Priorities for Wheat Intensification in the Eastern Indo-Gangetic Plains

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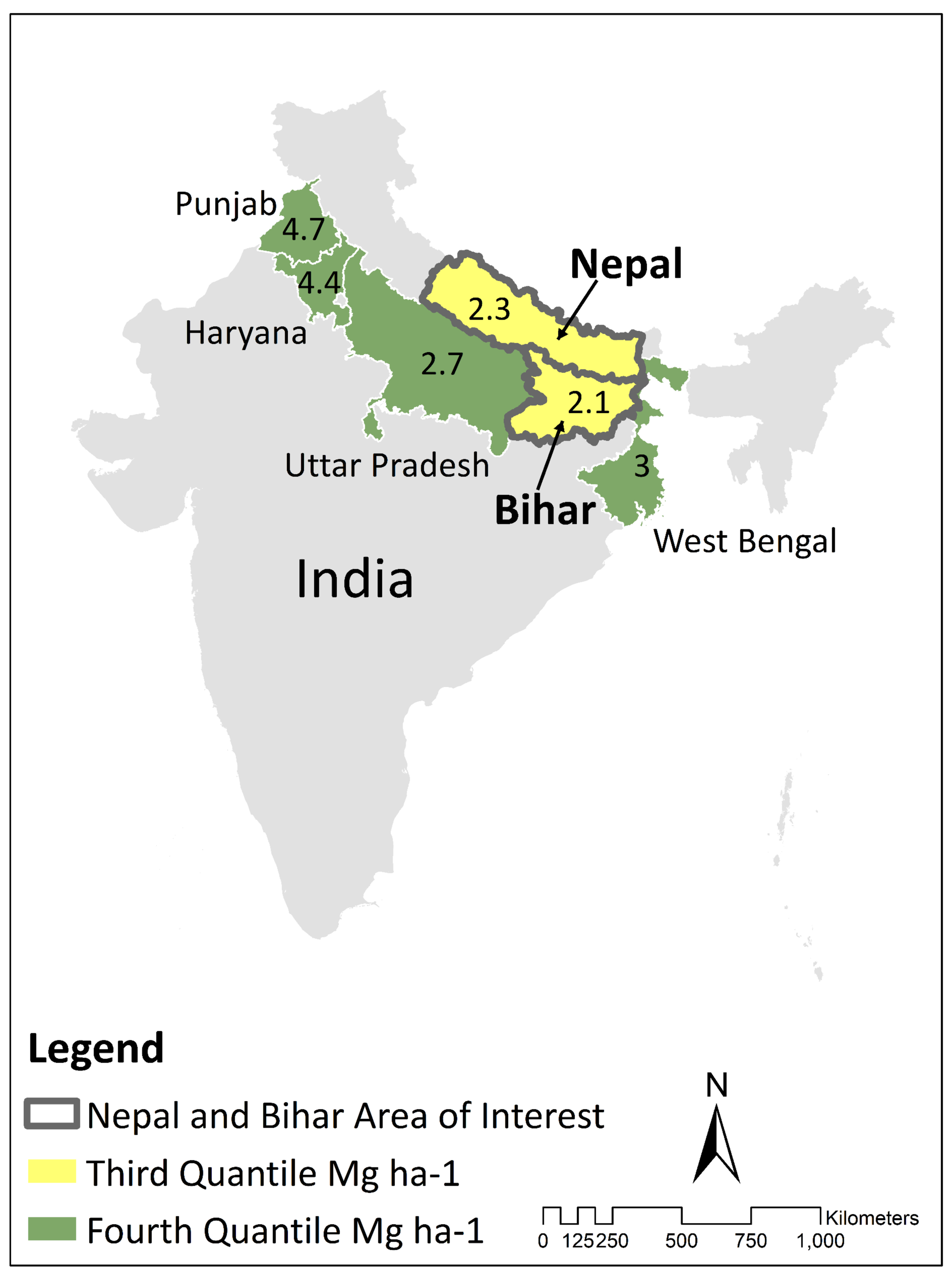
Food Security Challenge

- India is projected to consume more than its entire domestic wheat supply by 2030
- Nepal wheat imports have grown exponentially from India since 2011
- Both must increase domestic supply, increase imports, or face greater food insecurity
- Intra-village yield gaps between maximum village yield and farmer averages equal 31% unrealized yield

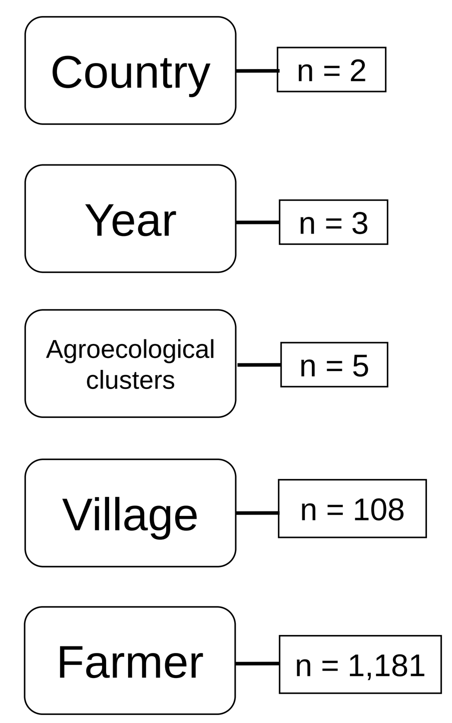


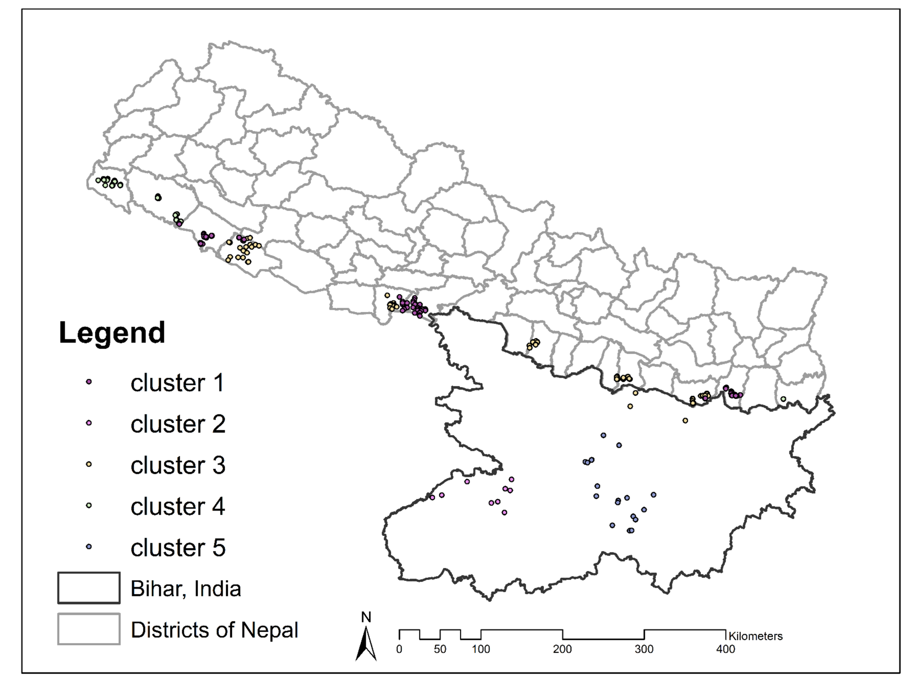
Average wheat yields (Mg ha^{-1}) between 2010 and 2015 in the Indo-Gangetic Plain. Nepal and Bihar are in the third quantile of wheat yields, behind the top quantile in India of Punjab, Haryana, Uttar Pradesh and West Bengal. Quantiles are calculated based on all available Indian state and Nepali yields.

Research Question

- Can wheat yield gaps in the Eastern Indo-Gangetic Plains be closed with current agronomic practices, and if so, which should be prioritized?

Development Data





On-farm production practice and yield estimation surveys taken at 1,181 farms in 108 villages in Bihar, India and the Terai Region of Nepal. Surveys taken in 2012, 2013, and 2016, but not universally replicated yearly at all locations.

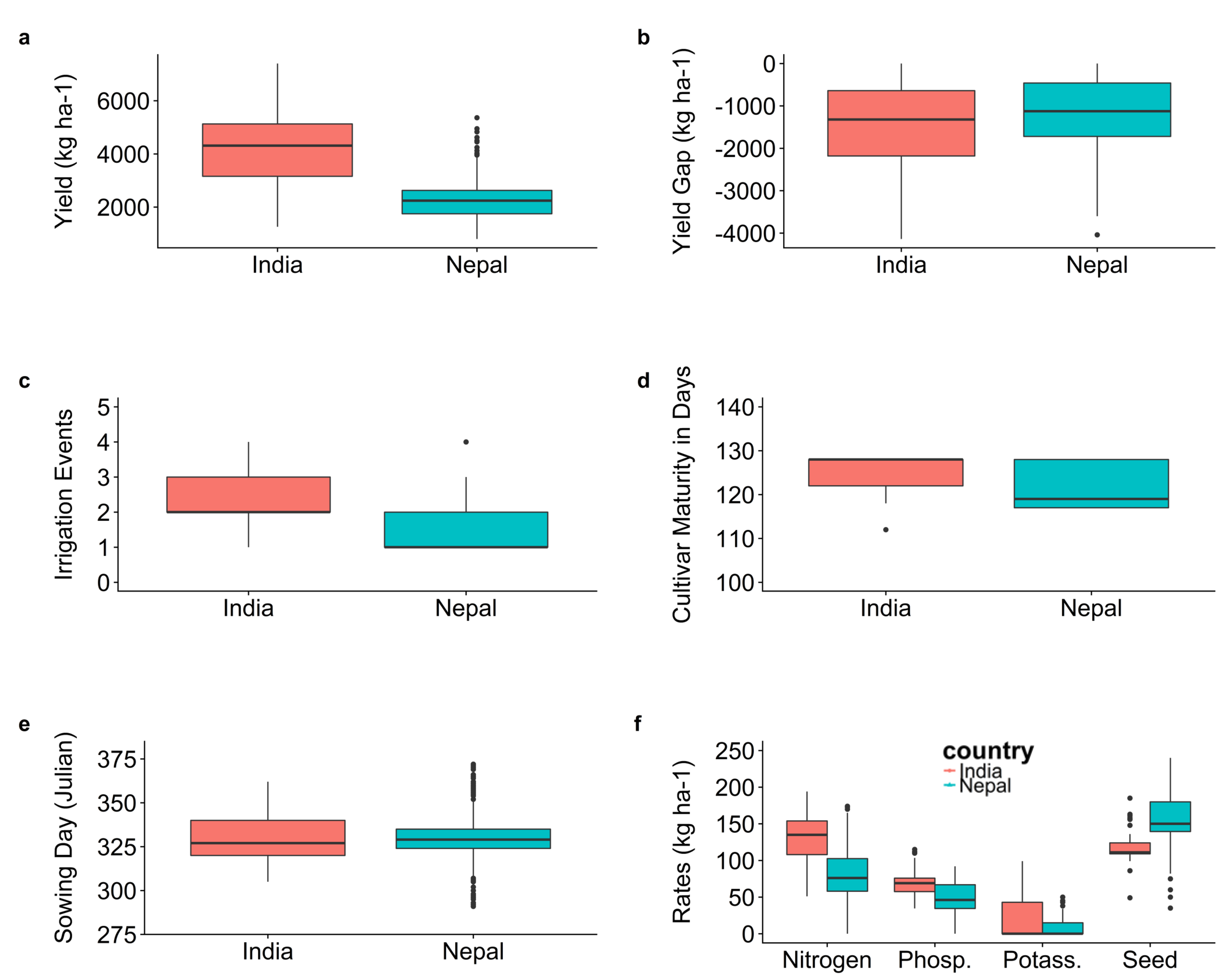
Agronomic, Environmental and Economic Factors

Yield Gap = (Maximum Village Yield) – (Farmer Yield Within Village)

Agronomic data: Cultivar maturity rating (dtm), seeding day of year (sdoy), Nitrogen in in kg per ha^{-1} (n.kgha), Phosphate in kg per ha^{-1} (p.kgha), Potassium in kg per ha^{-1} (k.kgha), seed kg per ha^{-1} (sd.kgha), number of irrigation events (irrig).

Environmental data: Soil texture (silt, clay, sand), organic matter, cation exchange capacity, bulk density, maximum and minimum temperature during wheat growing season (October-May), radiance during growing season, precipitation during growing season.

Economic data: Per Capita Income by district (PCI)



a) Yield disparity between India and Nepal; b) inter-country yield gap disparity; c) inter-country irrigation disparity; d) inter-country cultivar maturity rating disparity; e) inter-country sowing day of year disparity, f) inter-country Nitrogen, Potassium, Phosphate and seed rate in kg per ha-1 disparity.

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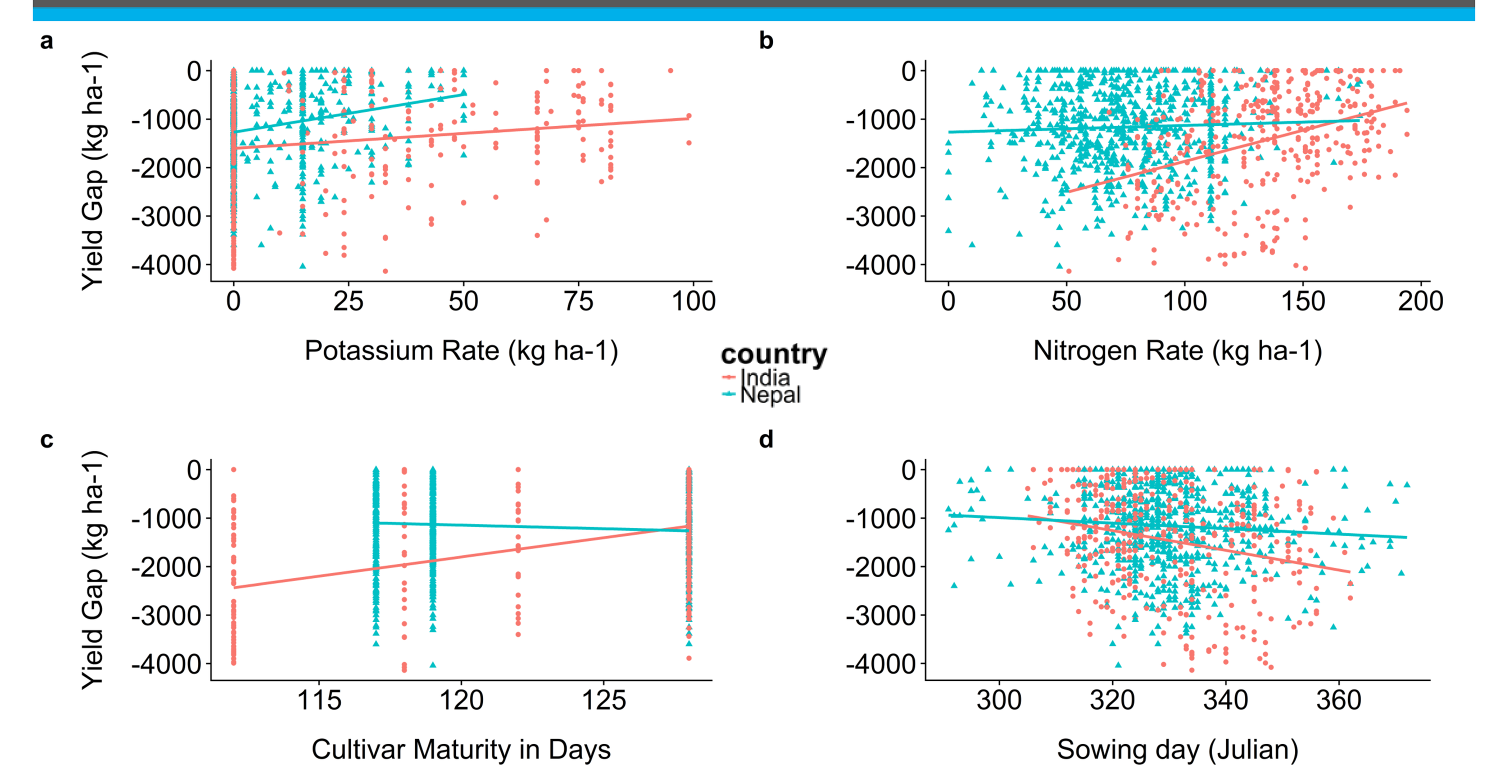
Linear Mixed Effect Models Selection

Model	Fixed effects
1	dtm + sd.kgha + sdoy + p.kgha + k.kgha + n.kgha + irrig + PCI
2	dtm + sd.kgha + sdoy + p.kgha + k.kgha + n.kgha + irrig + PCI
3	dtm + sdoy + k.kgha + n.kgha + irrig + PCI
4	**dtm + sdoy + k.kgha + n.kgha + irrig**

Model	Random effects	AIC	*wi*
1	~ 1|country/year/cluster/village/farm.id	18976	0.02
2	~ 1|country/year/cluster/village	18974	0.04
3	~ 1|country/year/cluster/village	18971	0.26
4	**~ 1|country/year/cluster/village**	**18969**	**0.68**

Agronomic and economic variables as fixed effects. Environmental factors incorporated by clustering in agroecological zones. The symbol , ~1 indicates that fixed effects refer to model intercepts only. Model selection criteria abbreviations: AIC, Akaike's information criterion; *wi*, Akaike weights, larger values indicate the probability that a given model represents the most parsimonious model (shown in bold) within the group.

Results and Conclusion



a) Potassium rates were significant and positive in Nepal (β_1=15.5, $F_{1,814}$=37.3, p <0.01) and India (β_1=6.2, $F_{1,163}$=10.3, p <0.01) in predicting yield gap; b) Nitrogen rates were significant for India (β_1=12.8, $F_{1,163}$=57, p <0.01) but not Nepal (β_1=1.9, $F_{1,814}$=1.85, p=1.85); c) Cultivar maturity was significant and positive for India (β_1=79.3, $F_{1,163}$=92.3, p <0.01) and significant and negative for Nepal (β_1=-14.7, $F_{1,814}$=5.1, p=0.02); d) Seeding day of year was significant and negative for both Nepal (β_1=-5.7, $F_{1,814}$=5.1, p=0.02) and India (β_1=-20.4, $F_{1,163}$=23.5, p<0.01). Irrigation was positive and significant for both countries (not shown). Post-hoc analysis of random effects showed the best model captured the variability associated with different management and environmental variability.

- Five agronomic factors reduced magnitude of yield gaps when controlling for environmental and economic variability: Nitrogen (β_1=4.6) and Potassium (K) (β_1=6.9) rates, more irrigation events (β_1=209.2), early sowing (β_1= -14), and longer maturing cultivars (β_1=32.7)
- Prioritize increased K rates because of its under-adoption (30% Nepal, 48% India) and high scaling potential (existing marketplace)
- Encourage use of popular longer maturity varieties 'PBW 343' and 'PBW 502' in Bihar
- Agroecological cluster #2 with highest yield and largest yield gap planted earlier with longer duration varieties (t(-2)=-6.8, p=0.04)