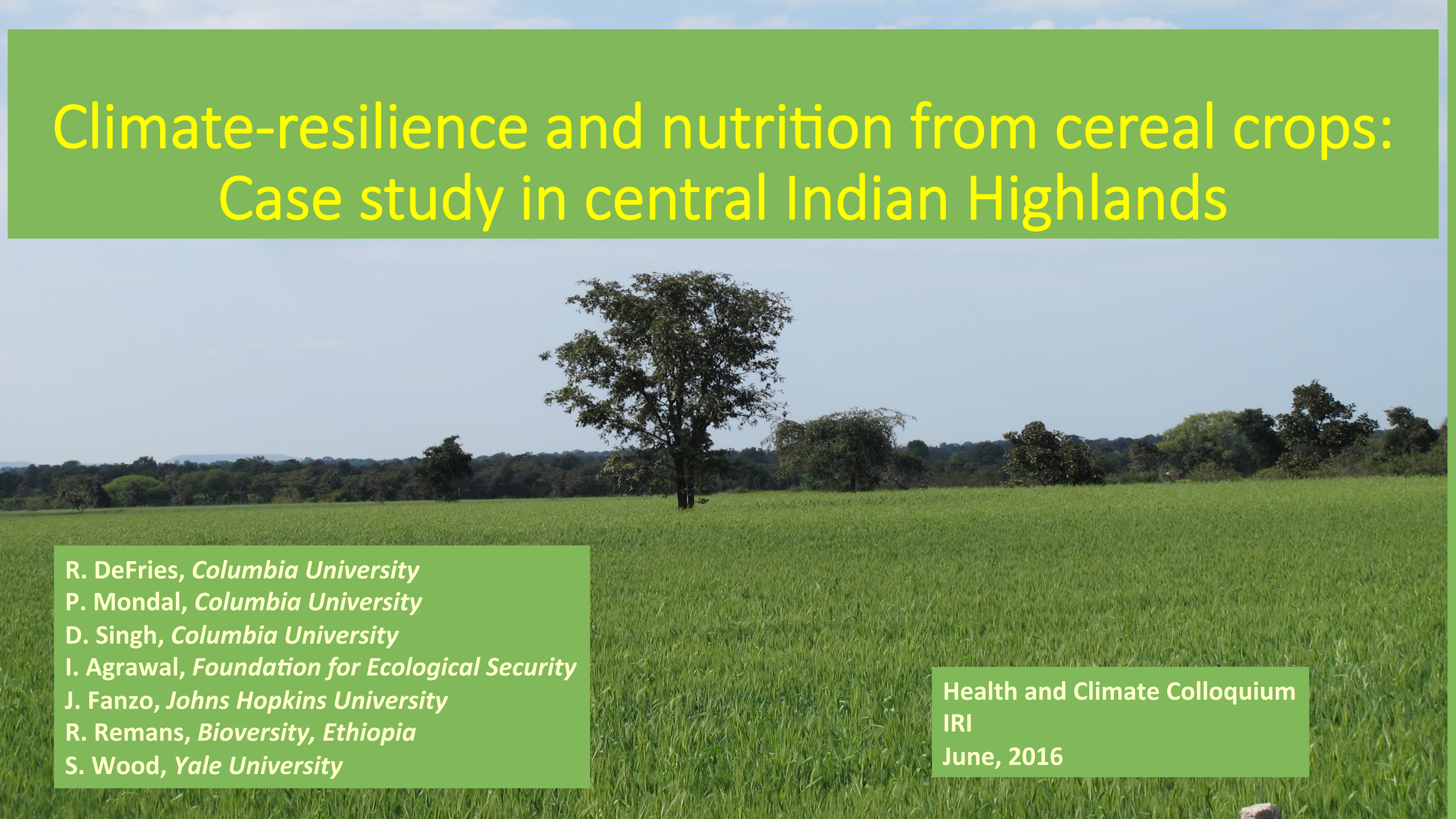
Climate-resilience and nutrition from cereal crops: Case study in central Indian Highlands



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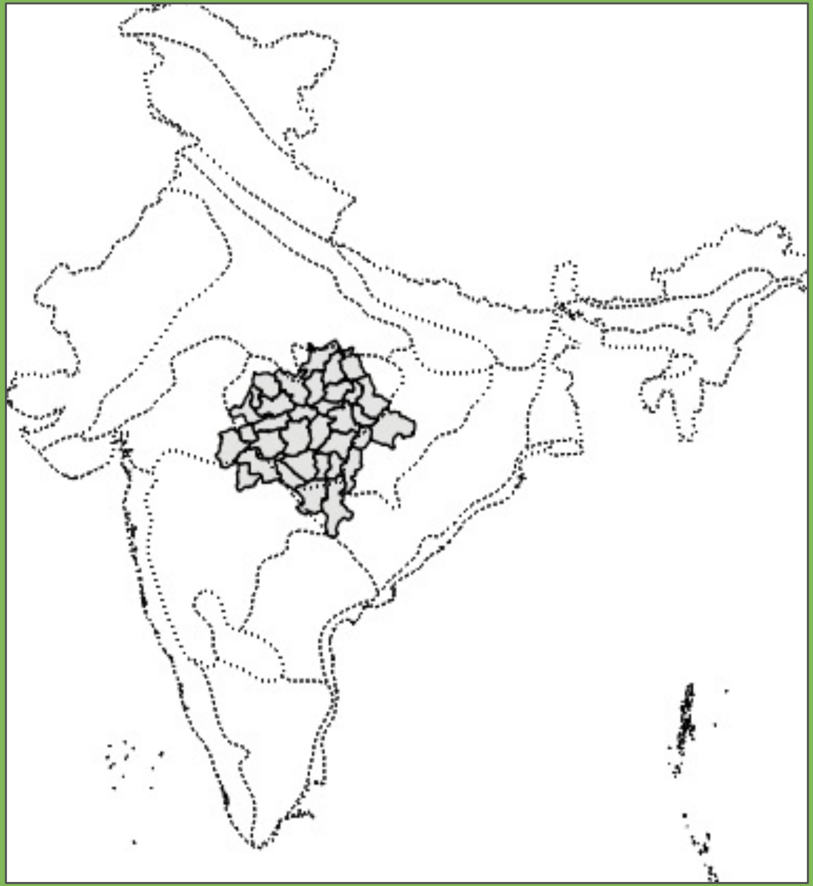
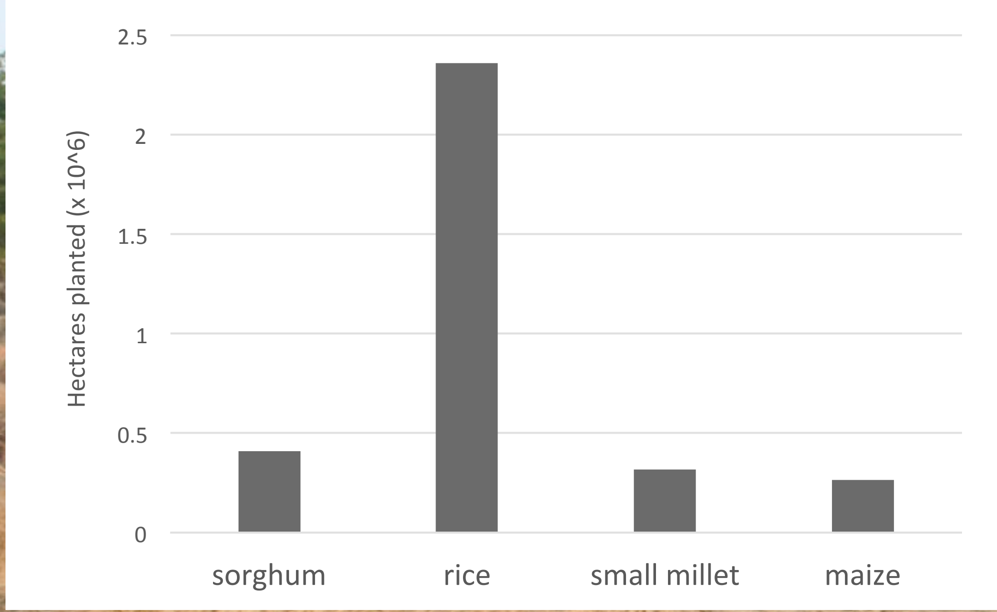
Health and Climate Colloquium
IRI
June, 2016

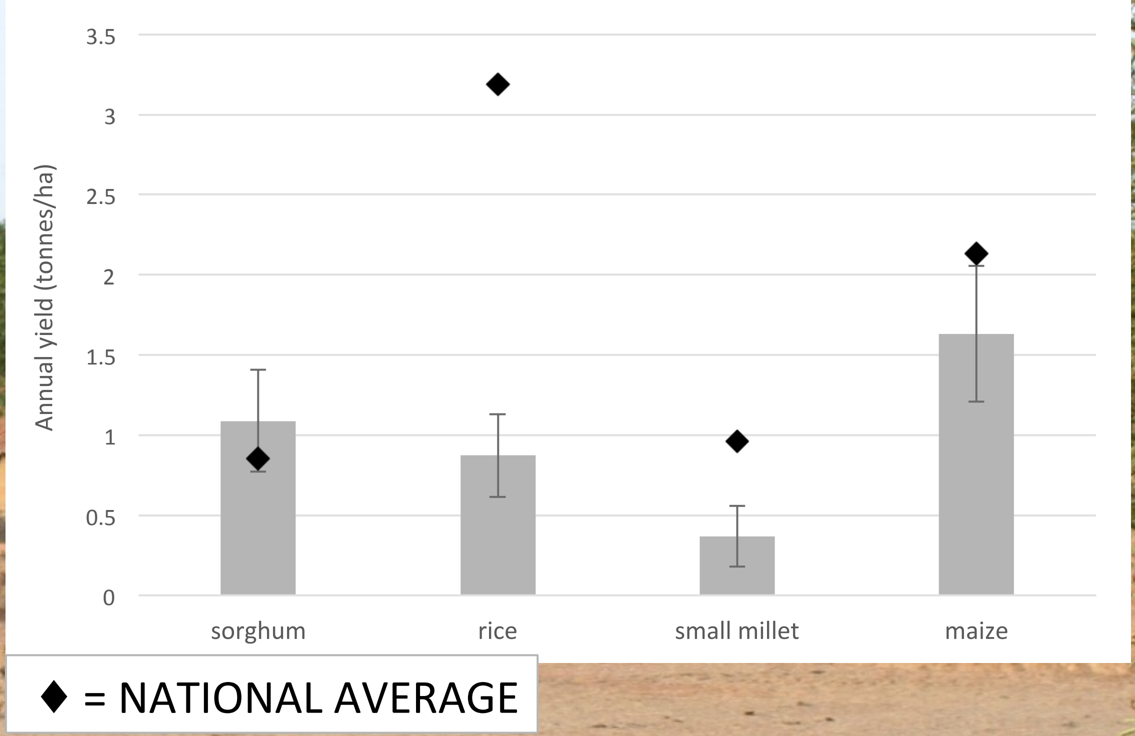
WHICH CEREAL CROPS MEET MULTIPLE OBJECTIVES FOR CLIMATE AND HEALTH?: *CASE STUDY IN CENTRAL INDIAN HIGHLA*



RICE IS DOMINANT CROP



MEAN AREA PLANTED



MEAN ANNUAL YIELD ACROSS 34 DISTRICTS FOR 2000-12

(DeFries et al, in review, Global Food Security)

MULTIPLE OBJECTIVES FOR CEREAL CROPS

PROVIDE NUTRITION

USE LAND EFFICIENTLY

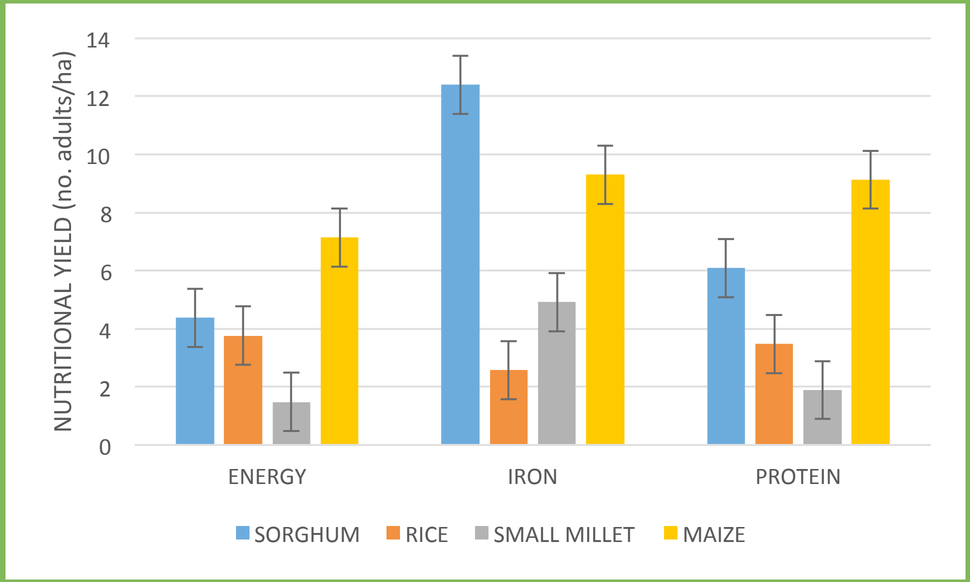
RESILIENCE TO CLIMATE VARIABILITY

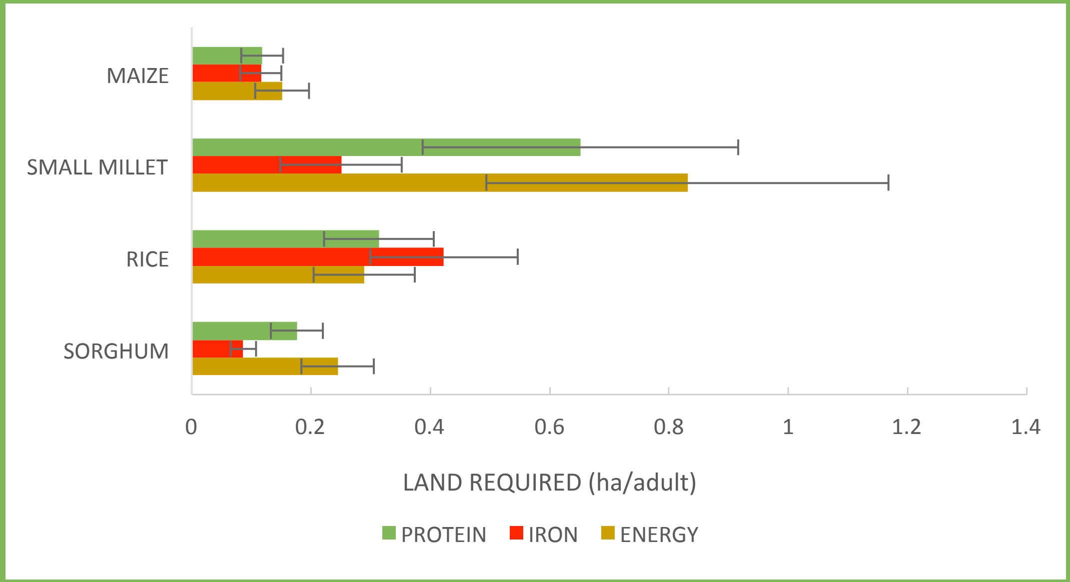
FARMER INCOME

NUTRITIONAL YIELD
(DeFries et al., *Science*, 2015)

STATISTICAL MODELS USING MULTIPLE CLIMATE DATA SETS

NUTRITIONAL YIELDS HIGHEST FOR SORGHUM AND MAIZE





(DeFries et al, in review, Global Food Security)

CLIMATE SENSITIVITY OF CEREAL CROPS FROM MIXED MODELS: REPONSE VARIABLE YIELD

VARIABLE	SOURCE	MEAN
Total monsoon rainfall (mm)	(Anon, 2016a)	1062 (237)
Mean seasonal temperature (°C)	(Fan and Van den Dool, 2008)	28.77 (1.19)
Soils: fraction vertisols	(FAO/Unesco, 1971)	0.084 (.162)
Soils: fraction cambisols	(FAO/Unesco, 1971)	0.149 (.167)
Soils: fraction lithosols	(FAO/Unesco, 1971)	0.177 (.299)
Irrigation: fraction area sorghum	(Government of India, 2015)	0.003 (0.015)
Irrigation: fraction area rice	(Government of India, 2015)	0.107 (0.154)
Irrigation: fraction area small millet	(Government of India, 2015)	0
Irrigation: fraction area maize	(Government of India, 2015)	0.009 (0.025)

4 gridded precip data sets
3 gridded temperature data sets

Fixed effects district and year

(DeFries et al, in review, Global Food Security)

EXAMPLE MODEL RESULTS: RICE

Rice (n=294)

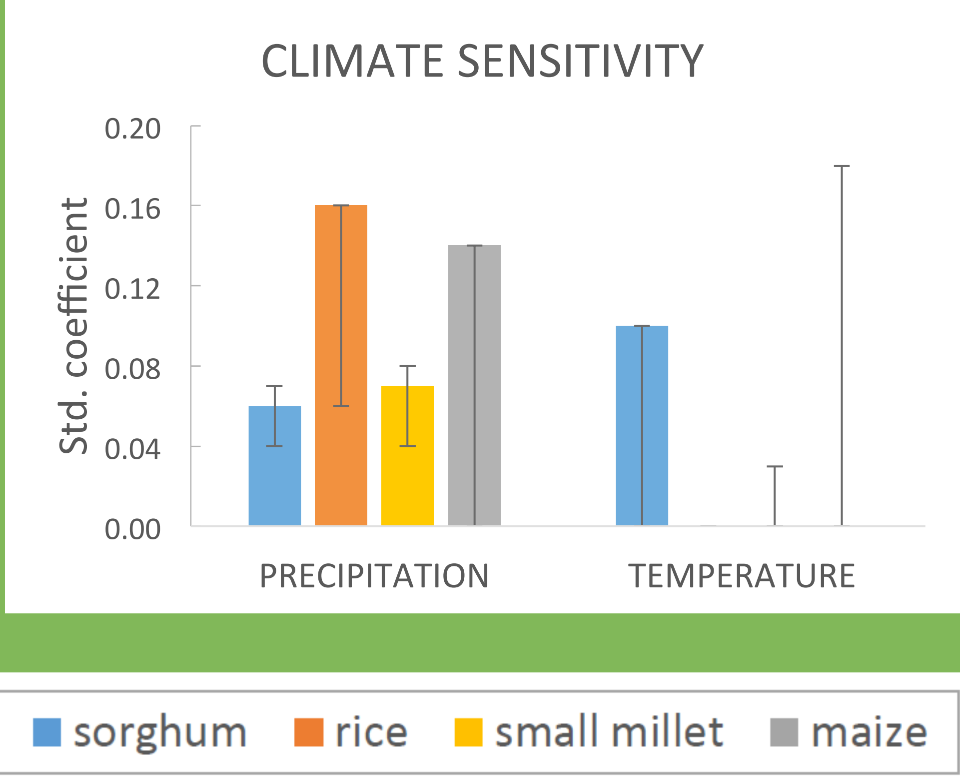
TEMPERATURE DATA	D	D	D	D	A	B	C	E
PRECIPITATION DATA	F	H	I	G	G	G	**G**	G
VARIABLES:								
PRECIPITATION	0.07	0.06	0.12	0.16	0.16	0.16	**0.16**	0.16
SOILS: VERTISOLS	-0.01	0.00	-0.01	-0.01	-0.01	-0.01	**-0.01**	-0.01
SOILS: CAMBISOLS	0.03	0.04	0.05	0.04	0.05	0.04	**0.05**	0.05
SOILS: LITHOSOLS	0.03	0.03	0.01	-0.01	-0.01	-0.02	**-0.01**	-0.01
TEMPERATURE	0.03	0.03	0.04	-0.01	-0.02	-0.01	**-0.02**	-0.01
IRRIGATION OF CROP	0.12	0.12	0.12	0.12	0.11	0.12	**0.12**	0.11
PRECIP_QUADRATIC	-0.01	0.01	-0.01	0.02	0.02	0.02	**0.02**	0.02
TEMP_QUADRATIC	0.01	0.01	0.07	0.01	0.00	0.01	**0.01**	-0.01
marginal r2	0.18	0.21	0.26	0.37	0.37	0.37	**0.37**	0.38
conditional r2	0.74	0.68	0.74	0.74	0.74	0.75	**0.74**	0.74
AIC	51.63	53.61	35.25	7.66	8.47	7.57	**7.46**	8.42

A= BEST mean daily maximum; B= CRU mean daily maximum; C= NOAA mean; D= CRU mean; E= W-M mean. JJA total precipitation: F=IMD; G=TRMM; H=W-M; I=CHIRPS.

RICE IS LEAST RESILIENT TO VARIABILITY IN PRECIPITATION

PREDICTOR	SORGHUM	RICE	MAIZE	SMALL MILLET
PRECIPITATION: TOTAL MONSOON RAINFALL	0.06	0.16	0.14	0.07
SOILS: VERTISOLS	0.10	-0.01	0.27	0.07
SOILS: CAMBISOLS	0.08	0.05	0.27	0.03
SOILS: LITHOSOLS	-0.10	-0.01	0.16	0.04
TEMPERATURE: SEASONAL MEAN	-0.10	-0.02	0.07	0.01
IRRIGATION: FRACTION OF SOWN AREA	0.00	0.12	-0.01	n.a.
PRECIP_QUADRATIC	-0.04	0.02	-0.02	-0.01
TEMP_QUADRATIC	-0.02	0.01	-0.01	0.00
marginal r2 (fixed effects)	0.26	0.37	0.29	0.15
conditional r2 (fixed + random effects)	0.71	0.74	0.64	0.72
n	277	294	280	216

(TRMM precip, NOAA mean temp)



MULTIPLE OBJECTIVES FOR CLIMATE-RESILIENT NUTRITION

(DeFries et al, in review, Global Food Security)

CONCLUSIONS

- **Climate-resilience and nutrition both components for healthy agriculture**
- **Rice, the most dominant crop, is less resilient to variability in monsoon precipitation and provides less nutrition per hectare than other cereals (millet, sorghum, maize) in this study area**
- **No single cereal crop provides highest nutritional yield and climate resilience. Choices involve trade-offs**
- **Empirical analysis with multiple climate data sets needed to support planting decisions and agricultural investments**

THANKS

NUTRITIONAL YIELD: NUMBER OF ADULTS WHO CAN OBTAIN 100% DRI OF NUTRIENT PER HECTARE PER YEAR

$$NY_{ij} = \text{fraction of } DRI_i/100g_j \times \text{tonnes}_j/\text{ha/year} \times 10^4/365$$

NY_{ij} = nutritional yield of nutrient *i* from food item *j* in units of fraction of DRI_i/ha-year

Fraction of $DRI_i/100g_j$ = fraction of daily dietary reference intake of nutrient *i* provided by 100 grams of food item *j*, calculated as $(g_i/100g_j)/DRI_i$.

tonnes_j/ha/year = metric tons of food item *j* produced per hectare per year (the traditional yield measure)

Metrics for land-scarce agriculture

Nutrient content must be better integrated into planning

By Ruth DeFries,[1*] Jessica Fanzo,[2] Roseline Remans,[3,4] Cheryl Palm,[3] Stephen Wood,[1,3] Tal L. Anderman[5]

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17 JULY 2015 • VOL 349 ISSUE 6245