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FORECASTING LOCATIONS OF FOREST FIRES IN INDONESIA THROUGH NONPARAMETRIC PREDICTIVE INFERENCE WITH PARAMETRIC COPULA: A CASE STUDY

(Meramal Lokasi Kebakaran Hutan di Indonesia Melalui Inferens Ramalan Bukan Parametrik dengan Kopula Parametrik: Kajian Kes)

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ABSTRACT

Wildfires caused major damage and incurred high restoration costs. Despite numerous predictive studies in this field, wildfire management still had uncertainties. The machine learning technique was popular on this topic, but it portrayed gaps of non-generalisable and inaccuracy possibilities. This study intended to apply nonparametric predictive inference (NPI) with a parametric copula to predict the next wildfire location using the coordinate parameters. The NPI quantifies the uncertainties via imprecise probabilities, $(\underline{P}, \overline{P})$, while the copula integration considers the spatial correlation by modelling the dependence structure between the past coordinates in predicting the next location. Unlike other methods, the NPI generates a set of bounded probabilities that provide confidence in the prediction result. This paper applied the proposed method to the Moderate Resolution Imaging Spectroradiometer satellite dataset for Indonesia (2020). Several wildfire hotspots in Sumatra and Kalimantan archipelago were focused on this study. It was evaluated via the differences $(\bar{d})$ within the $(\underline{P}, \overline{P})$ and showcased low values ($\bar{d} < 0.001$). The results show that NPI with parametric copula was highly accurate for both archipelagoes, highlighting its generalisability specifically for Indonesia. Each wildfire hotspot had a different optimal copula to predict the best future hotspot. Clayton and Gumbel copulae were the best to be integrated with NPI to predict the next wildfire location in Sumatra while Normal and Gumbel copulae for Kalimantan locations. In conclusion, the NPI is considered a reliable alternative for wildfire location prediction.

Keywords: copula; imprecise probability; Indonesia; nonparametric predictive inference; wildfire hotspot

ABSTRAK

Kebakaran hutan menyebabkan kerosakan serius yang menyumbang kepada kos pemulihan yang tinggi. Walaupun terdapat banyak kajian ramalan dalam bidang ini, pengurusan kebakaran hutan masih mempunyai ketidakpastian. Teknik pembelajaran mesin popular dalam topik ini, tetapi tetap mempunyai jurang kajian seperti tidak boleh digeneralisasikan dan ketidak tepatan. Kajian ini bertujuan untuk menggunakan inferens ramalan bukan parametrik (NPI) dengan kopula parametrik dalam meramalkan lokasi kebakaran hutan yang seterusnya berdasarkan parameter koordinat. NPI mengukur ketidakpastian melalui kebarangkalian yang tidak tepat, $(\underline{P}, \overline{P})$, manakala integrasi kopula mempertimbangkan korelasi keruangan melalui pemodelan struktur pergantungan antara koordinat lepas dalam meramalkan lokasi seterusnya. Tidak seperti kaedah lain, NPI menjana satu set kebarangkalian terhad yang memberikan keyakinan terhadap hasil ramalan. Kajian ini menggunakan kaedah cadangan ini kepada data Indonesia (2020) yang diperoleh daripada satelit Spektroradiometer Pengimejan Resolusi Sederhana. Kajian ini menumpukan beberapa lokasi titik panas kebakaran di kepulauan Sumatera dan Kalimantan sahaja. Analisis ini dinilai melalui perbezaan $(\bar{d})$ dalam $(\underline{P}, \overline{P})$ dan mempamerkan nilai yang rendah ($\bar{d} < 0.001$). Keputusan menunjukkan bahawa NPI dengan kopula parametrik adalah sangat tepat untuk kedua-dua kepulauan tersebut, menunjukkan keupayaan metod ini untuk digeneralisasikan, khususnya untuk keseluruhan Indonesia. Setiap titik panas kebakaran hutan mempunyai kopula optimum berbeza untuk meramalkan lokasi titik panas pada masa depan. Kopula *Clayton* dan *Gumbel* adalah yang terbaik untuk diintegrasikan dengan NPI bagi meramalkan lokasi kebakaran hutan seterusnya di Sumatera manakala kopula *Normal* dan *Gumbel* pula untuk lokasi di Kalimantan. Kesimpulannya, NPI boleh dianggap sebagai alternatif yang dipercayai untuk ramalan lokasi kebakaran.

Kata kunci: Indonesia; inferens ramalan bukan parametrik; kebarangkalian terhad; kopula; titik panas kebakaran hutan

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