Rice & Malaria in Africa:

A Growing Problem

Kallista Chan, Kazuki Saito, Jo Lines

LONDON SCHOOL of HYGIENE & TROPICAL MEDICINE

CGIAR RESEARCH PROGRAM ON Agriculture for Nutrition and Health

Led by IFPRI


- **What will make the absence of malaria stable in Africa?**
  - with An gambiae ..
  - …but without insecticides

- **Committed to Arms Race**
  - not keeping up
  - can manage a decade or two
  - cannot manage >50y

- **Must avoid losing….but cannot win!**

- **How Exit from the Arms Race?**

Ministries of Agriculture in Africa
are planning for
a major expansion in irrigated rice

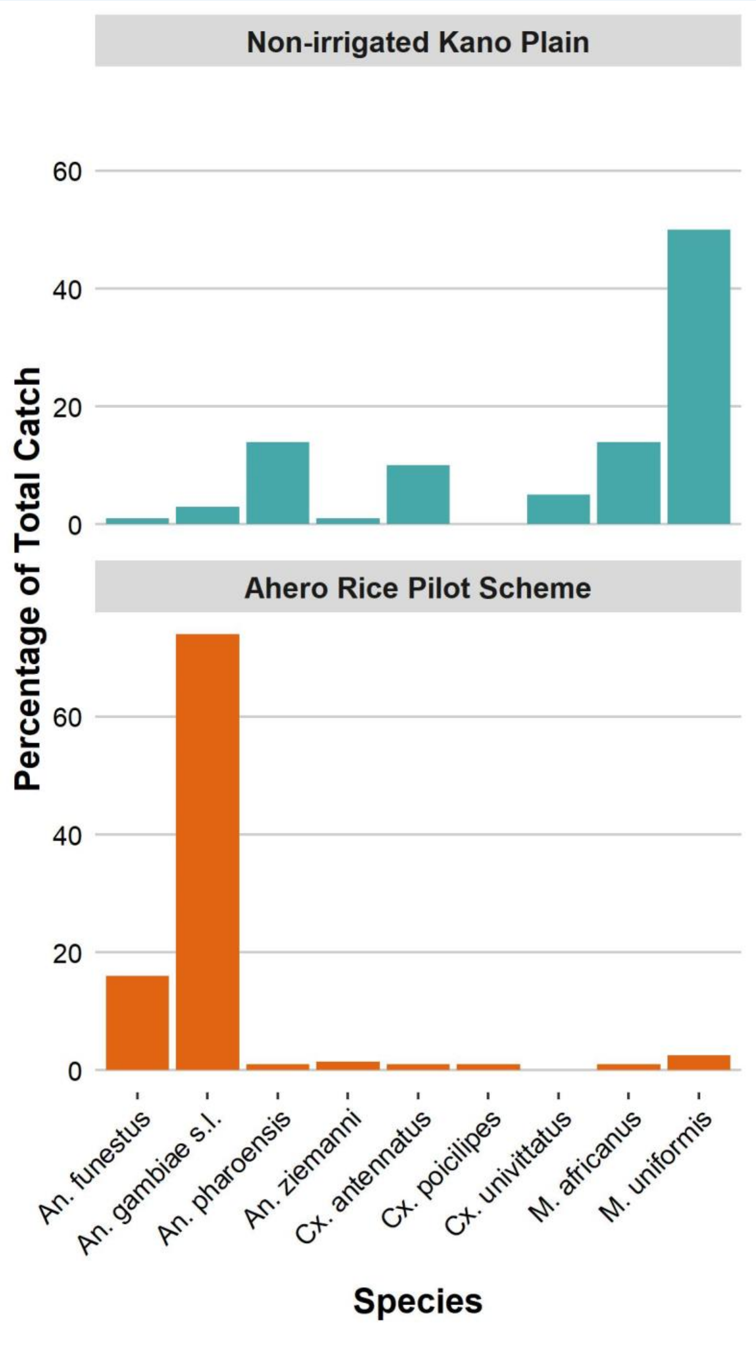
Ministries of Health in Africa
are planning for
the elimination of malaria

Evidence 1: From wetlands to paddies

Q: What happens when we introduce irrigated rice? What happens to the mosquito fauna when natural wetlands are replaced by irrigated rice?

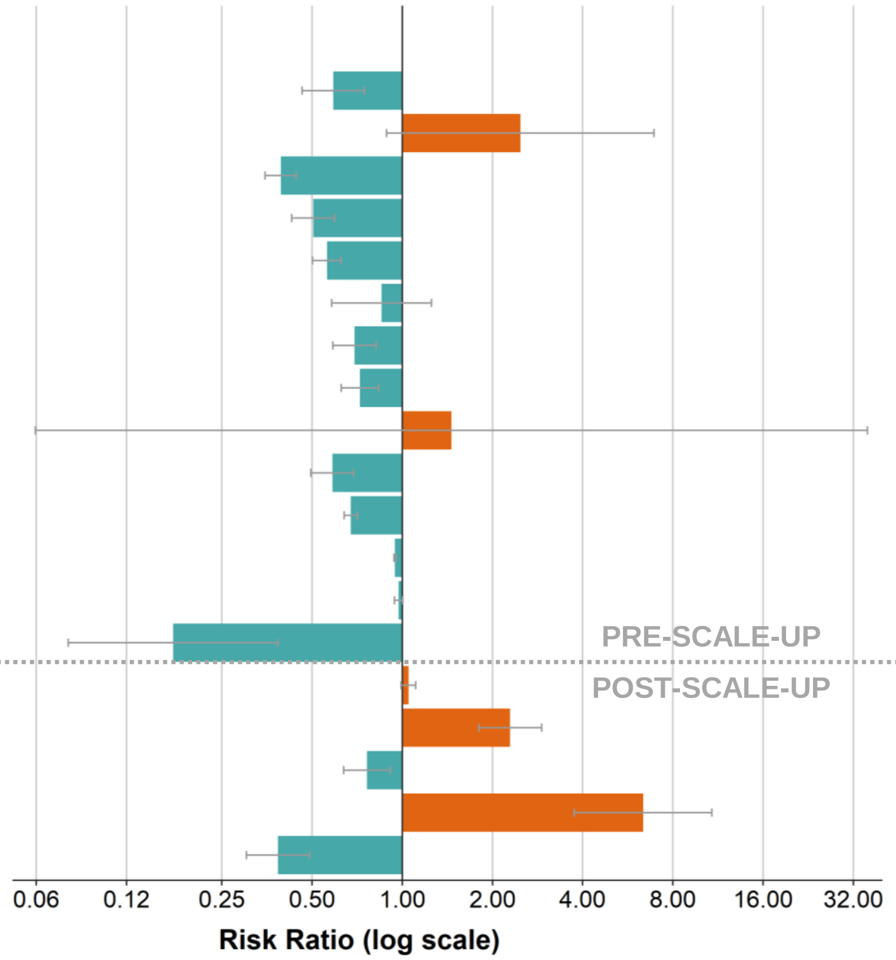
A: Non-vector culicines are replaced by malaria vector anophelines in roughly equal numbers.

Source: Chandler, J.A., Highton, R.B. and Hill, M.N., 1975. Mosquitoes of the Kano Plain, Kenya. I. Results of indoor collections in irrigated and nonirrigated areas using human bait and light traps. Journal of Medical Entomology, 12(5), pp.504-510.



Our re-analysis: Hypothesis 1

Reference	Country	Year	PfPR2-10 Control	PfPR2-10 Rice	Risk Ratio
Audibert et al. (1990)	Cameroon	1979	0.14	0.08	0.59 (0.46 - 0.75)
Couprie et al. (1985)	Cameroon	1981	0.03	0.08	2.48 (0.89 - 6.93)
Coosemans et al. (1985)	Burundi	1982	0.47	0.19	0.39 (0.35 - 0.44)
Josse et al. (1987)	Cameroon	1985	0.28	0.14	0.50 (0.43 - 0.59)
Boudin et al. (1992)	Burkina Faso	1985	0.64	0.36	0.56 (0.50 - 0.62)
Faye et al. (1993b)	Senegal	1990	0.09	0.08	0.85 (0.59 - 1.25)
Thomson et al. (1994)	The Gambia	1991	0.5	0.35	0.69 (0.59 - 0.82)
Gbakima et al. (1994)	Sierra Leone	1991	0.69	0.5	0.72 (0.63 - 0.83)
Faye et al. (1995)	Senegal	1992	0	0	1.46 (0.06 - 35.67)
Ijumba et al. (2002)	Tanzania	1994	0.22	0.13	0.58 (0.50 - 0.69)
Sissoko et al. (2004)	Mali	1995	0.49	0.33	0.67 (0.64 - 0.71)
Henry et al. (2003)	Cote d'Ivoire	1997	0.88	0.83	0.95 (0.94 - 0.95)
Assi et al. (2013)	Cote d'Ivoire	1998	0.7	0.68	0.97 (0.94 - 1.00)
Mutero et al. (2004)	Kenya	2001	0.39	0.07	0.17 (0.08 - 0.38)
Koudou et al. (2009)	Cote d'Ivoire	2002	0.7	0.73	1.05 (0.99 - 1.11)
Mboera et al. (2011)	Tanzania	2004	0.22	0.51	2.29 (1.80 - 2.92)
Toure et al. (2016)	Mali	2010	0.35	0.27	0.76 (0.64 - 0.91)
Mboera et al. (2015b)	Tanzania	2012	0.03	0.19	6.36 (3.74 - 10.81)
Hien et al. (2017)	Burkina Faso	2014	0.56	0.21	0.38 (0.30 - 0.49)



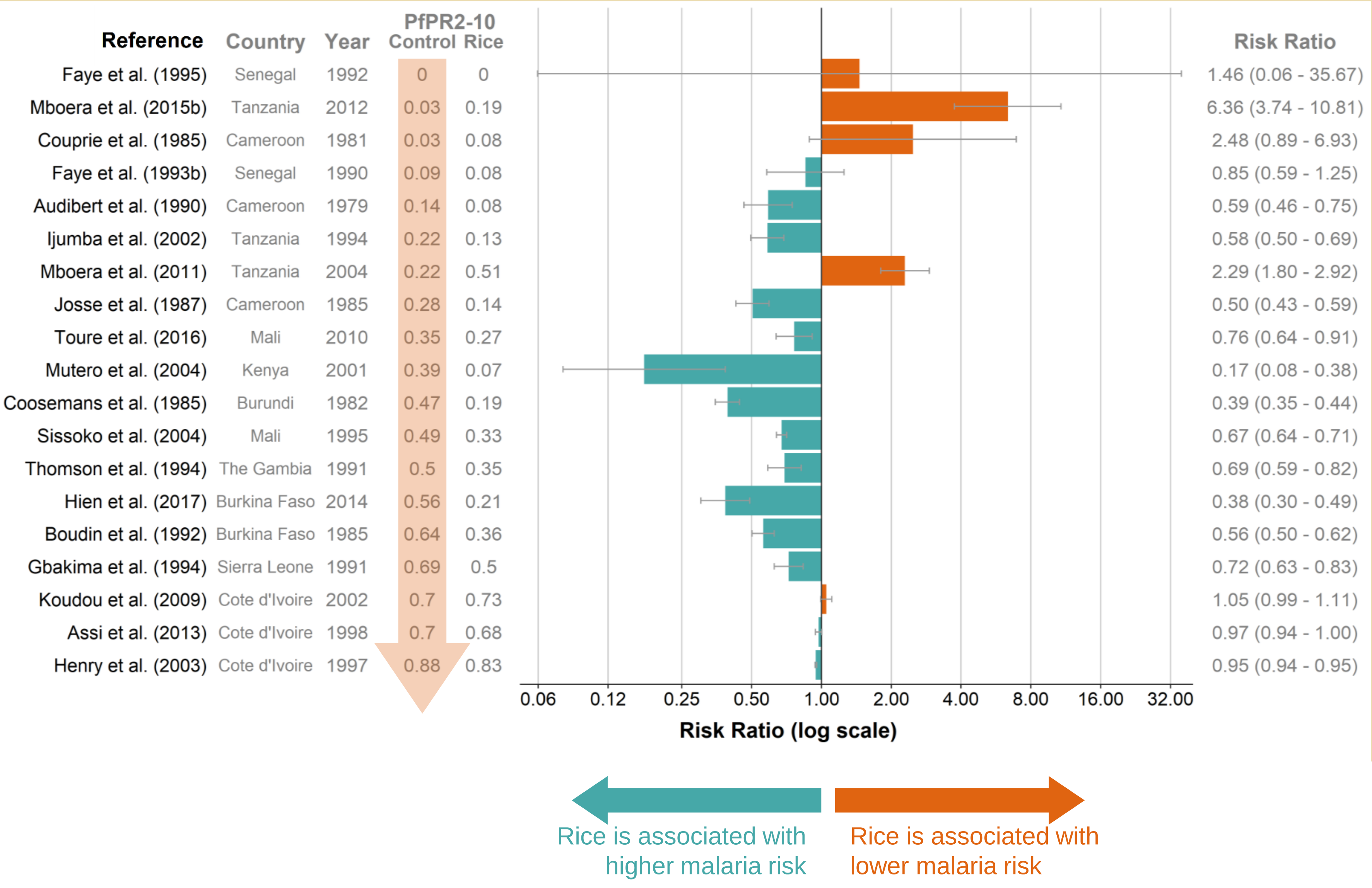
Rice is associated with lower malaria risk

Rice is associated with higher malaria risk

Rice-malaria trend against time:

Risk ratios (and their confidence intervals, presented as error bars) were calculated to compare malaria infection prevalence in rice and non-rice communities and plotted according to year of study.

Our re-analysis: Hypothesis 2



Rice-malaria trend against underlying malaria intensity:

Risk ratios (+ 95% CI) comparing malaria infection prevalence in rice and non-rice communities. Studies are ordered according to underlying malaria intensity, measured as the prevalence in the baseline (non-rice) areas of each study.

Paddies Paradox - Update

- The additional mosquitoes created by rice were never “harmless”;

- Rice did bring higher vectorial capacity, but did not bring higher malaria prevalence because humans had better defences.

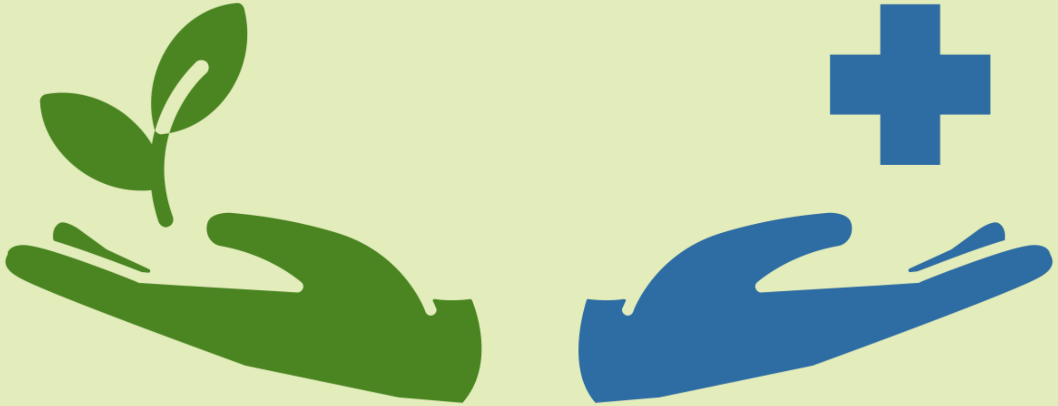
- Now, with less malaria and better intervention coverage, there are signs that rice-communities do now have more malaria.

Conclusion

How can we grow rice without growing mosquitoes?

Whose problem?

Agricultural sector or public health sector?

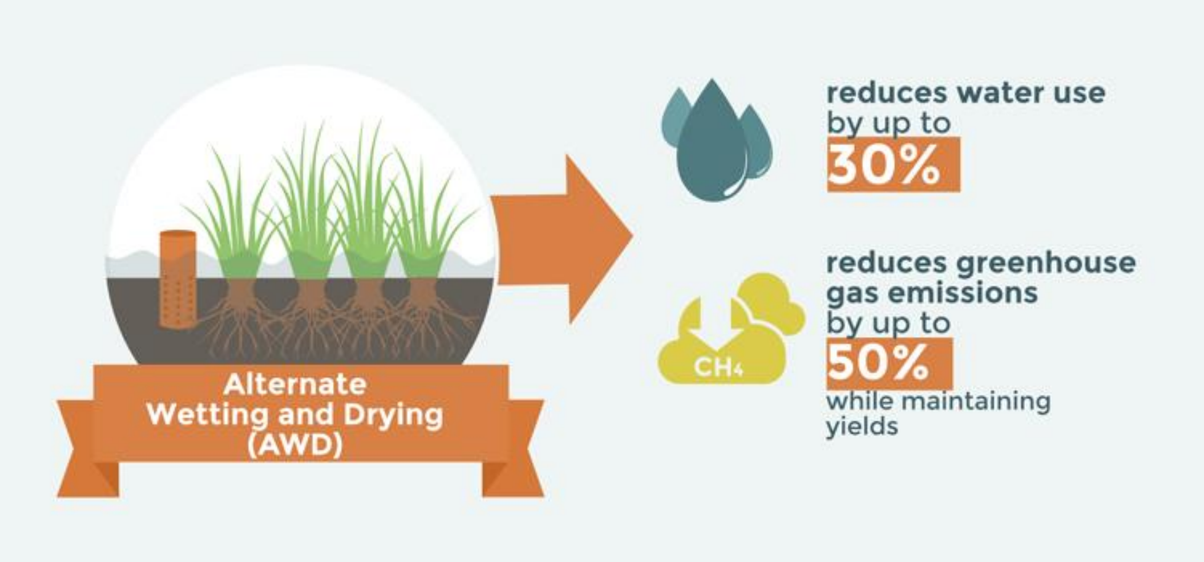


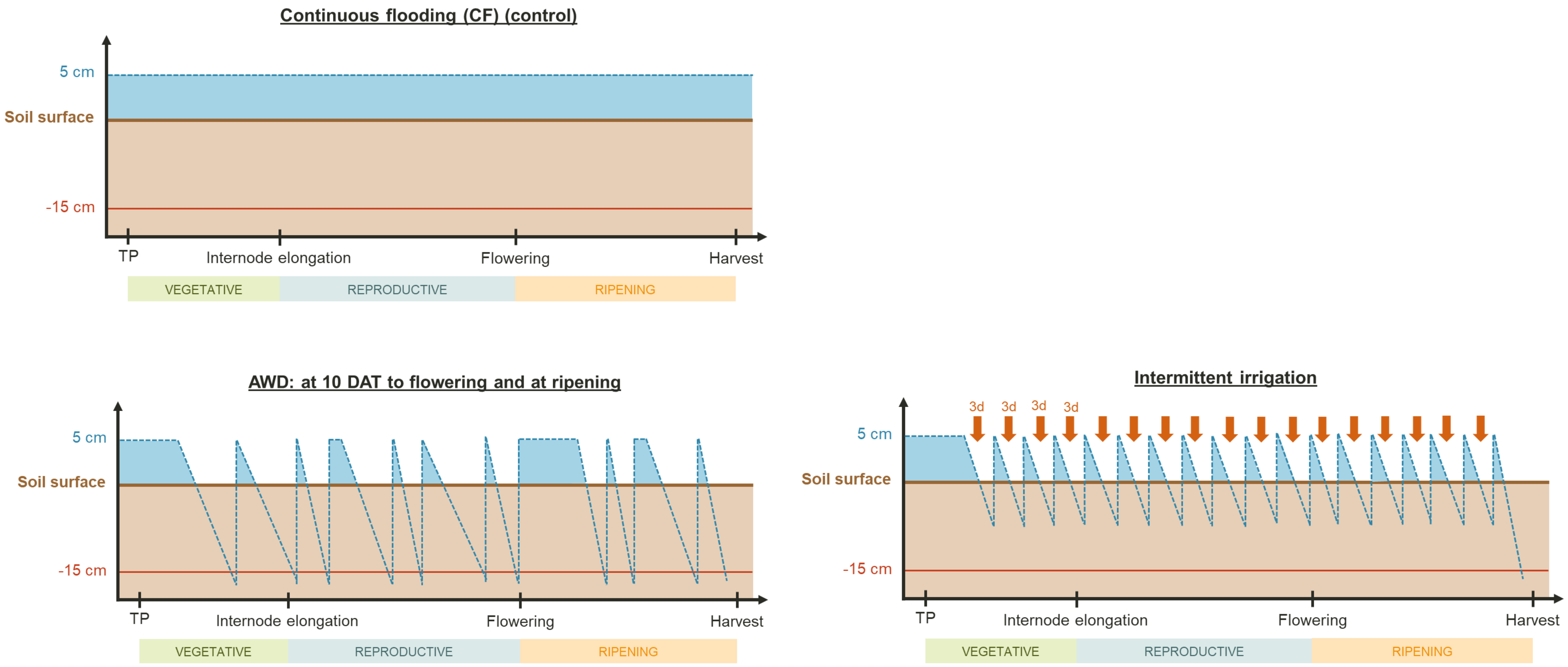
How can they work together on this problem?

Next steps

- Collaboration with AfricaRice and International Rice Research Institute (IRRI)
- Rice experts should know – sooner and better than anyone else – what effect their recommended production methods have on mosquitoes

- Recent interest in alternate wetting and drying irrigation (AWD) as a strategy for climate change mitigation and adaptation
- What effect on malaria vectors?





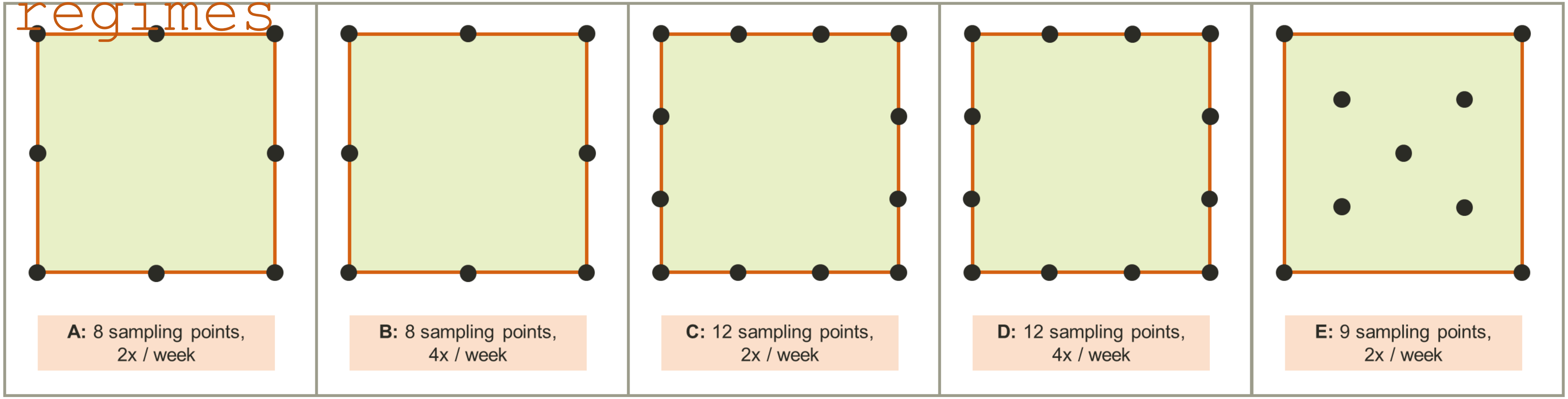
Continuous flooding (CF) (control)
5 cm
Soil surface
-15 cm
TP
Internode elongation
Flowering
Harvest
VEGETATIVE
REPRODUCTIVE
RIPENING
AWD: at 10 DAT to flowering and at ripening
5 cm
Soil surface
-15 cm
TP
Internode elongation
Flowering
Harvest
VEGETATIVE
REPRODUCTIVE
RIPENING
Intermittent irrigation
3d
3d
3d
3d
5 cm
Soil surface
-15 cm
TP
Internode elongation
Flowering
Harvest
VEGETATIVE
REPRODUCTIVE
RIPENING

Developing an efficient and representative method of sampling mosquitoes in rice fields

20 5x5m rice plots
with “standard” rice-growing
- Transplanting
- Continuous flooding
- 3x weed management
- 2x fertilisers

Larval mosquito sampling
- From land preparation to 3 weeks after harvest
- Counted according to developmental stage:
  - L1/L2 = early instar
  - L3/L4 = late instar
  - Pupae

Comparing a range of larval sampling regimes

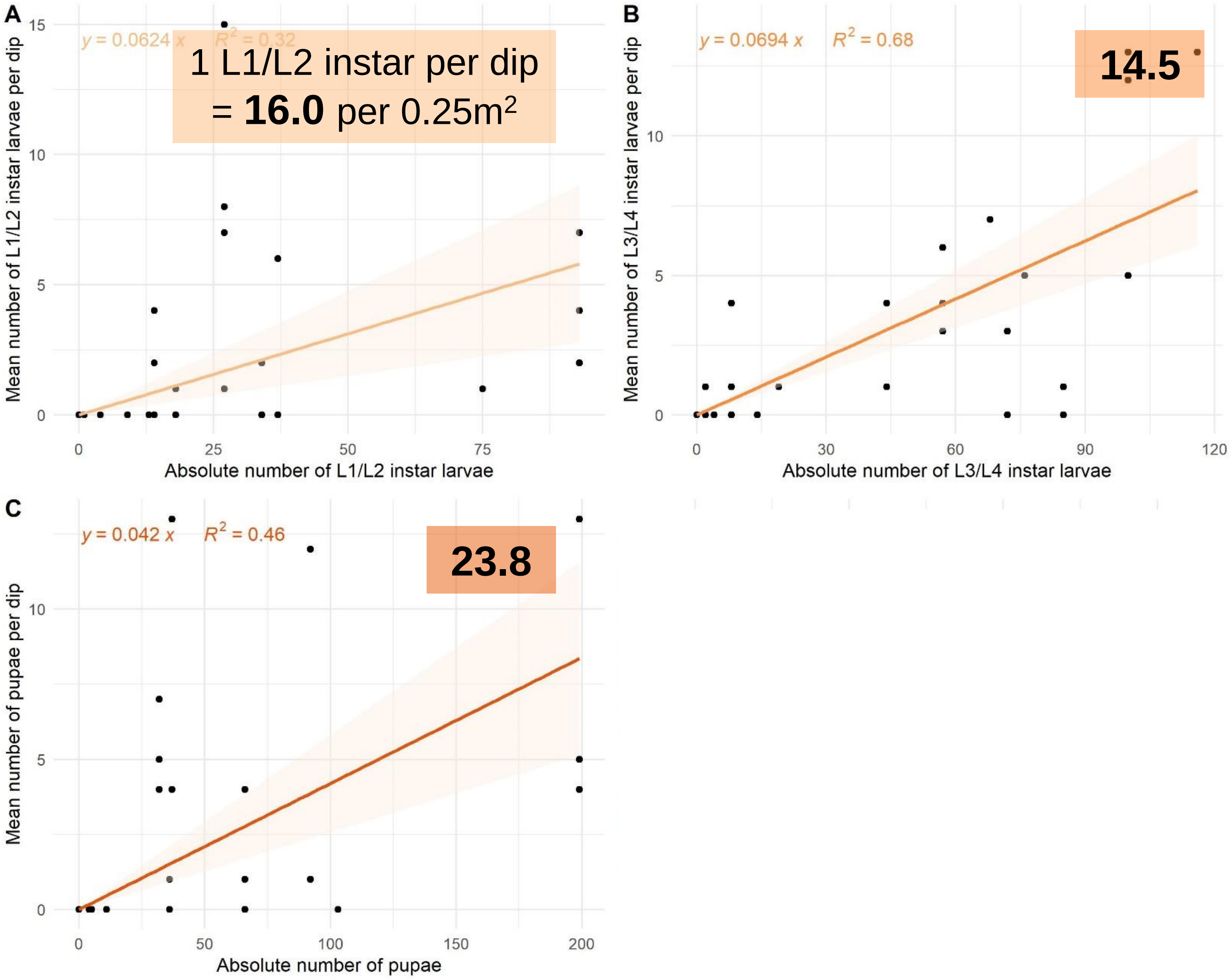


$$\textbf{Efficiency} = \frac{\text{Mean number of mosquitoes collected per week}}{\text{Time taken}}$$

Regime	Time taken (min per week)	Mean number of mosquitoes/plot/week sampled				Immatures efficiency (all stages /min)	Pupae efficiency (pupae/ min)
		Early instar (L1/L2)	Late instar (L3/L4)	Pupae	All stages		
A	9 m 40 s	23.3	18.4	6.9	48.7	5.43	0.963
B	18 m 36 s	40.9	51.3	11.1	103.0	5.89	0.598
C	13 m 42 s	29.7	30.3	9.5	69.5	5.62	0.918
D	25 m 54 s	80.3	78.0	13.0	171.0	6.68	0.467
E	10 m 30 s	21.9	19.7	4.3	45.9	4.12	0.436

Estimating vector productivity

Number found in quadrats = absolute number
Number found in dip = sample



Rainfall levels (mm)
Height of rice (cm)
Number of Anopheles larvae
Height of water (cm)
Mean per plot
Date
Herbicide application
Puddling & plowing
Puddling & levelling
Puddling & levelling
Transplanting & fertiliser app.
Replanting
Weeding
Fertiliser app.
Weeding
Fertiliser app.
Draining
Harvest
15-Apr
22-Apr
29-Apr
06-May
13-May
20-May
27-May
03-Jun
10-Jun
17-Jun
24-Jun
01-Jul
08-Jul
15-Jul
22-Jul
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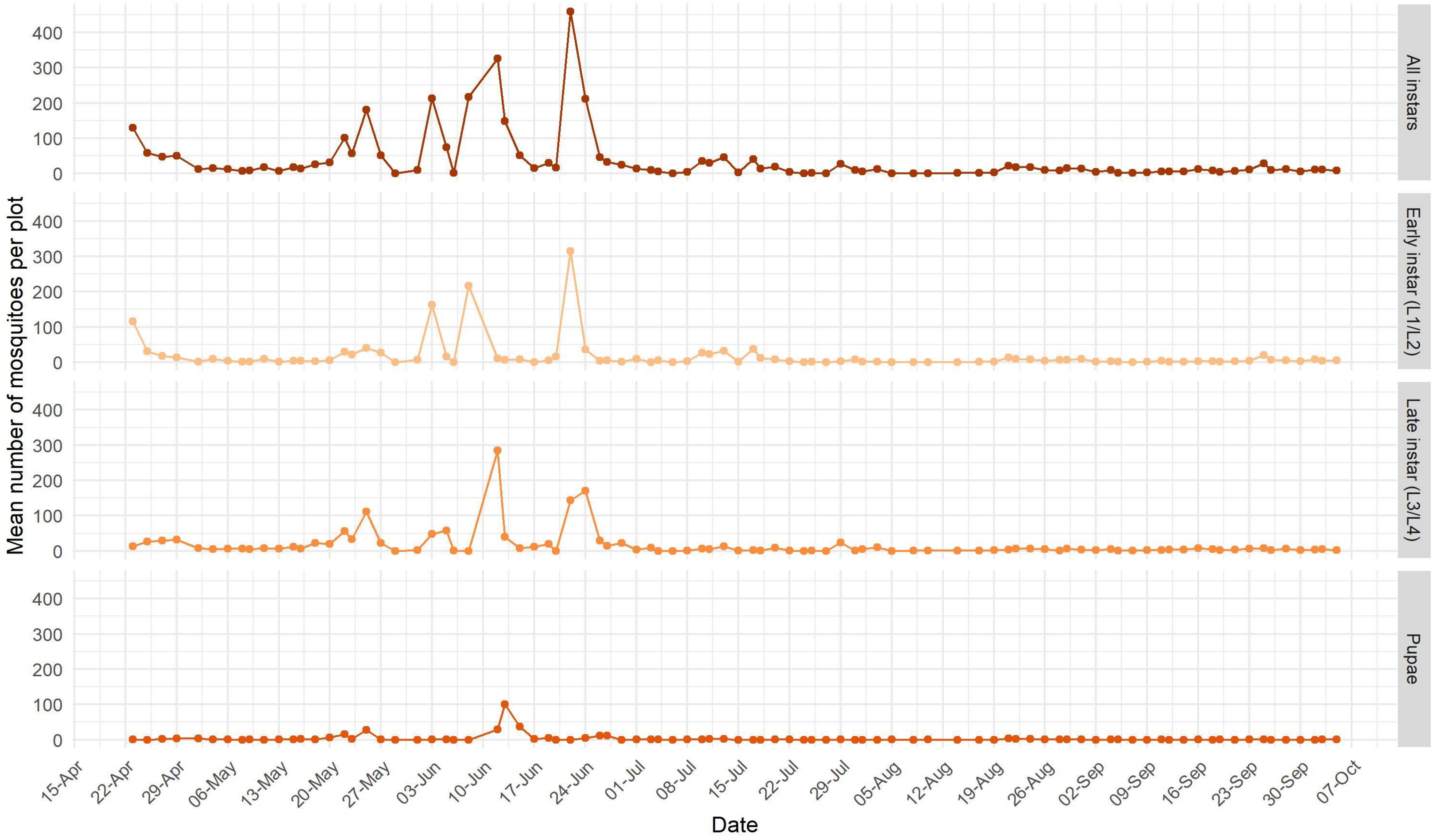
05-Aug
12-Aug
19-Aug
26-Aug
02-Sep
09-Sep
16-Sep
23-Sep
30-Sep
07-Oct



Mean number of mosquitoes per plot
All instars
Early instar (L1/L2)
Late instar (L3/L4)
Pupae
0
100
200
300
400
15-Apr
22-Apr
29-Apr
06-May
13-May
20-May
27-May
03-Jun
10-Jun
17-Jun
24-Jun
01-Jul
08-Jul
15-Jul
22-Jul
29-Jul
05-Aug
12-Aug
19-Aug
26-Aug
02-Sep
09-Sep
16-Sep
23-Sep
30-Sep
07-Oct
Date

Towards an estimate of total production ….

- Using the calibration factors, we could estimate the absolute pupal population produced by a rice plot

- It was estimated that in a 150-day cropping season, a 5m x 5m rice plot can produce 124,000 pupae

- Pupae emerge in 24h to 36h

- So at least **80,000** adults per 5mx5m plot per season

Water management and crop establishment

- At least 2 seasons
- Randomised complete block design
- 3 replications
- Same rice variety
- Square distances of 20 cm

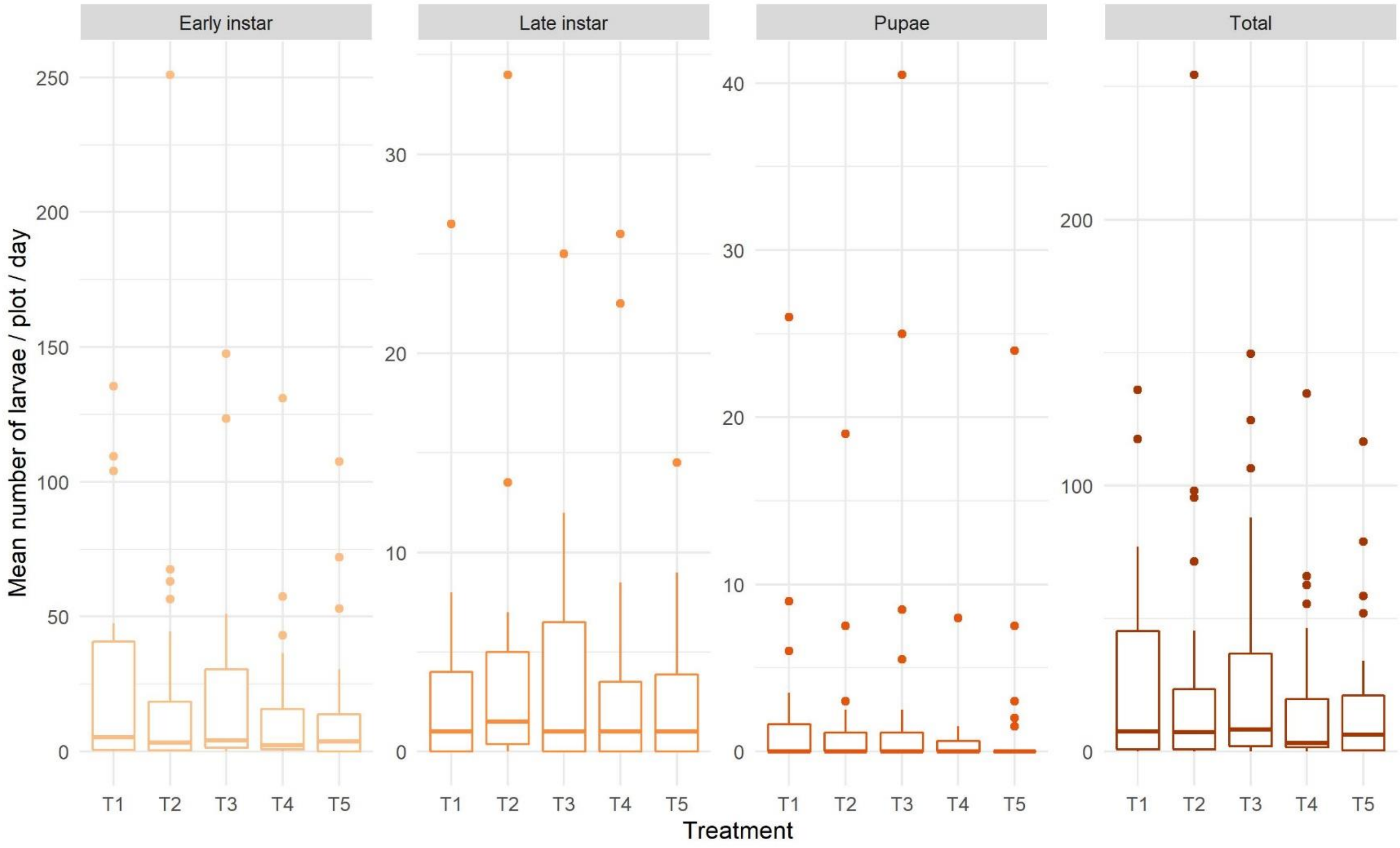
- Larval mosquito sampling
  - From land preparation to 3 weeks after harvest, 2x/week
  - At every 5 m interval on the borders of each plot

1) CF and manual wet direct broadcast seeding
2) CF and manual line dry seeding
3) CF and line wet seeding with a drum-seeder
4) CF and manual square transplanting (control)
5) AWD and manual square transplanting

Water management and crop establishment

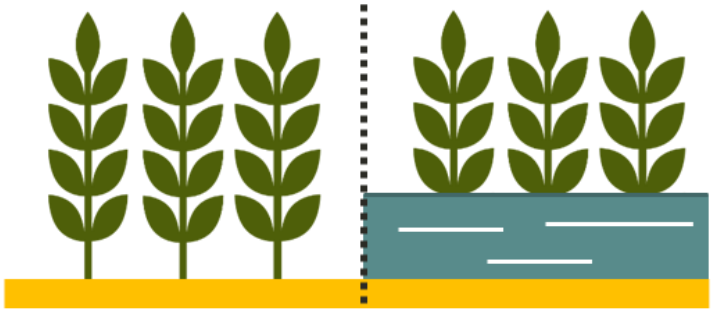
- Negative binomial GLMs: rice treatment ~ mosquito density + plot position + date

Treatment	Rate Ratio	95% CI	p	Likelihood ratio test
All stages of larvae				
T1	1.030	0.426 – 2.487	0.946	
T2	1.183	0.511 – 2.743	0.684	
T3	1.154	0.489 – 2.729	0.740	
T4	(reference)	-	-	
T5	1.005	0.442 – 2.305	0.991	
Date	0.970	0.958 – 0.982	<0.001	
Row X	(reference)	-	-	0.298
Row Y	0.516	0.276 – 0.955	0.029	(p = 0.990)
Row Z	0.915	0.499 – 1.682	0.786	
Column 1	(reference)	-	-	
Column 2	1.099	0.483 – 2.536	0.818	
Column 3	0.841	0.357 – 1.975	0.689	
Column 4	1.000	0.433 – 2.312	1.000	
Column 5	1.229	0.537 – 2.807	0.617	
Pupae				
T1	5.480	1.152 – 28.64	0.024	
T2	2.890	0.683 – 12.14	0.134	
T3	6.391	1.329 – 31.52	0.011	
T4	(reference)	-	-	
T5	1.615	3.554 – 6.613	0.489	
Date	0.979	0.959 – 0.999	0.003	
Row X	(reference)	-	-	6.283
Row Y	0.188	0.061 – 0.542	0.001	(p = 0.179)
Row Z	0.536	1.942 – 1.431	0.200	
Column 1	(reference)	-	-	
Column 2	1.143	0.289 – 4.444	0.842	
Column 3	0.511	0.110 – 2.345	0.354	
Column 4	0.236	0.043 – 1.207	0.057	
Column 5	0.558	0.126 – 2.357	0.415	



Descriptive statistic	Pupae	Larvae (early and late instars)
Mean number per plot at each sampling occasion	0.35	3.07
Variance	6.37	121.16
Standard deviation	2.52	10.99
Standard error	0.03	0.11
Between-plot variance	187.90	4459.94
Within-plot variance	58219.80	1105749.70
Intra-class correlation coefficient	0.00181	0.00267
Number of samples over a season (fixed)	350	350
Effect size	2-fold reduction: 0.17	2-fold reduction: 1.535
Number of plots required per treatment	15	5

Scientists from the rice sector and the public health sector have independently developed:



Alternate wetting and drying
vs.
intermittent irrigation

Water use:
30% reduction

Methane emissions:
48% reduction

Rice yield:
No reduction

Vector production:
95% reduction

TRANSDISCIPLINARY
WIN-WIN-WIN-WIN
SOLUTION

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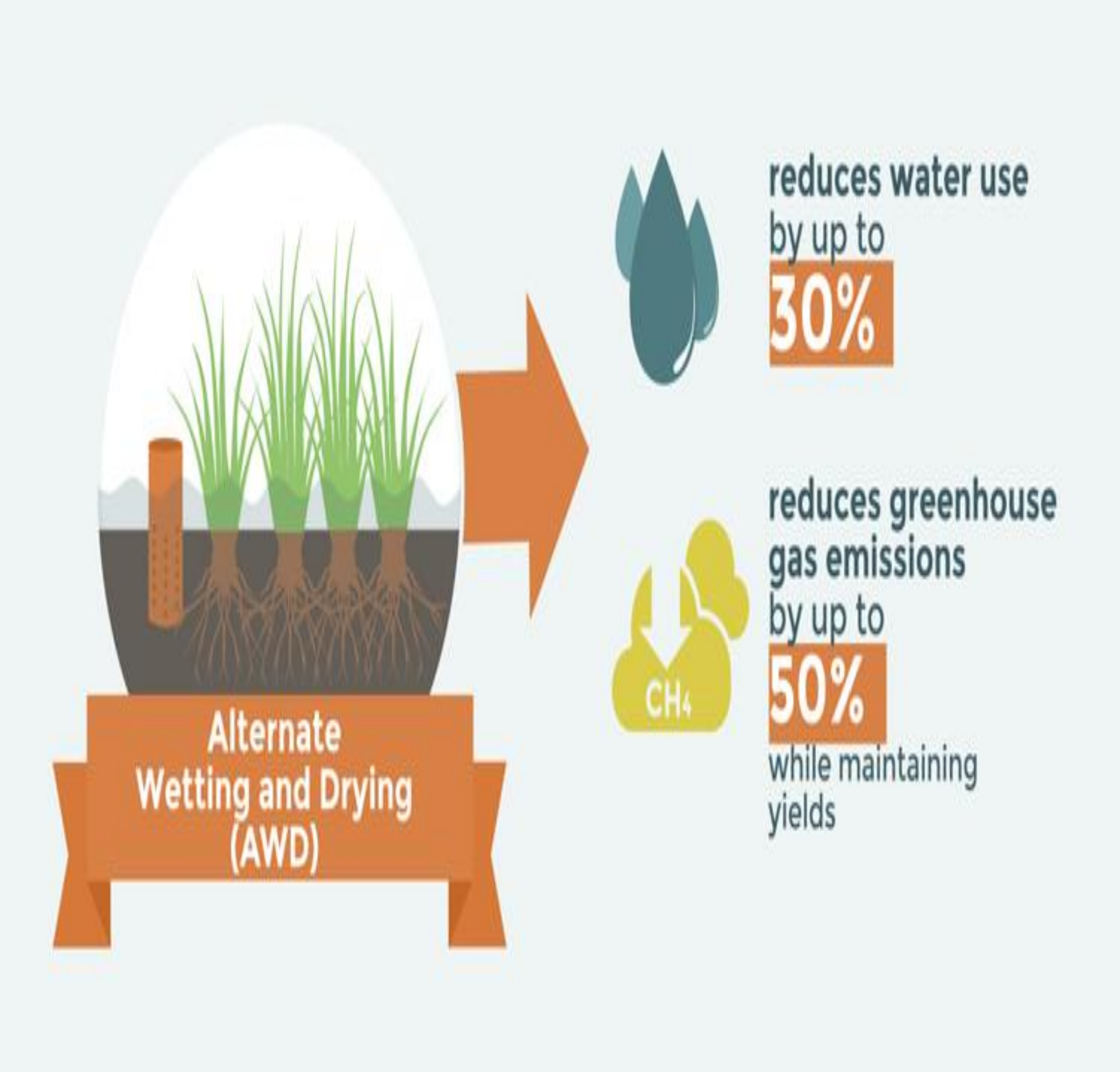

- **Wellcome “Our Planet Our Health”**

- **Why link with Climate Change?**
  - $$$$
  - They DO address externalities

- **Start to work with IRRI in E Africa**
  - Tz? Ke?

- **Start to work with Ministries:**
  - Ag+Health.   Nigeria?   Ghana?

- **Initial Meeting in June 2020**

Thank you

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