# Malaria Anticipation Project: development of a predictive malaria early warning system for anticipatory action in Jonglei State, South Sudan

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## Introduction

Climate and environmental conditions are critical factors in malaria transmission. Médecins Sans Frontières (MSF) teams in South Sudan have seen changes in the timing and intensity of malaria seasonal peaks over the past decade. The Malaria Anticipation Project (MAP) aims to develop predictive early warning systems to better predict and act upon any expected rise in malaria cases, through routine surveillance.

## Methods

Predictive models were developed using environmental data collected from climate and space agencies and weekly outpatient department (OPD) malaria case count in Lankien hospital (Jonglei State, South Sudan) as the epidemiological input and output. An ensemble modelling approach was developed using linear regression and extreme gradient boosting (XGBoost) models in a recursive modelling framework. The models were developed using data from 2012–2020, verified with data from 2020–2022, and then monitored in real time in the 2022/23 season. To assess model performance, observed OPD malaria cases were compared with the monthly average cases and classified into categories to assess how often the model prediction was in the same category as the observed number of cases. We also conducted a qualitative survey to explore community understanding of malaria and its relationship to climate.

## Ethics

This study was approved by the MSF and South Sudan Ethics Review Boards.

## Results

During model development, the predictive performance was very high at 2 weeks' lead time (75% classification accuracy). Model performance remained satisfactory at up to 8 weeks' lead time (70% classification accuracy), while beyond this, it became increasingly susceptible to large prediction errors. In the 2020/21 and 2021/22 malaria seasons, the predictive performance at 2 weeks' lead time was good, but it overpredicted for both seasons at 4–8 weeks. The 2022–23 season saw the lowest number of malaria cases of any year in the data used to train the model. The models predicted that the number of cases would be below the long-term average for Lankien hospital, but overpredicted the burden. Across all models, the shorter the lead time of the models, the greater their predictive performance.

## Conclusion

This modelling approach has the potential to inform anticipatory action within an operationally useful timeframe. Given the models are trained on historical data and cannot include all factors affecting malaria transmission, if relationships between malaria and other conditions change over time, this will impact model performance, demonstrating the limits of forecasting approaches. The next stage of the MAP project will focus on replicability in other settings and pilot implementation to understand operational feasibility and improve performance.

## Conflicts of interest

All authors declare no competing interests.