

UTILIZING NDVI TO DEFINE SEASONALITY IN DIARRHEAL DISEASE IN URBAN AND RURAL COMMUNITIES IN SOUTH INDIA

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BACKGROUND

- Seasonal fluctuation in infectious disease is a well documented phenomenon, and diarrheal diseases show a strong cyclical periodicity.
- Better insight into the nature of disease seasonality can be gained from understanding associations with meteorological conditions and environmental drivers, enhancing the ability to predict the timing and amplitude of seasonal outbreaks.
- Normalized Difference Vegetation Index (NDVI) is an accepted proxy for temperature and precipitation, and has been successfully used in predicting seasonal fluctuations in rotavirus and cryptosporidium (Jagai, 2009 & 2012) among other infectious diseases.

Epidemiological Study

- Joint with Christian Medical College (CMC) in Vellore, India
- Prospective cohort study that focuses on 2 urban slums and 3 rural communities in Vellore district, Tamil Nadu province of South India.
- Diarrheal disease information is collected from study households on a weekly basis but the disease counts were aggregated monthly for each community for remote sensing analysis.
- Daily meteorological records obtained from a local weather station maintained by the Government of India provided daily records of minimum and maximum temperature, morning and evening humidity and rainfall.
- Monthly temperature (average of daily max temperatures) and natural log of cumulative monthly rainfall were used in the analysis for disease seasonality.

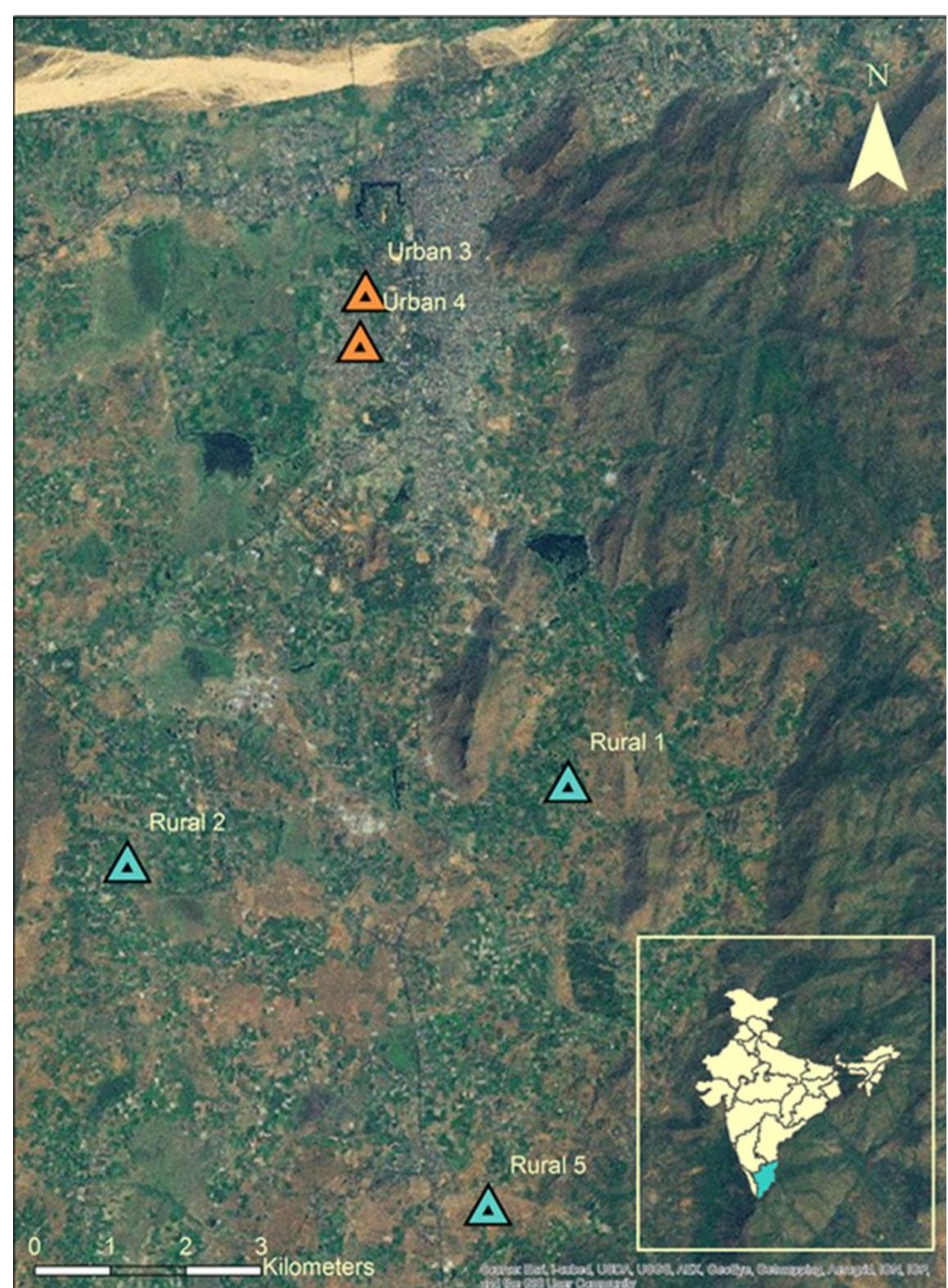


Figure 1: Study sites near Vellore, India

Objectives and Problem Statement

- Our work is to explore the seasonality in diarrheal disease counts in the four (2 urban areas are aggregated for this analysis) study sites and how it is influenced by meteorological factors obtained by the local weather station, and environmental factors that extracted from satellite imagery.

RESEARCH QUESTIONS:

- Can NDVI can serve as a distinguishing factor between the study sites?
- How does the performance of NDVI as a predictor of diarrheal disease compare to maximum ambient temperature and rainfall in each study site?

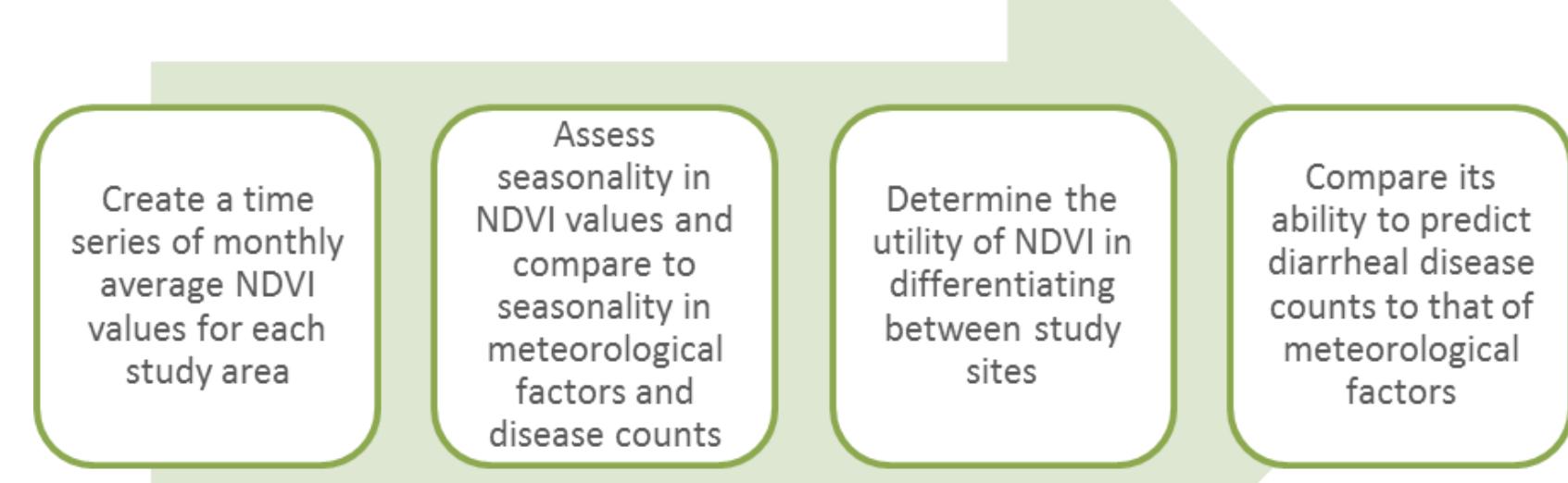


Figure 2: Project work flow

REMOTE SENSING DATA

- MODIS Aqua and Terra satellite images were used to compute the NDVI. The images were downloaded with band 1 (620-670 nm, visible red) and band 2 (841-876 nm, near infrared).
- NDVI measures the density of plant growth. As the chlorophyll in the plant absorbs the red light and the cell structure reflects the near infrared, the band rationing can be used to quantify the vegetation.
- One cloud free image per month was selected for analysis.
- Average NDVI for each study site was extracted by drawing regions of interest (ROI) around the sites and averaging the pixel values underneath.

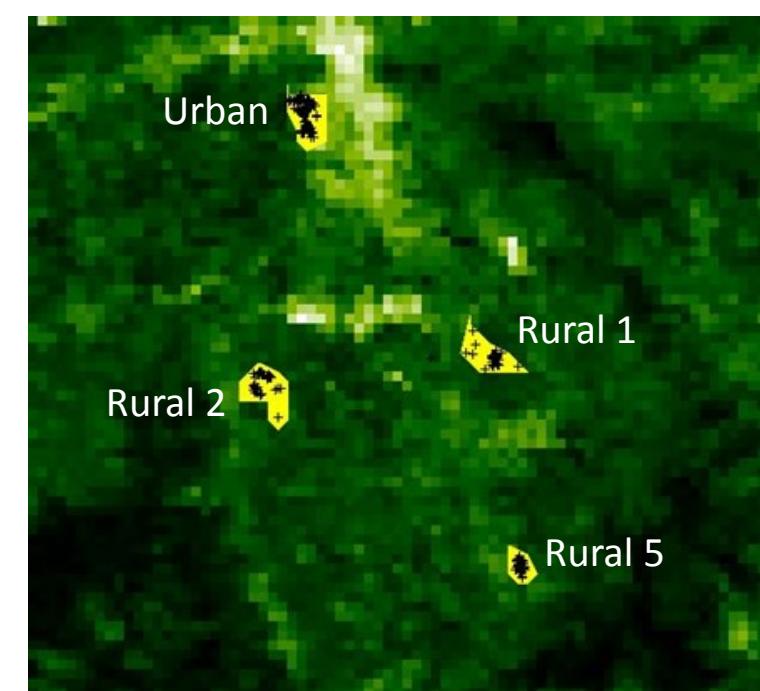


Figure 3: ROIs outlining the study sites

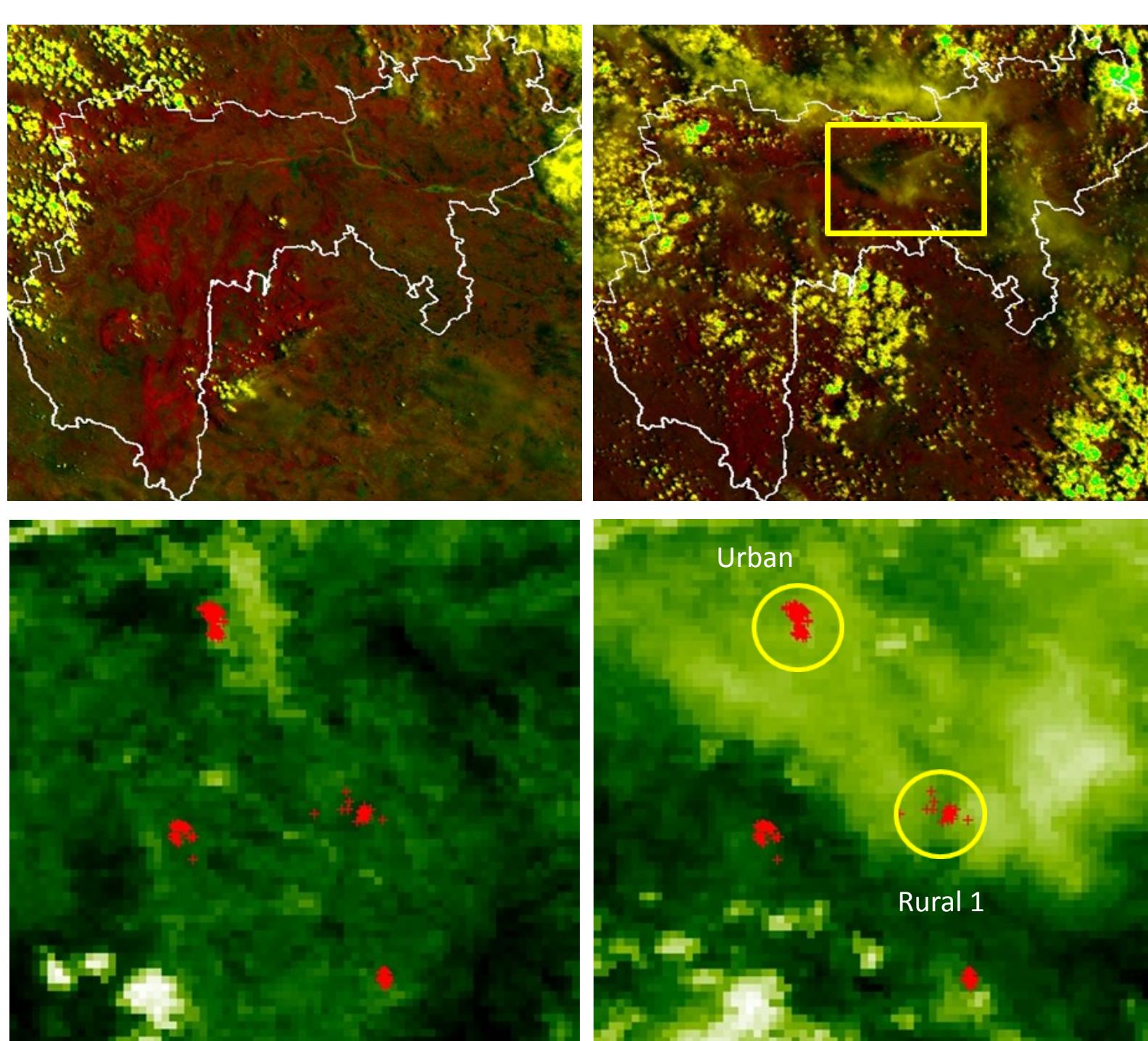


Figure 4: Example of two false color composite images (top row) and their corresponding NDVI pixel values (bottom row). In the false color images, clouds are shown in yellow. In the images on the left, there is no cloud interference in the area of interest; in images on the left, clouds artificially lower NDVI values for the urban area and rural area 1.

RESULTS

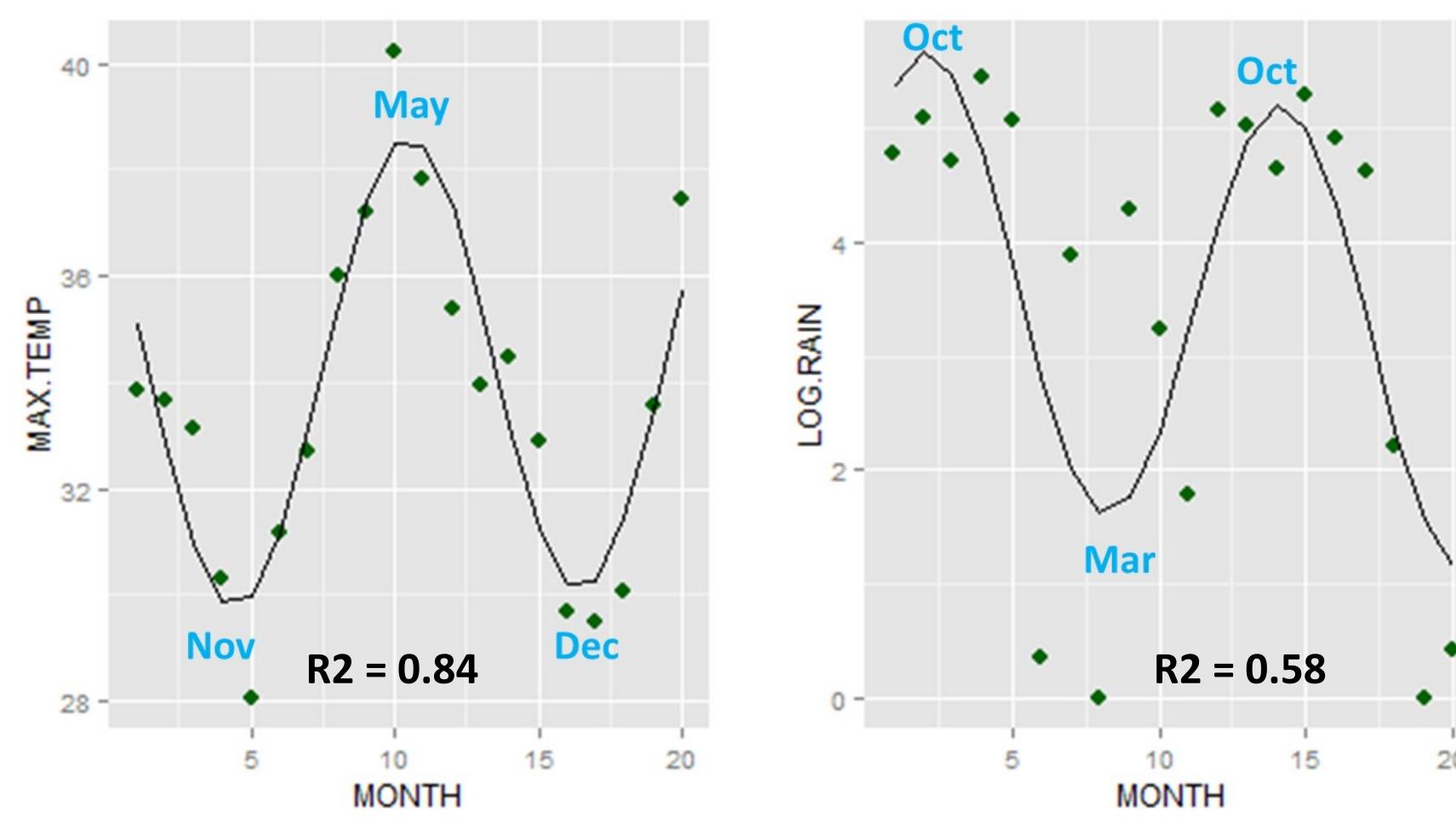


Figure 5: Actual (green) and predicted with one seasonal harmonic (black) values of maximum temperature and natural log of cumulative monthly rainfall

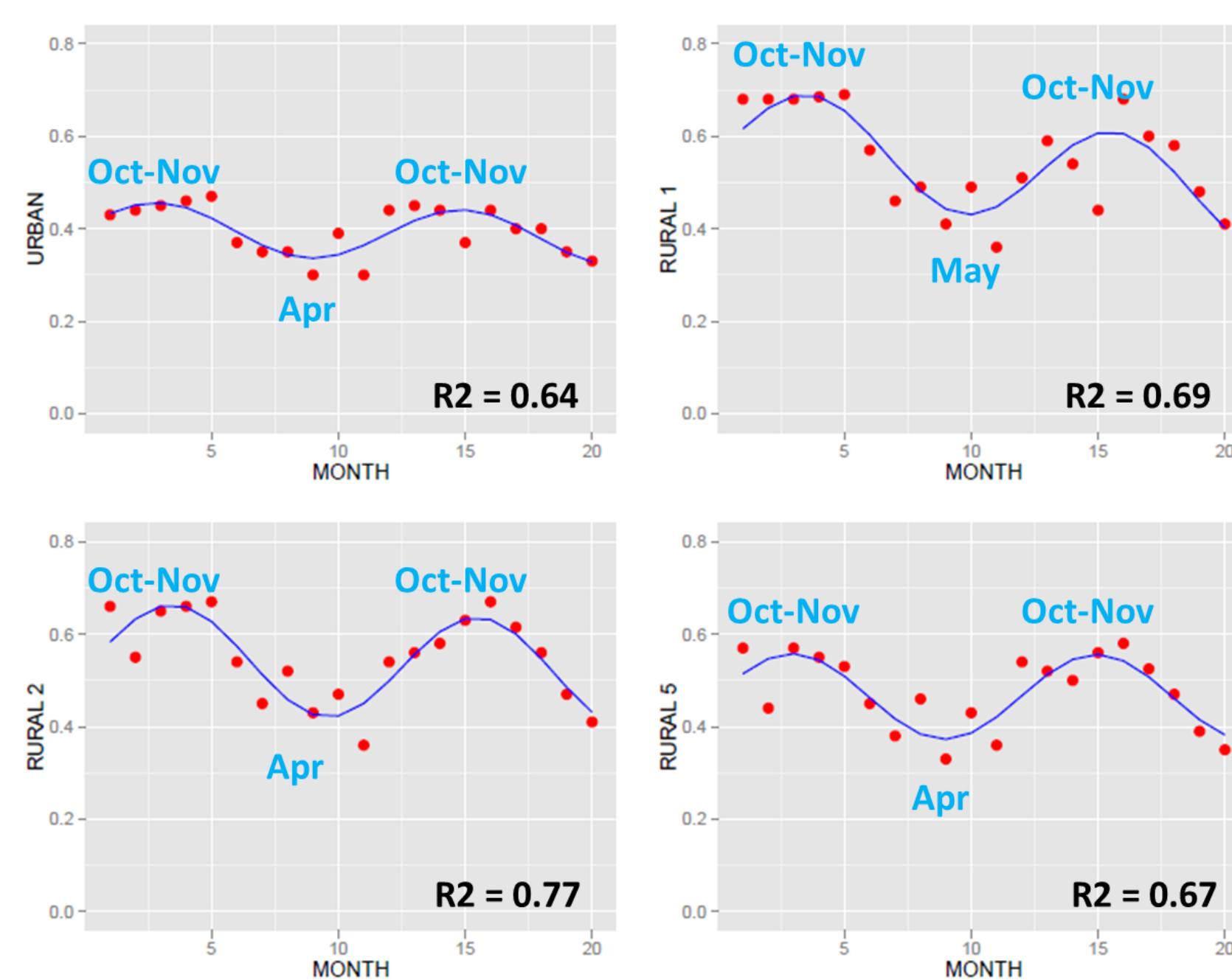


Figure 6: Actual (red) and predicted with one seasonal harmonic (blue) values of monthly NDVI in each study site

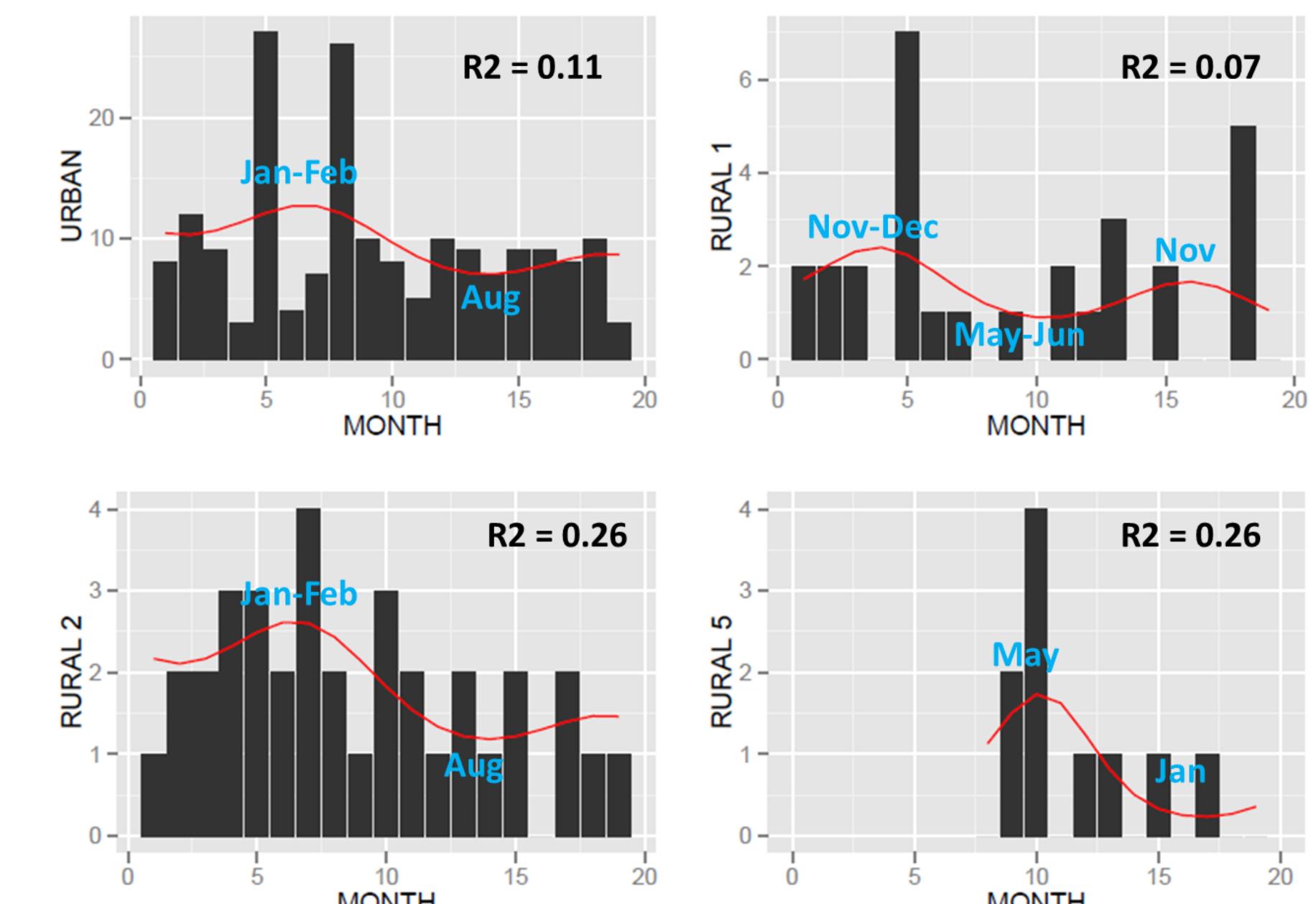


Figure 7: Actual (black) and predicted with one seasonal harmonic (red) values of diarrheal disease counts in each study site

Table 1: Summary of disease count regression models

Predictors used in regression	Variability explained (%)			
	Urban	Rural 1	Rural 2	Rural 5
1 Seasonal harmonic	11	7	26	26
2 Seasonal harmonic + NDVI	25	8	30	29
3 Seasonal harmonic + temperature	16	34	27	36
4 Seasonal harmonic + rainfall	12	8	30	55
5 Seasonal harmonic + temperature*rainfall	37	36	37	88
6 Seasonal harmonic + temperature*NDVI	34	39	33	45
7 Seasonal harmonic + rainfall*NDVI	27	10	38	62

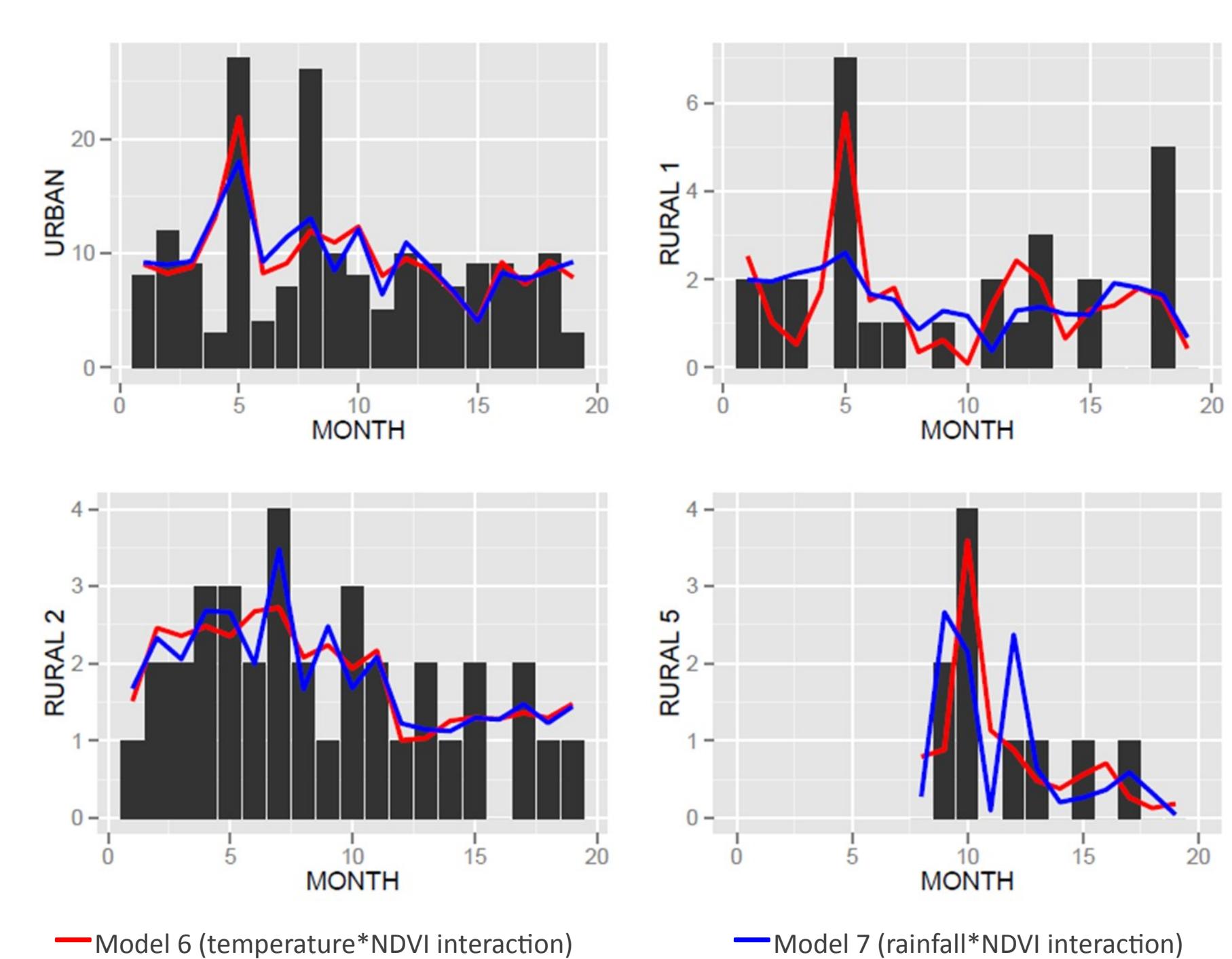


Figure 8: Diarrheal disease counts predicted by models 6 and 7 in Table 1 in each study site

CONCLUSIONS

NDVI shows a strong seasonal periodicity in all areas (R^2 0.64–0.77).

- NDVI is noticeably higher in Rural areas 1 (0.5513) and 2 (0.5498) vs. the urban area (0.3965) and Rural area 5 (0.4753).
- The urban area experiences higher rates of disease (0.22 cases/person) as compared to rural area 1 (0.15), 2 (0.15) and 5 (0.03).
- NDVI is not a good predictor of diarrheal disease counts by itself (R^2 0.02–0.07), but is a useful additional predictor. The interaction between NDVI*maximum temperature and NDVI*rainfall significantly improves R^2 in the Urban area and Rural area 5.
- Adding more parameters such as land surface temperature and soil moisture index to the analysis may help determine the best parameter to use as a proxy for meteorological data.

Limitations and Future Directions

- The disease time series was too short thus some of the predictors did not reach statistical significance. A longer study of diseases cases and corresponding NDVI is needed to confirm findings.
- Diarrheal counts are a combination of different diseases that may exhibit different seasonal patterns. Analysis using a specific pathogen would likely exhibit more defined seasonality.
- Clouds are a major issue with MODIS Aqua and Terra satellite images in the area. It may be beneficial to limit the analysis to dry seasons only and add more remote sensing parameters (e.g. land surface temperature) or use a higher level of processing MODIS product such as a 16-day composite image.

SOURCES:

- Jagai, J., Castranova, D., Monchak, J., and Naumova, E. Seasonality of cryptosporidiosis: A meta-analysis approach. Environmental Research 109:465-478 (2009).
Jagai, J., Sarkar, R., Castranova, D. et al., Seasonality of rotavirus in South Asia: a meta-analysis approach assessing associations with temperature, precipitation, and vegetation index. PLoS ONE 7(5) (2012).