# Exploring Explainability (XAI)

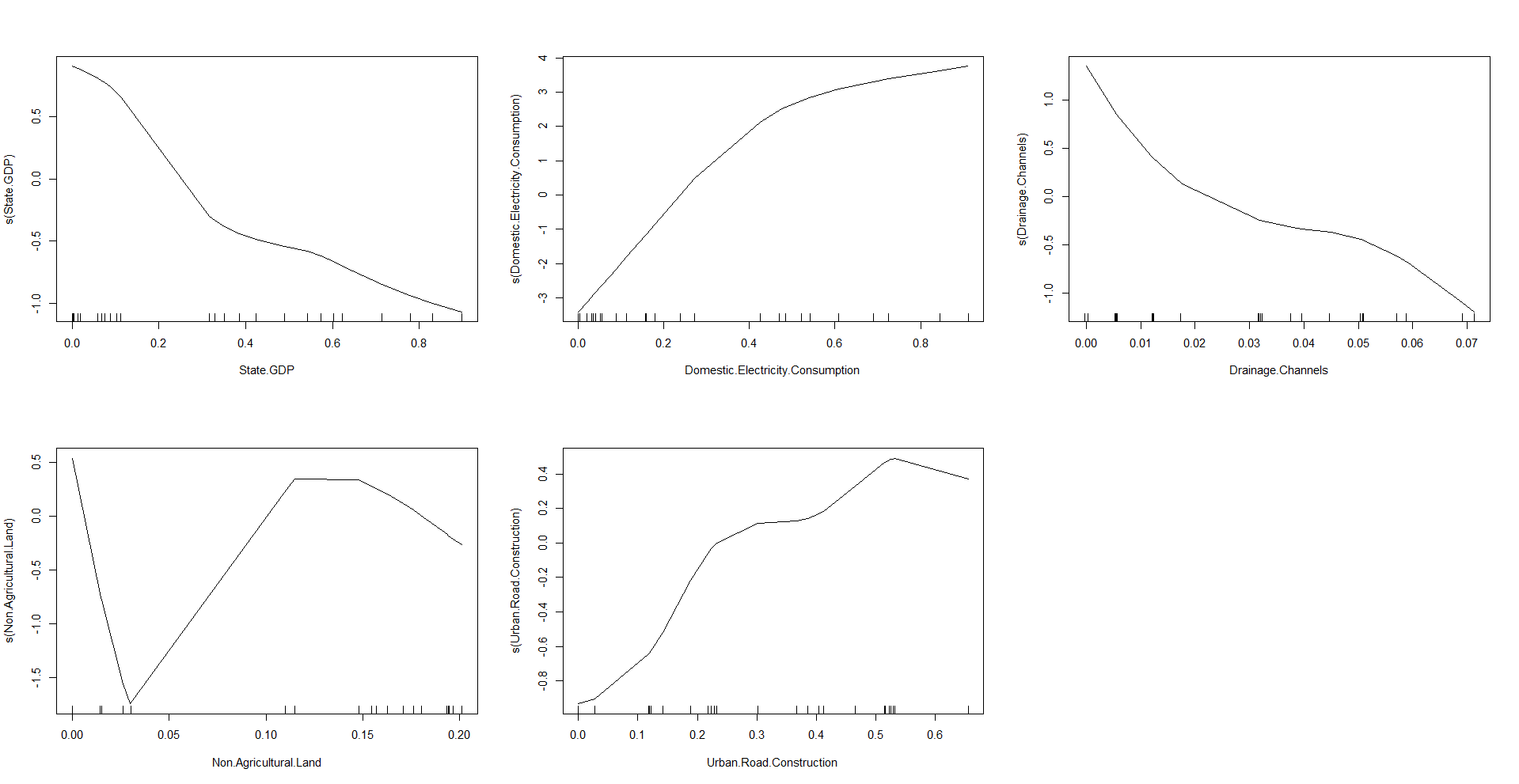
**Note on SHAP-Based Interpretability:**  
The SHAP analysis presented in this report is based on a relatively small dataset comprising 25 annual observations. While SHAP values offer valuable insights into feature-level contributions to individual predictions, caution must be exercised in interpreting global patterns and rankings. In small samples, SHAP values may be sensitive to outliers, limited permutations, and potential multicollinearity, which can lead to inflated or unstable attributions. The visualizations and explanations provided here should therefore be viewed as **exploratory aids** rather than definitive indicators of causal relationships or feature importance.

## Generalized Additive Models (GAM)

### Inherent explainability of GAMs

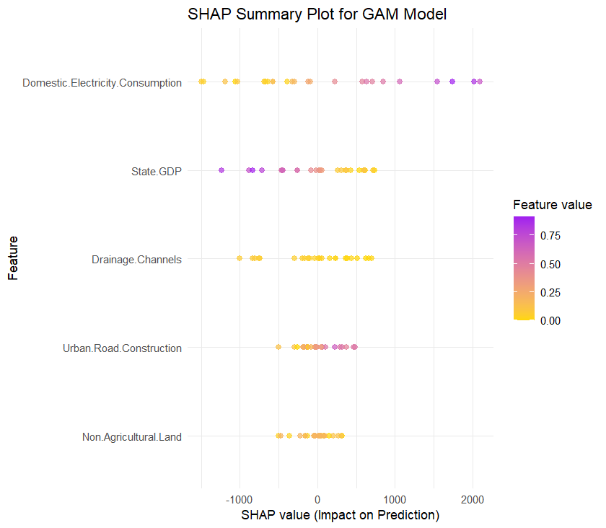
GAMs are inherently explainable due to their additive structure:

* Where,
* Each is a non-parametric smooth function estimated from data using splines.
* is the linear predictor on log-scale due to the canonical link for the NB family.



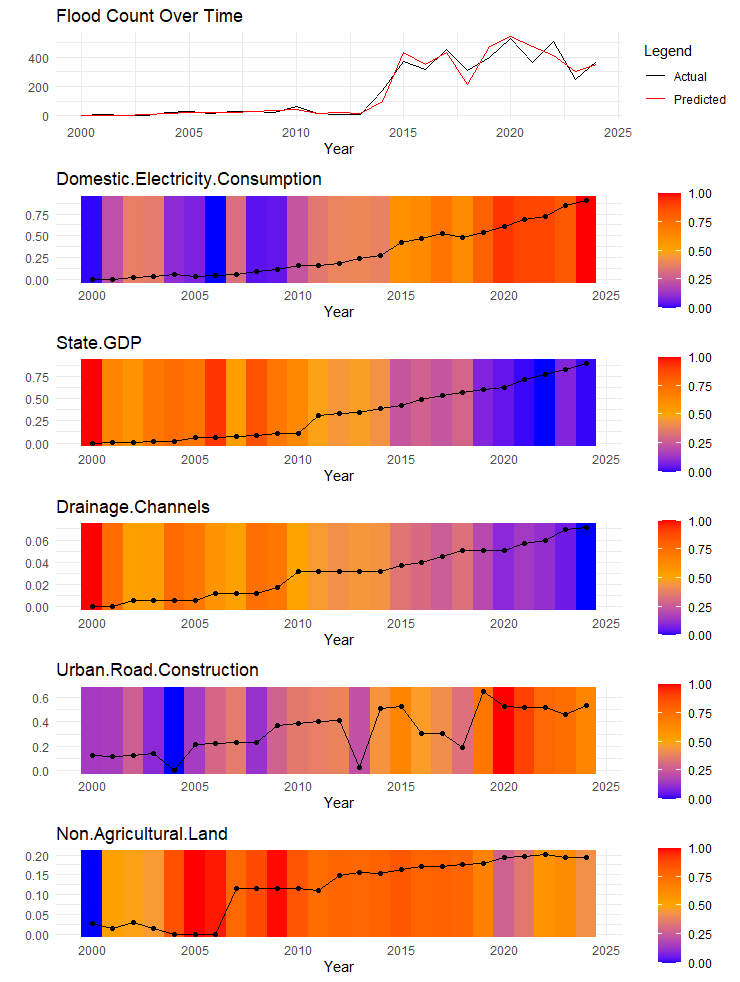
* The **x-axis** has normalized values of predictors, **y-axis** has centred smooth effect of the predictor. These are additive contributions to the log of expected flood counts. The **rug marks** on the x-axis indicate data density — where actual observations lie.
* **State GDP:** Decreasing effect → Higher GDP = Lower flood count? This is counter-intuitive, it may reflect non-linear effects or dominance of other correlated predictors.
* **Domestic Electricity Consumption:** The smooth is sharply increasing, especially for normalized values between 0.2 to 0.6. Suggests that higher electricity consumption (a proxy for urbanization) is associated with a higher flood risk, possibly due to increased impermeable surfaces.
* **Drainage Channels:** Declining curve → Better drainage may reduce floods. Makes physical sense, though the effect is subtle and not statistically significant.
* **Non-Agricultural Land:** Nonlinear "hill-shaped" relationship. Moderate values (0.05 to 0.15) increase flood risk, but both very low and very high values reduce it. Possible interpretation: urban fringe zones (moderately converted land) are more flood-prone than either fully rural or fully urbanized areas.
* **Urban Road Construction:** Increasing till a peak → Moderate infrastructure worsens flooding, but levels off. Again, reasonable — roads can worsen water runoff, but after a threshold, the marginal impact diminishes.

### SHAP Summary Plot



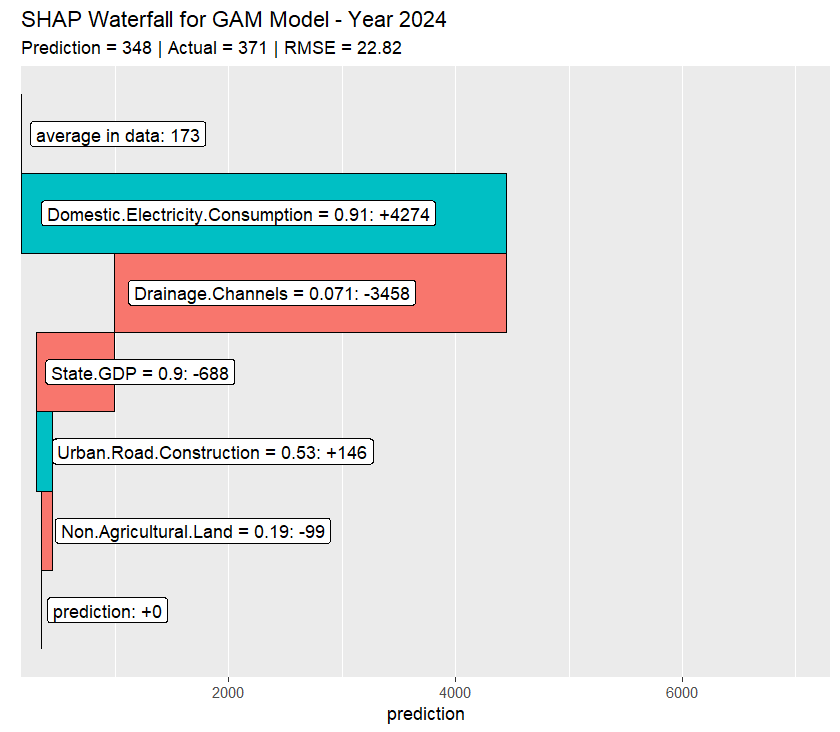
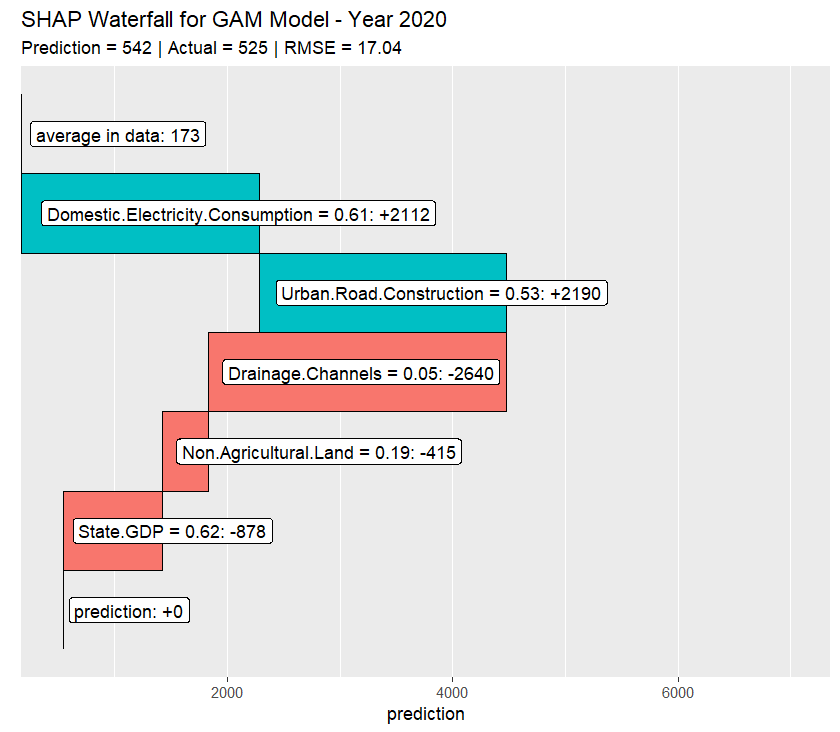
* Domestic electricity consumption and State GDP consistently have the strongest impact on model’s predictions.
* SHAP values for Domestic Electricity Consumption show a wider range, indicating a high level of influence in both directions depending on the feature value. Drainage Channels and Non-Agricultural Land have a narrower spread and smaller impact overall.

### SHAP Over Time



* In years like 2014–2020, where floods increase sharply, SHAP values (colour intensity) also spike for Domestic Electricity Consumption, Urban Road Construction, and State GDP.
* Drainage Channels become less impactful over time (despite rising in value), suggesting diminishing marginal explanatory power. Drainage channels increase in quantity, but their importance in predicting floods diminishes. This could reflect ineffectiveness or poor maintenance, which wasn’t clear from EDA alone.
* Non-Agricultural Land shows relatively stable SHAP intensity—despite a rising trend in the feature, its impact plateaus.

### SHAP Waterfall Breakdown



* For 2020, Model predicted 542 vs actual 525, with a RMSE of 17.
  + Drainage Channels and Non-Agricultural Land had strong negative SHAP values, pulling the prediction down.
  + Electricity and Urban Roads were the biggest positive drivers, consistent with EDA.
  + Despite Drainage Channels having a high value, they drastically reduced the flood prediction. This again raises questions about their functional utility, aligning with our EDA assumption that mere presence ≠ effectiveness.
* For 2024, Model predicted 348 vs actual 371, with a RMSE of 23.
  + Domestic Electricity consumption contributes the most while Drainage effect is strongly negative. This is not in line with what we have observed – indicating that the GAM model might be overfitting interactions in smooth terms.