- Estimated by the Random Walk Simulation (Thomas et al., 2013)
- Daily flight distance of 1040 m and daily survival rate of 0.8 were used (Verdonschot et al., 2014)



Irrigation Scenario Design

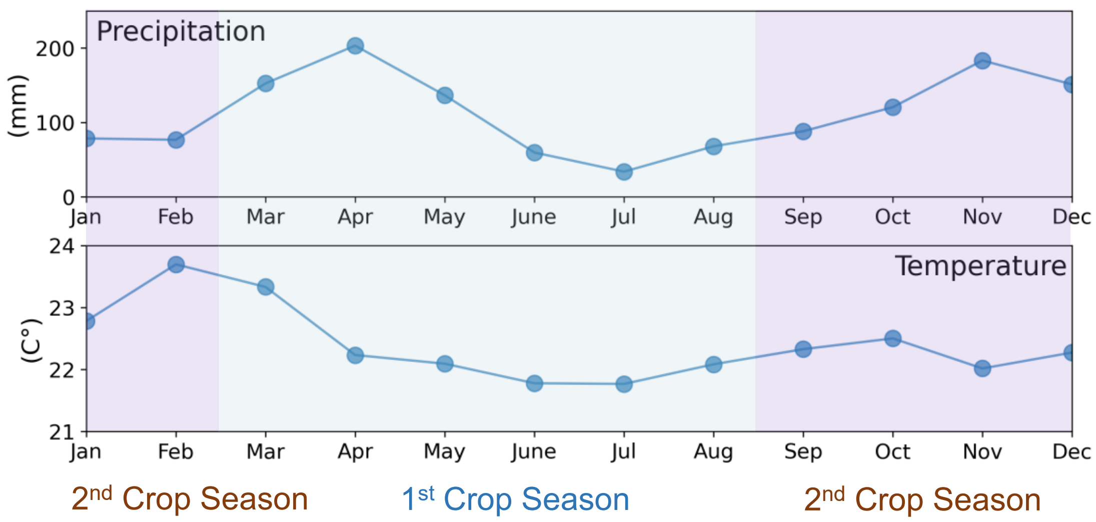
Long-Term Flooded Zone (LF):
Paddy rice with a mix of peas



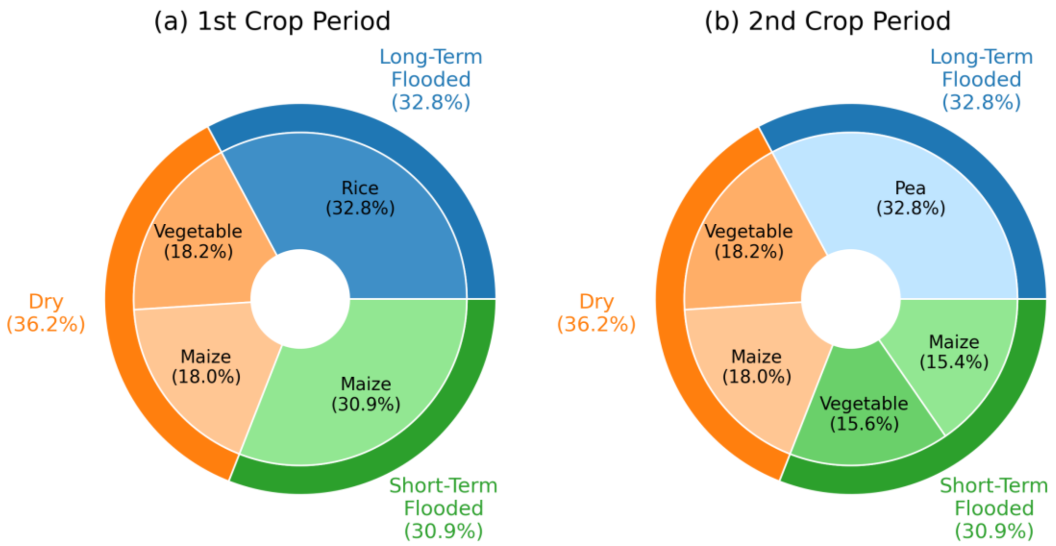
Dry Zone (D):
No restrictions

Short-Term Flooded Zone (SF):
Vegetables cannot be grown during long rain

Climatology in Homa Bay, Kenya



Proposed Crop Assignment by Feasibility Study



Model Scenario Development

Irrigation Area

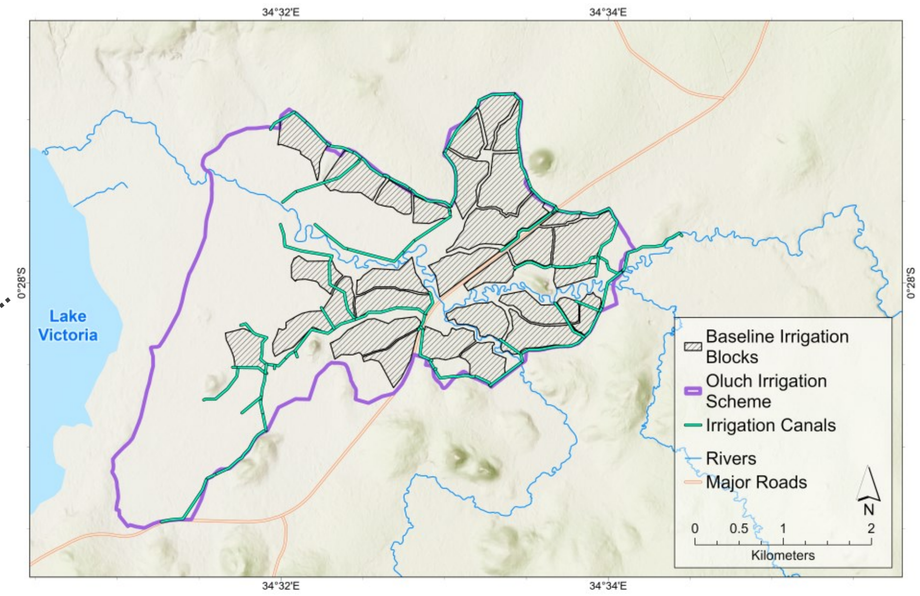
- Baseline (50% Irrigation)
- Full Scale Irrigation (100% Irrigation)

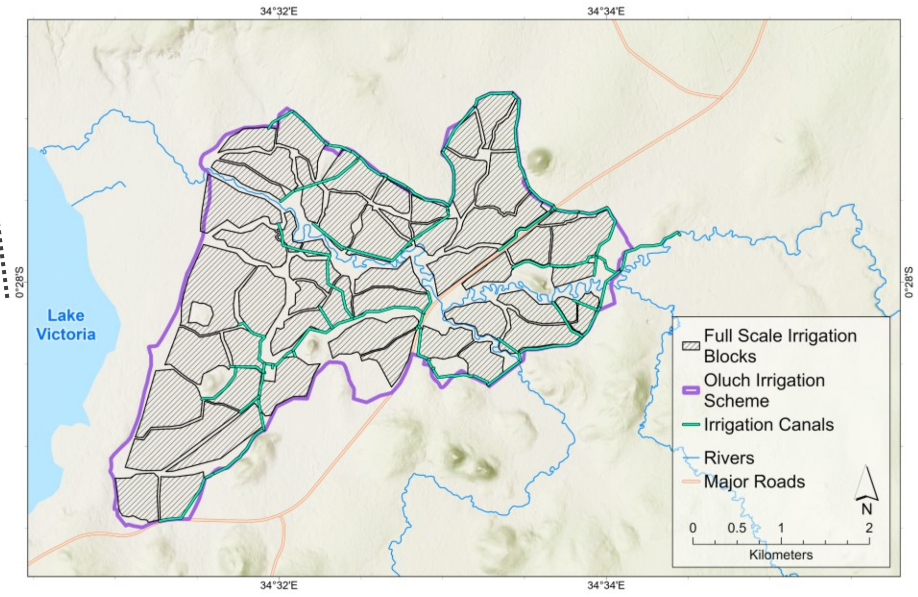
Cropping Practices

- Recommended Crop Assignment (Diverse Crops)
- Cash Crop Dominant
- Staple Crop Dominant

Irrigation Strategies

- Flood Irrigation
- Intermittent Irrigation (Rice Farm Only)
- Water Saving Irrigation (Intermittent + Drip)





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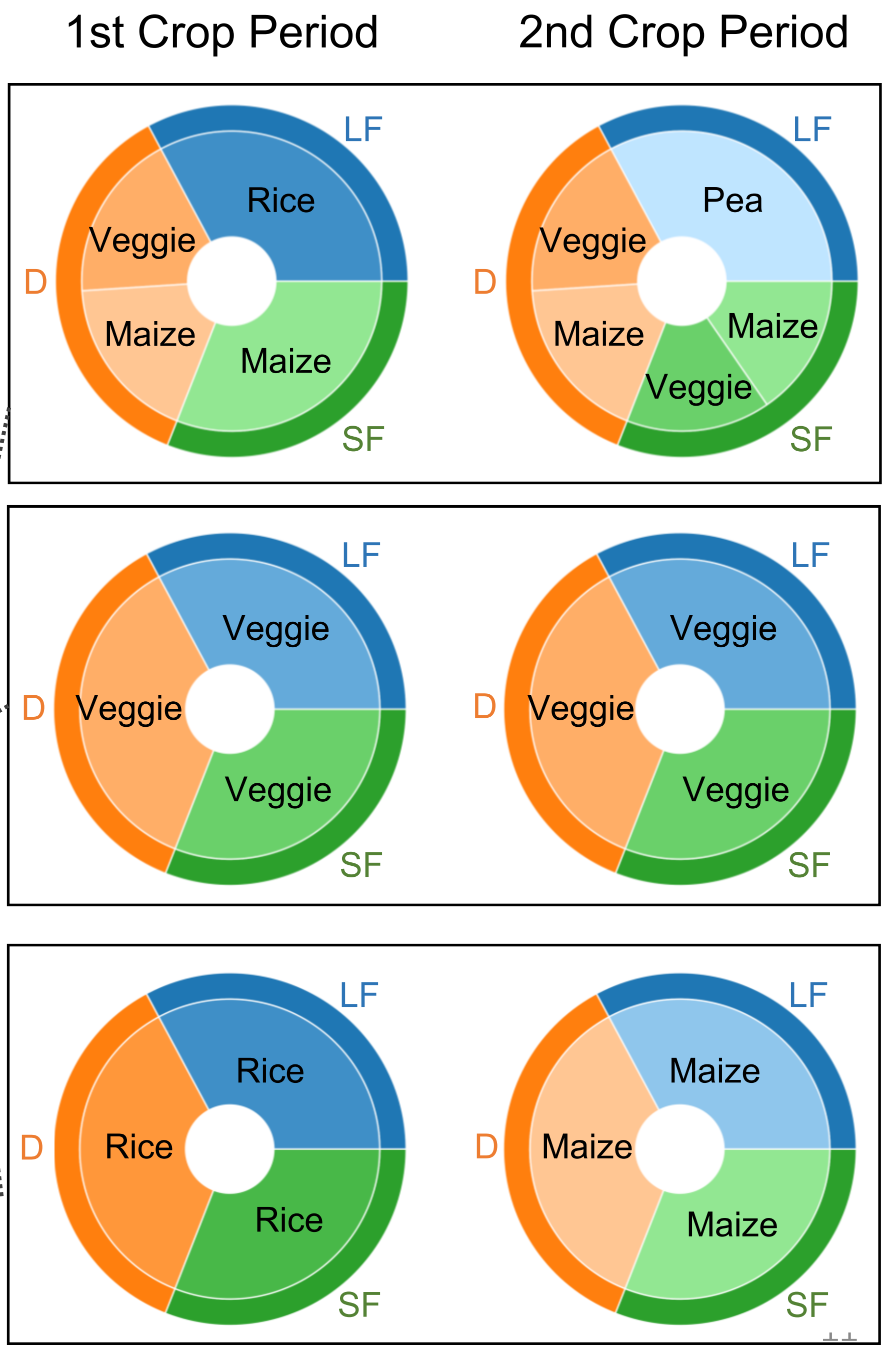

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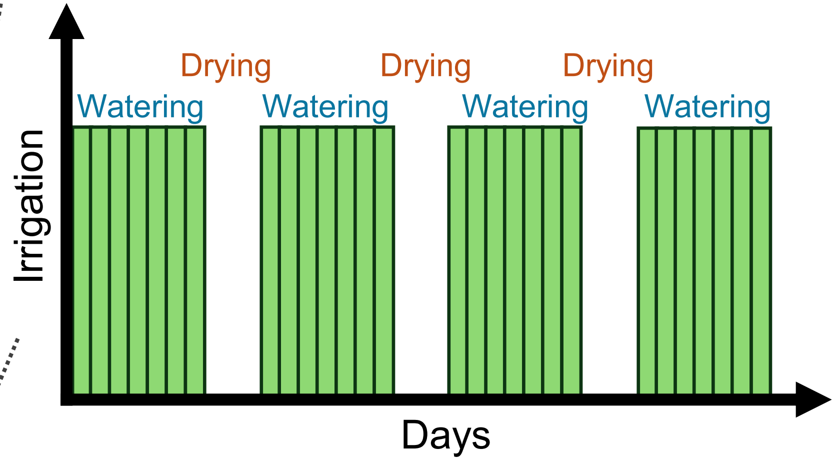
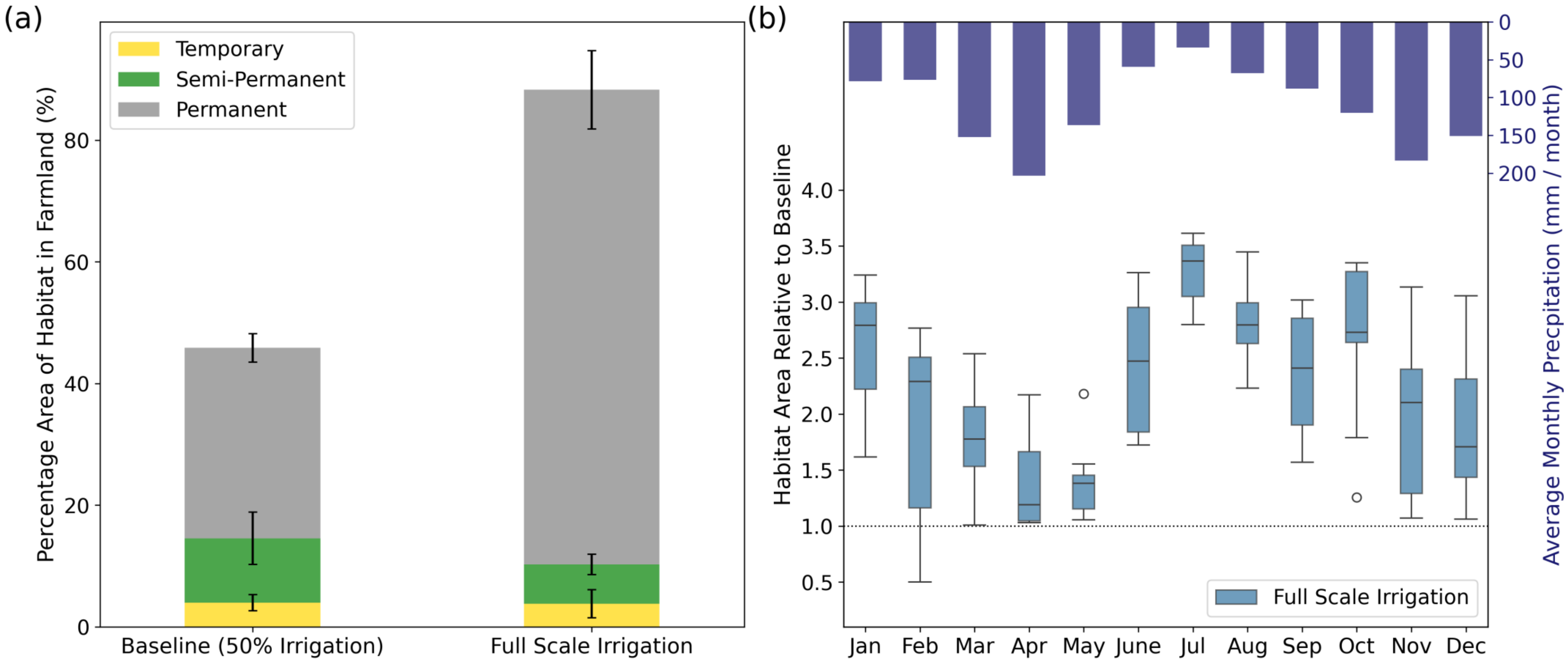
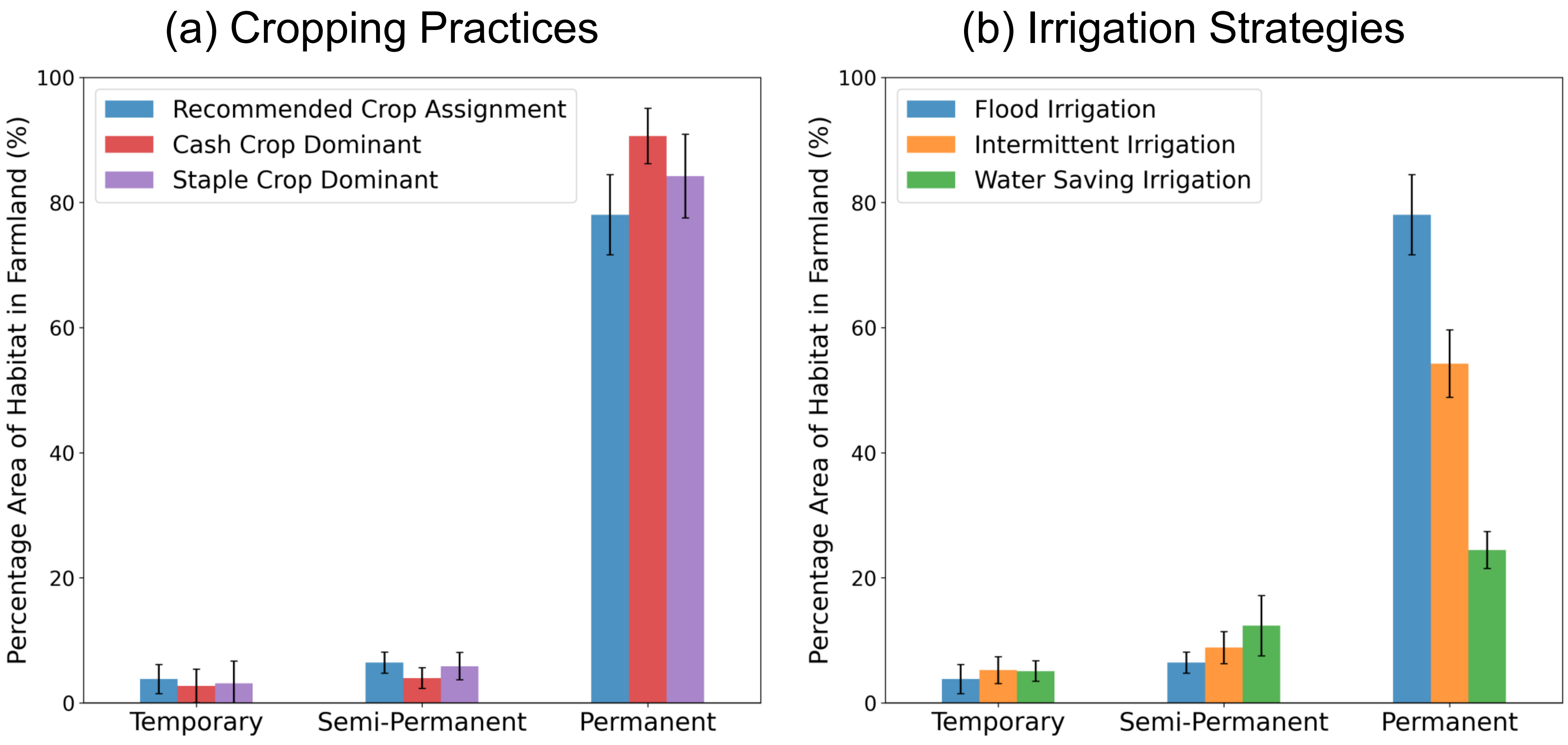


Maximizing irrigation coverage promotes larval habitats but the impact is moderated by precipitation



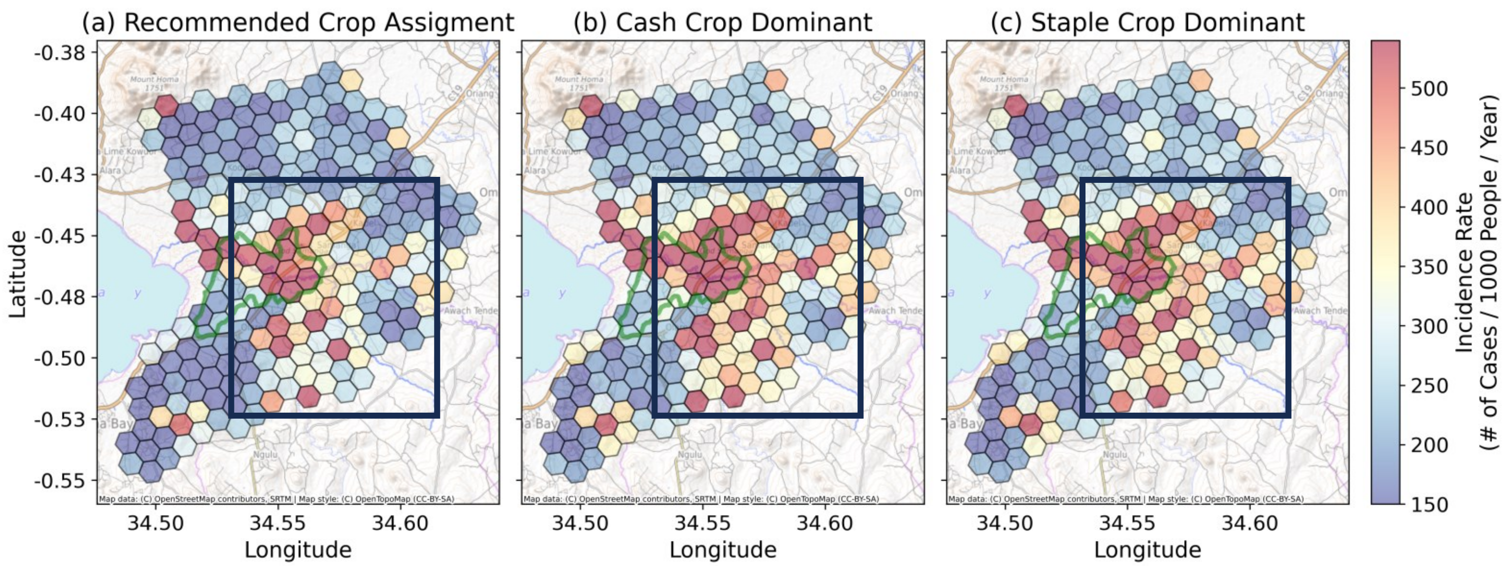
- Full scale irrigation increases potential larval habitats by almost 2 times
- The increase is negatively correlated with rainfall

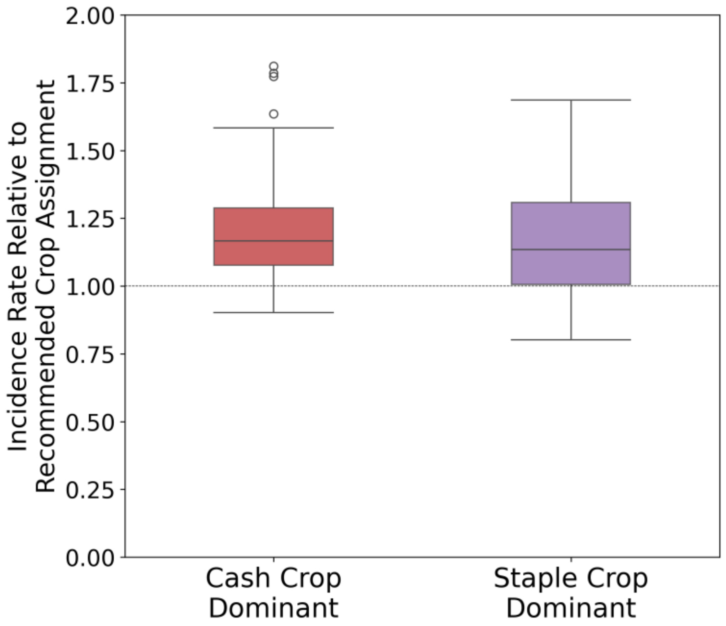
Habitat area is not affected much by crop assignment and can be highly reduced using efficient irrigation

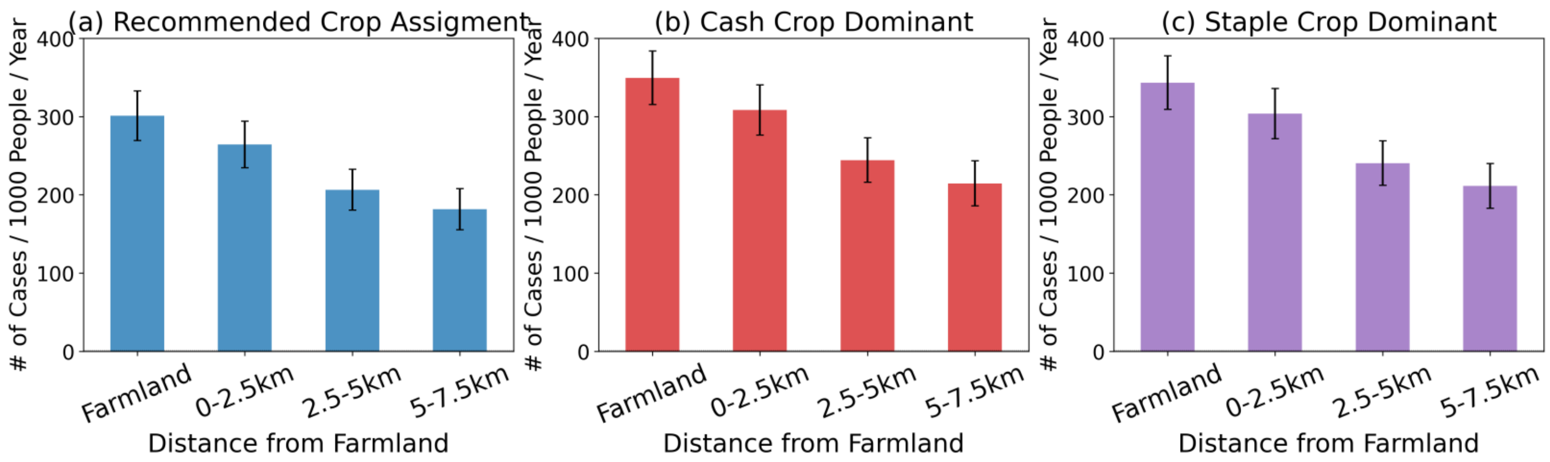


- Growing cash crops all year results in 10% higher habitats than growing diverse crops
- Water saving irrigation reduces habitat area by 53% compared to flood irrigation

Growing only cash crop or staple crop expands malaria risk hotspot compared to diversifying crop

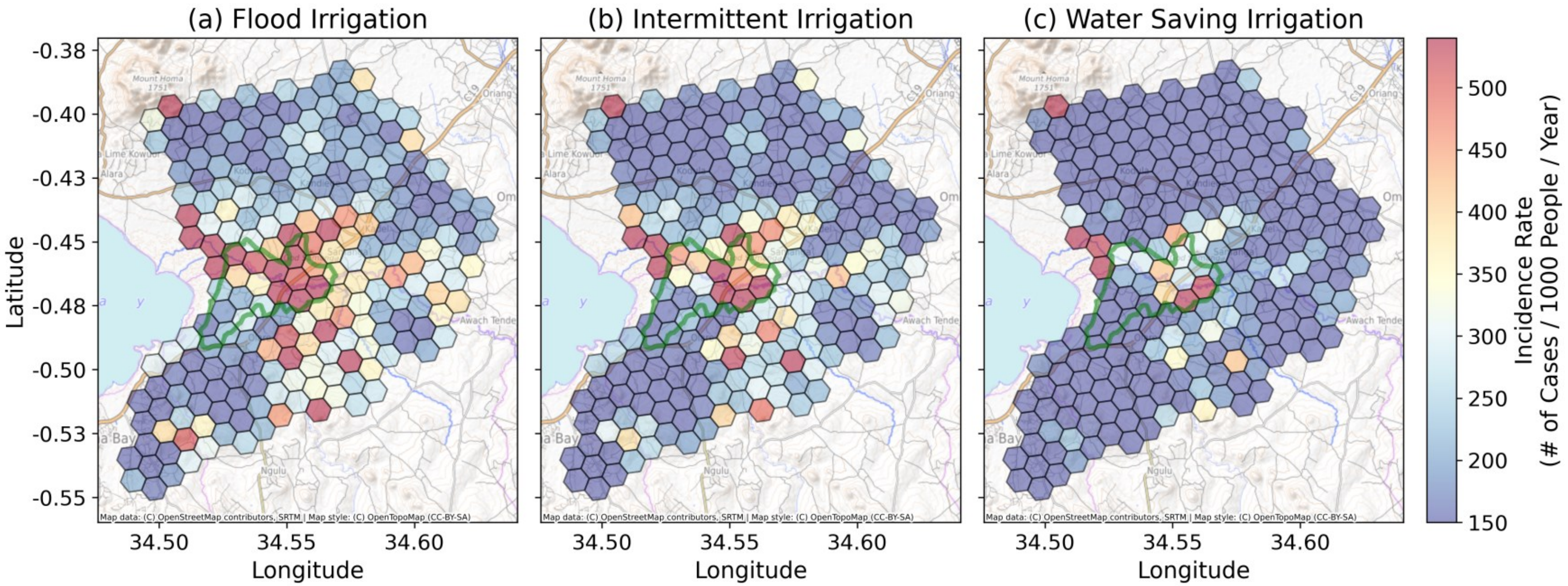


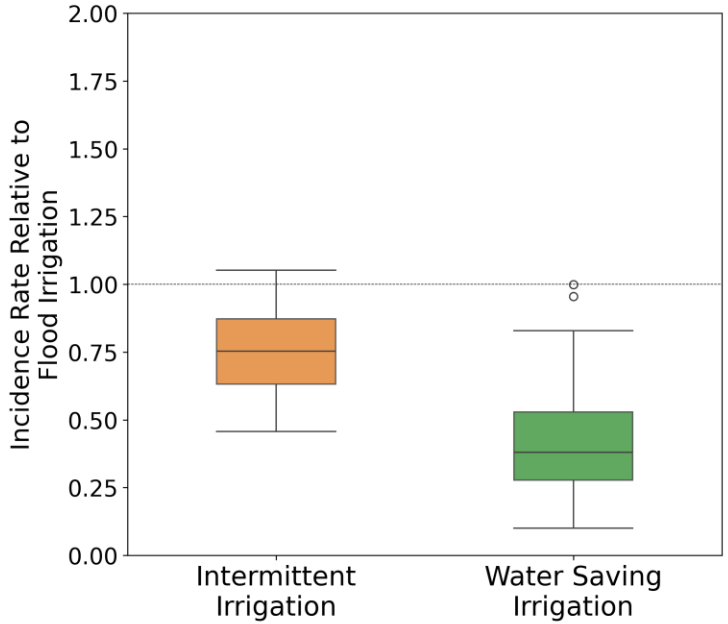




- Cash crop increases incidence rate by 20% and staple crop increases incidence rate by 15% compared to recommended crop assignment scenario
- Incidence rate decreases with distance from farmland

Efficient irrigation can reduce malaria incidence by more than half





- Intermittent irrigation reduce incidence rate by 25% compared to flood irrigation
- Water saving irrigation (intermittent + drip) further reduce incidence rate by 60%

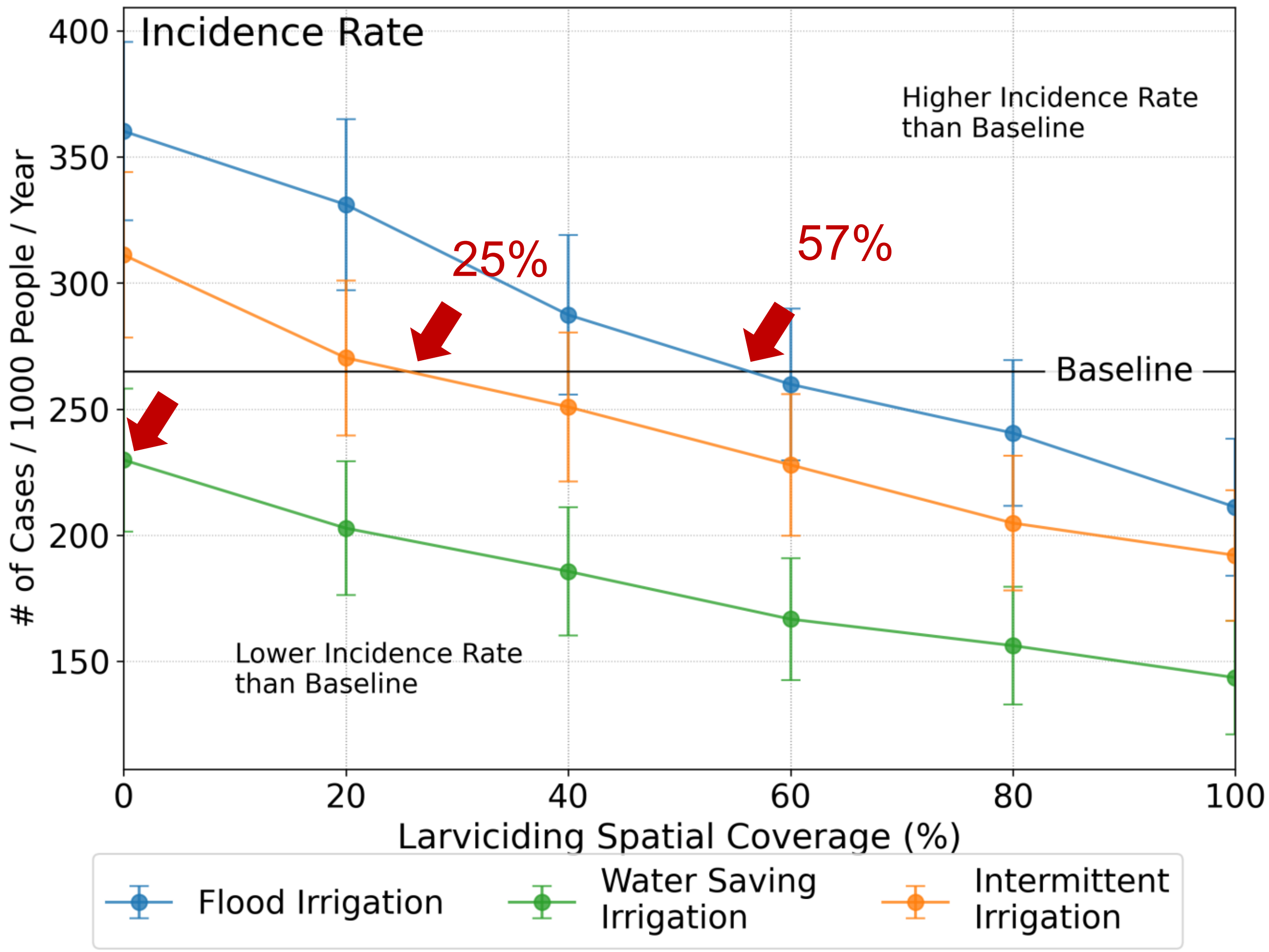
Growing diverse crops with water saving irrigation is recommended for future agriculture strategies

Relative irrigation volume, EIR and incidence rate compared to baseline scenario

	Model Scenario	Irrigation Volume	EIR	Incidence Rate
	Baseline (50% Irrigation)	**1.00**	**1.00**	**1.00**
Cropping Practices	**Recommended Crop Assignment**	1.91	2.27	2.21
Cropping Practices	**Cash Crop Dominant**	**1.91**	2.78	2.67
Cropping Practices	**Staple Crop Dominant**	**2.13**	2.68	2.54
Irrigation Strategies	**Flood Irrigation**	1.91	2.27	2.21
Irrigation Strategies	**Intermittent Irrigation**	1.58	1.62	1.59
Irrigation Strategies	**Water Saving Irrigation**	**1.04**	**0.78**	**0.80**

- Water saving irrigation results in lowest incidence rate.
- Higher irrigation volumes for staple crops do not result in higher malaria incidence

Water efficient irrigation strategies can enhance the effectiveness of larviciding



- Flood irrigation requires 57% coverage to maintain baseline incidence, reduced to 25% with intermittent irrigation, and none with water-saving irrigation
- Efficient irrigation strategies can supplement larviciding by reducing mosquito breeding sources

Conclusion

- Coupling hydrologic modeling with EMOD enables simulations of spatial-temporal dynamics of larval habitats, transmission intensity and malaria risks
- In our study, cropping practices and irrigation strategies have significant impact on malaria risk
- The framework can be used to model the effects of environmental modification to guide malaria control

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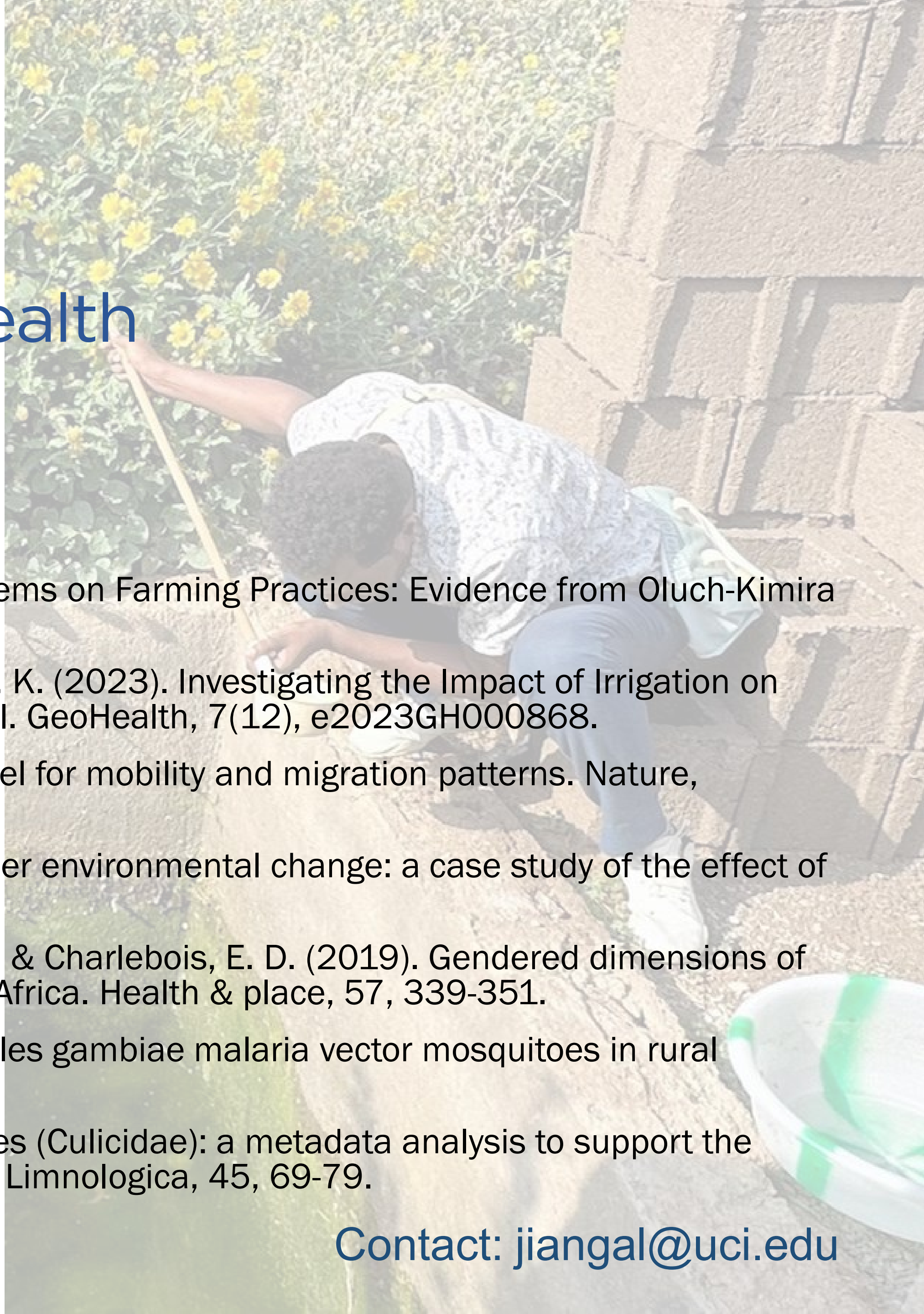
UCI Public Health



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Contact: jiangal@uci.edu