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UNIVERSIDADE
COIMBRA

Nuno Pires

INTELLIGENT SYSTEM FOR LOCALISING AND MONITORING FOREST FIRES

Dissertation in the context of the Master in Informatics Engineering, specialization in Information Systems, advised by Professor Alberto Cardoso and Professor Jacinto Estima and presented to the Department of Informatics Engineering of the Faculty of Sciences and Technology of the University of Coimbra.

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**SISTEMA INTELIGENTE PARA LOCALIZAÇÃO
E MONITORIZAÇÃO DE INCÊNDIOS
FLORESTAIS**

Dissertação no âmbito do Mestrado em Engenharia Informática,
especialização em Sistemas de Informação, orientada pelo Professor Alberto
Cardoso e Professor Jacinto Estima e apresentada ao Departamento de
Engenharia Informática da Faculdade de Ciências e Tecnologia da
Universidade de Coimbra.

Janeiro 2024

Abstract

Fire can have disastrous consequences. Decision-support systems play a central role in dealing with forest fires. Its early warning capacity and real-world impact help to protect forests, species, and communities from wildfire.

The presented work proposes a system for forecasting and monitoring forest fires using multiple data sources. Data fusion, aggregation, and enhancement techniques are also mentioned.

The main purpose of the system is to provide important information for emergency decision-making, such as the geolocation, severity, and temporal evolution of a wildfire. It will employ statistical and machine learning methodologies to predict and determine fire occurrence, susceptibility, and risk.

Finally, the system, with the help of data visualisation tools, will show findings and insights.

The document also presents current approaches and obstacles to forest fire prediction, as well as the suggested methodology and analysis of risk.

Keywords

Decision support system, Fire management, Fire forecasting, Machine learning, Spatial and temporal prediction

Resumo

Os incêndios podem ter consequências desastrosas. Os sistemas de apoio à decisão desempenham um papel central na luta contra os incêndios florestais. As suas capacidades de alerta e o seu impacto no mundo real ajudam a proteger as florestas, as espécies e as comunidades.

O trabalho apresentado propõe um sistema de previsão e monitorização de incêndios florestais que utiliza fontes diversas de dados. Onde são utilizadas técnicas de fusão, agregação e melhoramento de dados.

O principal objetivo do sistema é fornecer informações importantes para a tomada de decisões de emergência, tais como a geolocalização, a gravidade e a evolução temporal de um incêndio florestal. O sistema empregará metodologias estatísticas e de aprendizagem automática para prever e determinar a ocorrência, a suscetibilidade e o risco de incêndio.

Finalmente, com a ajuda de ferramentas de visualização de dados, o sistema será capaz de apresentar informações e resultados.

No documento também são analisadas as abordagens actuais e os obstáculos à previsão de incêndios florestais, bem como a metodologia sugerida e a análise de risco.

Palavras-Chave

Sistema de apoio à decisão, Gestão de incêndios, Previsão de incêndios, Aprendizagem automática, Previsão espacial e temporal

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Chapter 1

Graphs

1.1 Fire Weather Index variables

FFMC: Time lag is 2/3 day DMC: Time Lag is 12 days. DMC represents the moisture content of loosely compacted, decomposing organic matter weighing about 5 kg/m² when dry (?) DC:Time lag is 52 days (?) dá indicação do teor de umidade nas camadas profundas (10 a 20 cm), estimando indiretamente a intensidade dos fogos devido à secura dos combustíveis.

1.2 Sample Description

Dia 21 de Junho As 12 horas 2022: FWI:21.95067024230957 Drought Code (DC): 418.90625 Duff Moisture Code (DMC): 160.0711212158203 Fine Fuel Moisture Code (FFMC): 86.57350158691406

2015: 35.98046875 Drought Code (DC): 380.162109375 Duff Moisture Code (DMC): 72.5761489868164 Fine Fuel Moisture Code (FFMC): 95.732421875

2019: 22.05933380126953 Drought Code (DC): 384.6829833984375 Duff Moisture Code (DMC): 97.203125 Fine Fuel Moisture Code (FFMC): 87.82327270507812

1.3 Simulated FWI variables

Este local não teve incêndio

Figure 1.1: Comparison of FWI calculated values and Copernicus

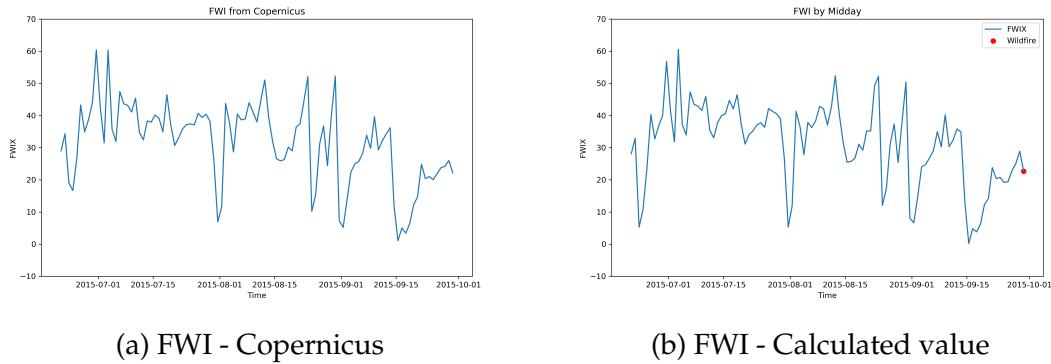


Figure 1.2: Comparison of FFMC calculated values and Copernicus

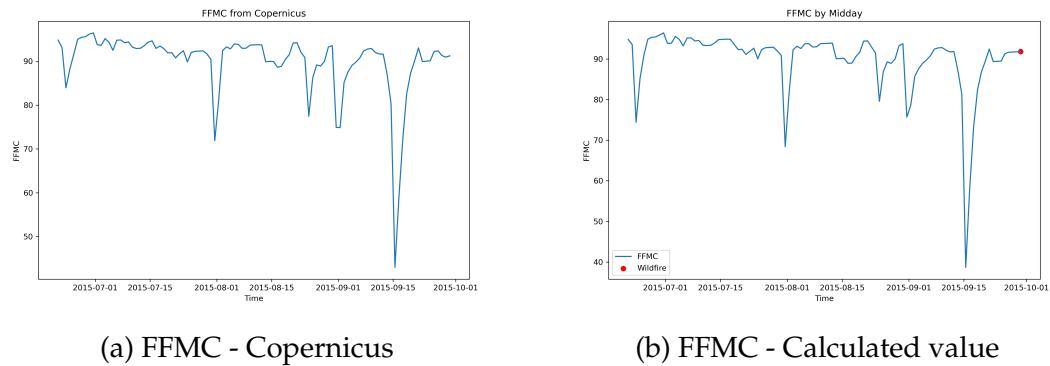


Figure 1.3: Comparison of DMC calculated values and Copernicus

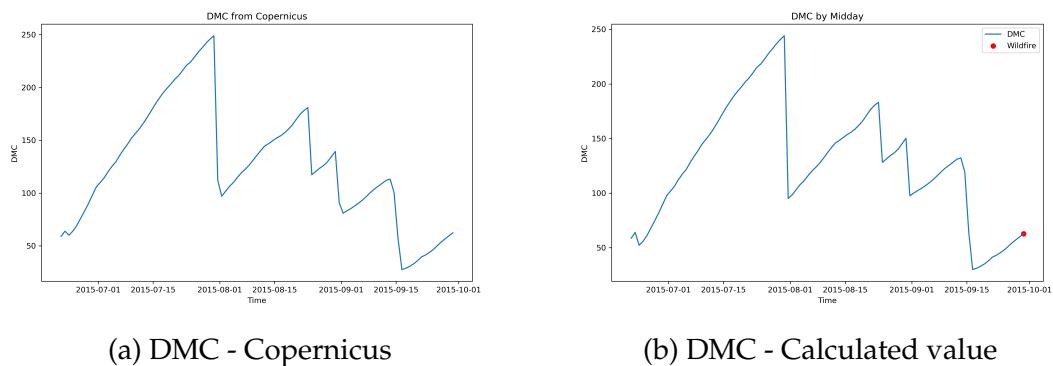


Figure 1.4: Comparison of DC calculated values and Copernicus

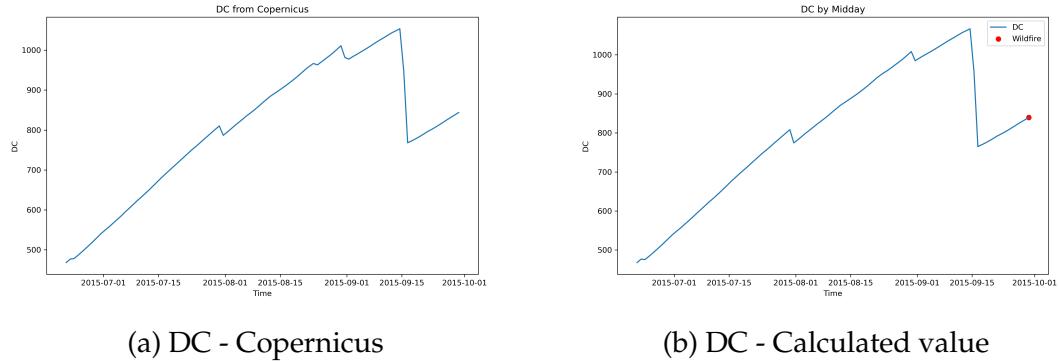


Figure 1.5: Comparison of ISI calculated values and Copernicus

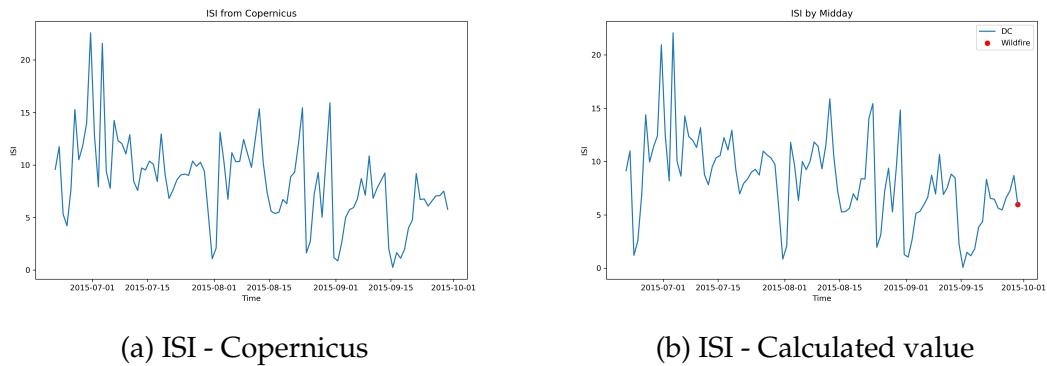
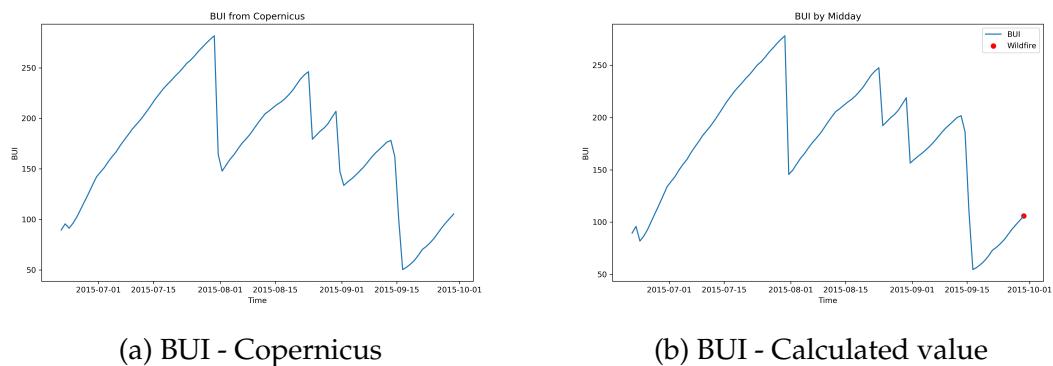


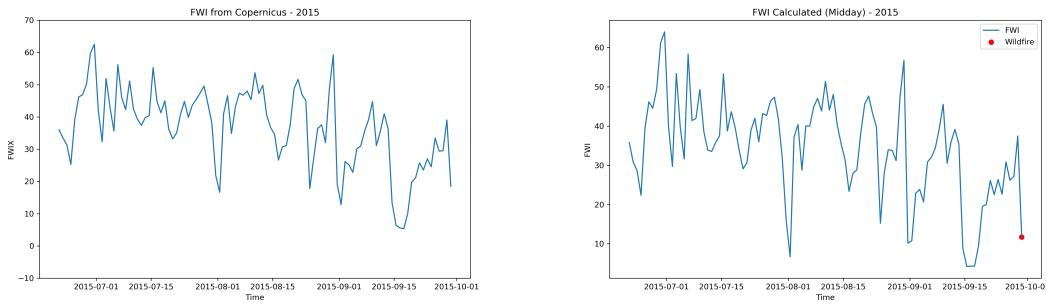
Figure 1.6: Comparison of BUI calculated values and Copernicus



1.4 Comparison of Copernicus and Simulated FWI

1.4.1 Fogo de 2015

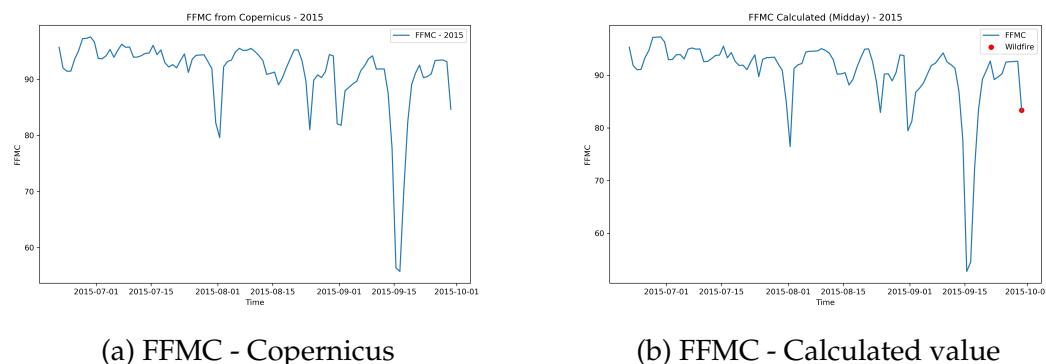
Figure 1.7: Comparison of FWI calculated values and Copernicus at midday



(a) FWI - Copernicus

(b) FWI - Calculated value

Figure 1.8: Comparison of FFMC calculated values and Copernicus at midday



(a) FFMC - Copernicus

(b) FFMC - Calculated value

Figure 1.9: Comparison of DMC calculated values and Copernicus at midday

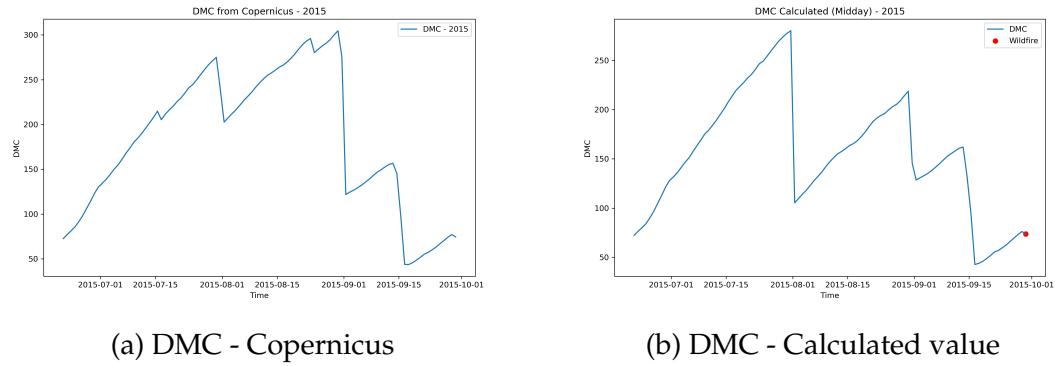


Figure 1.10: Comparison of DC calculated values and Copernicus at midday

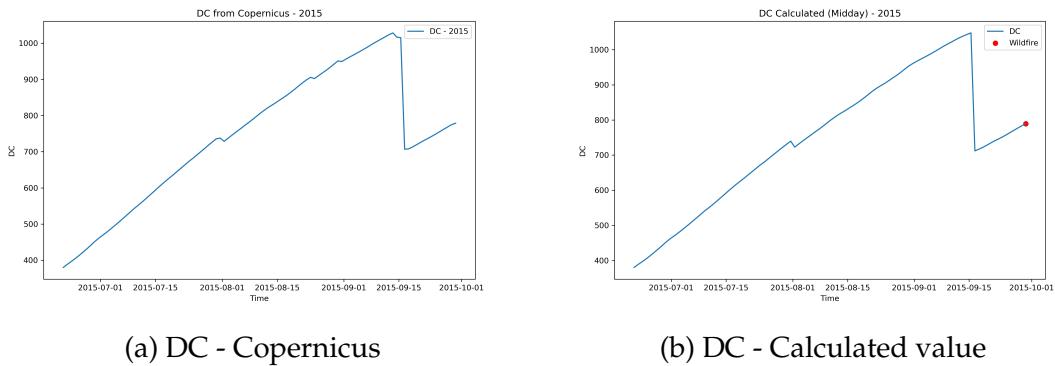


Figure 1.11: Comparison of ISI calculated values and Copernicus at midday

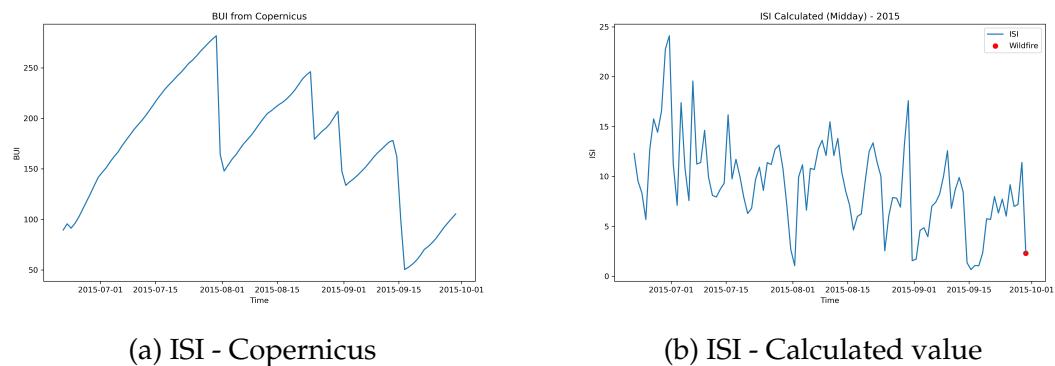
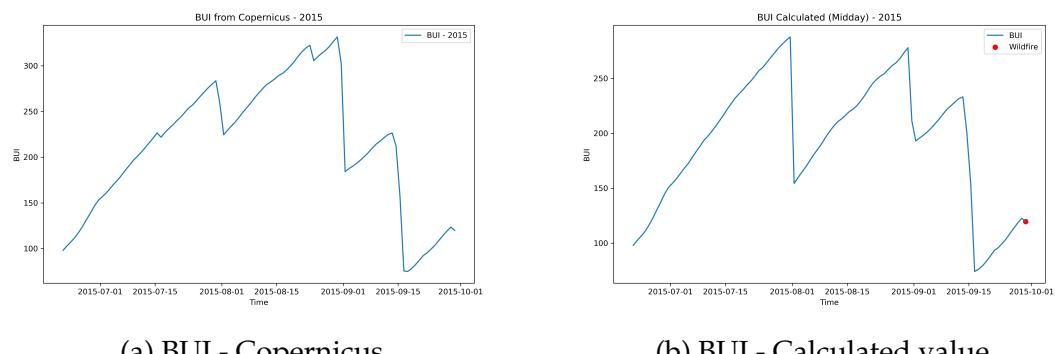
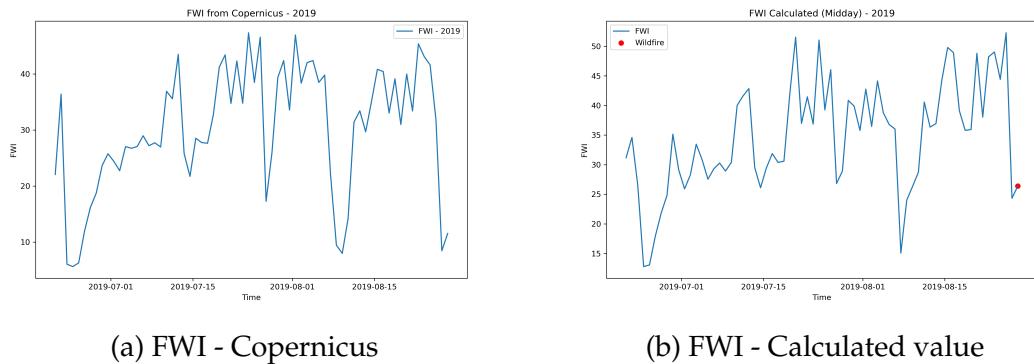


Figure 1.12: Comparison of BUI calculated values and Copernicus at midday



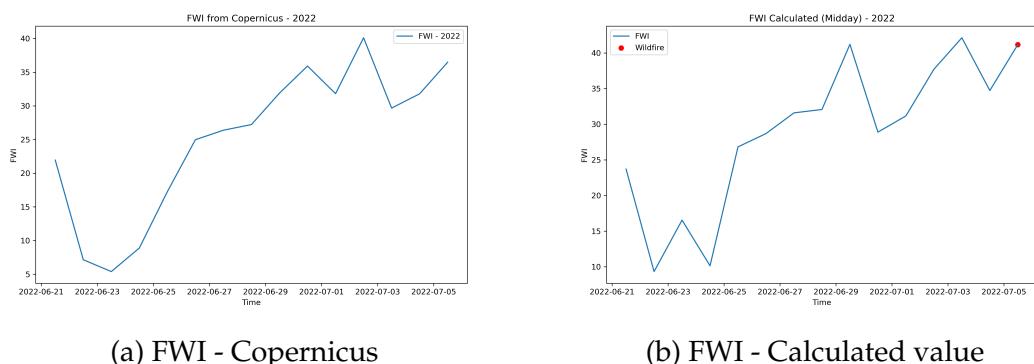
1.4.2 Fogo de 2019

Figure 1.13: Comparison of FWI calculated values and Copernicus at midday - 2019



1.4.3 Fogo de 2022

Figure 1.14: Comparison of FWI calculated values and Copernicus at midday - 2022



1.5 Hourly FWI variables

Figure 1.15: Calculated hourly FWI value for 2015, 2019, and 2022

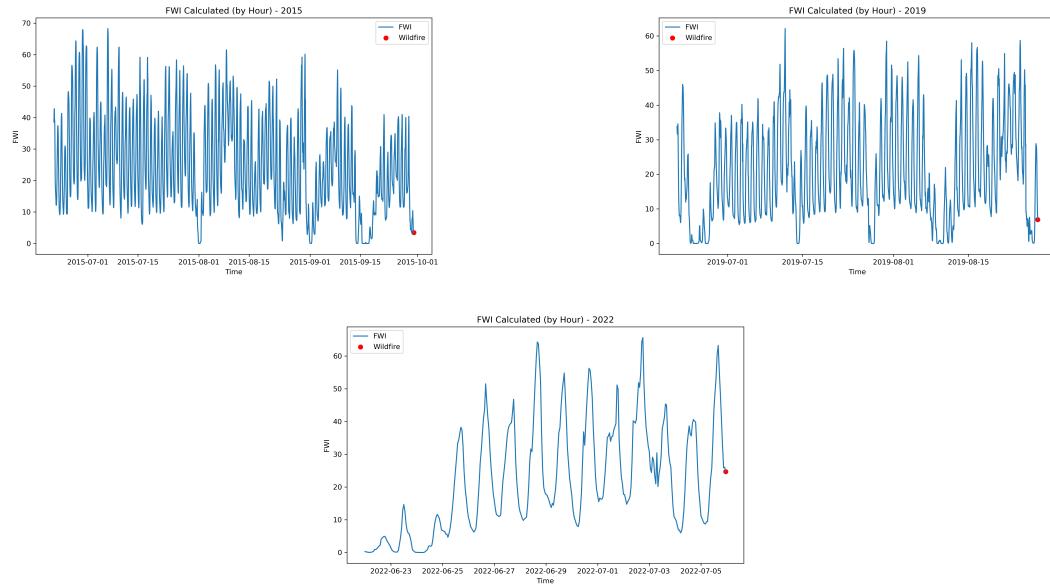


Figure 1.16: Calculated hourly FFMC value for 2015, 2019, and 2022

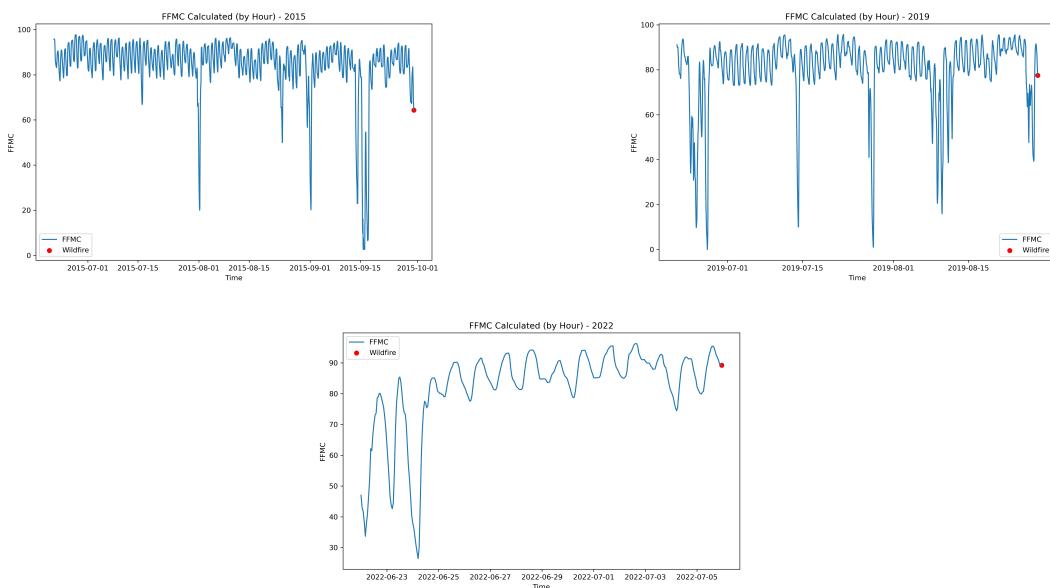


Figure 1.17: Calculated hourly DMC value for 2015, 2019, and 2022

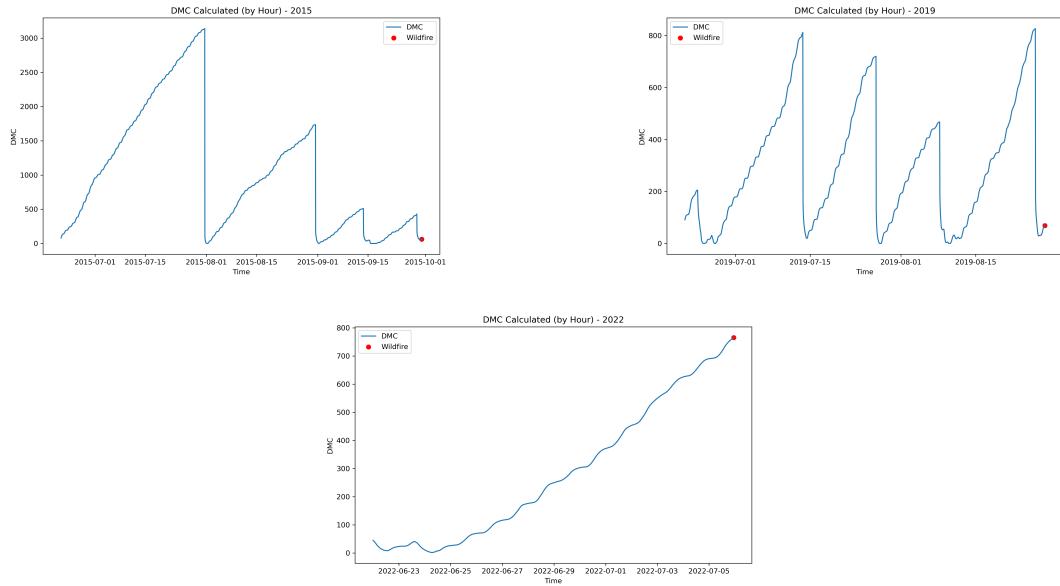


Figure 1.18: Calculated hourly DC value for 2015, 2019, and 2022

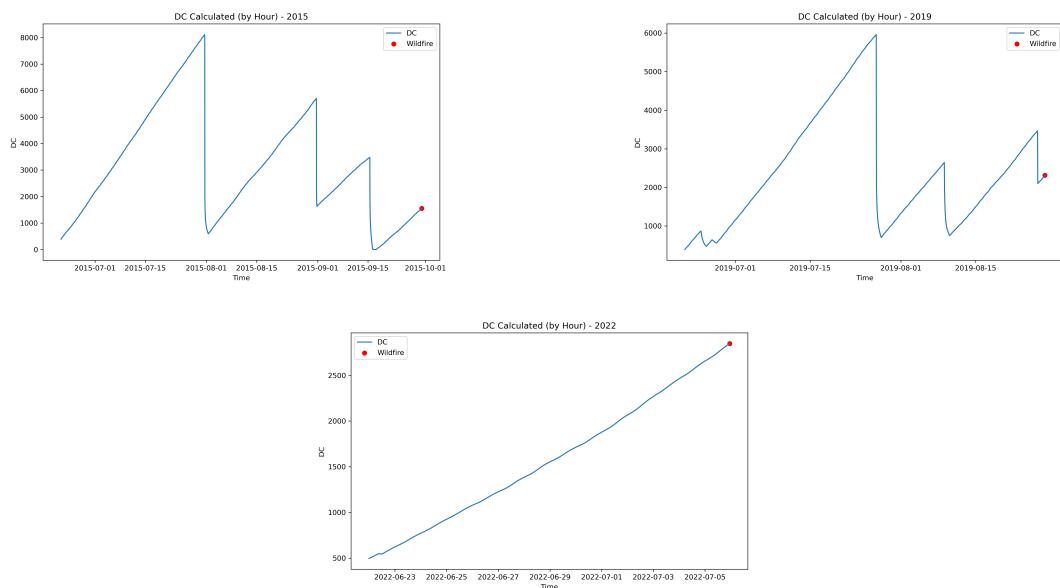


Figure 1.19: Calculated hourly ISI value for 2015, 2019, and 2022

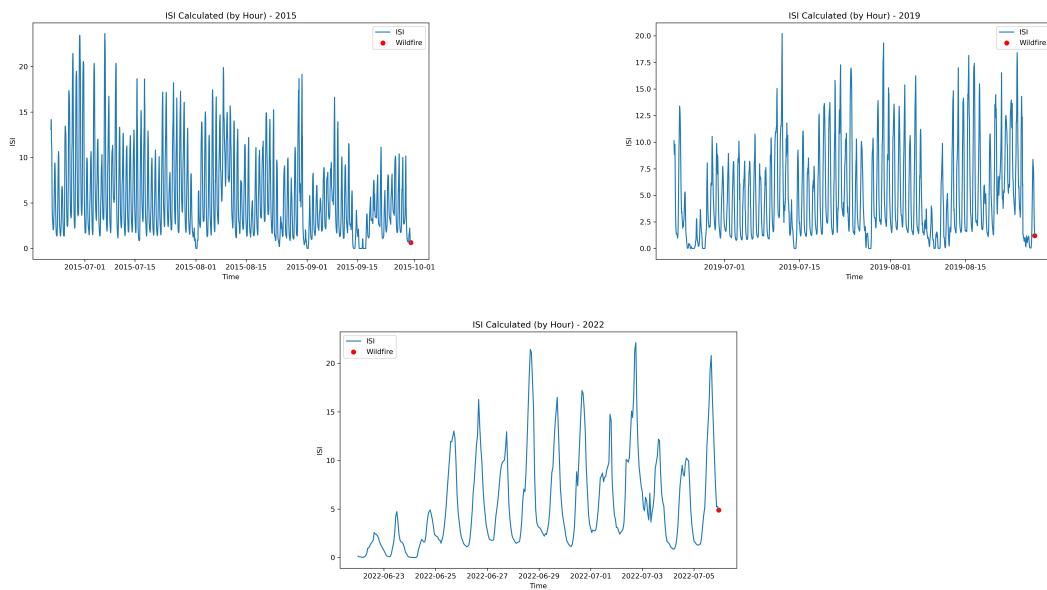
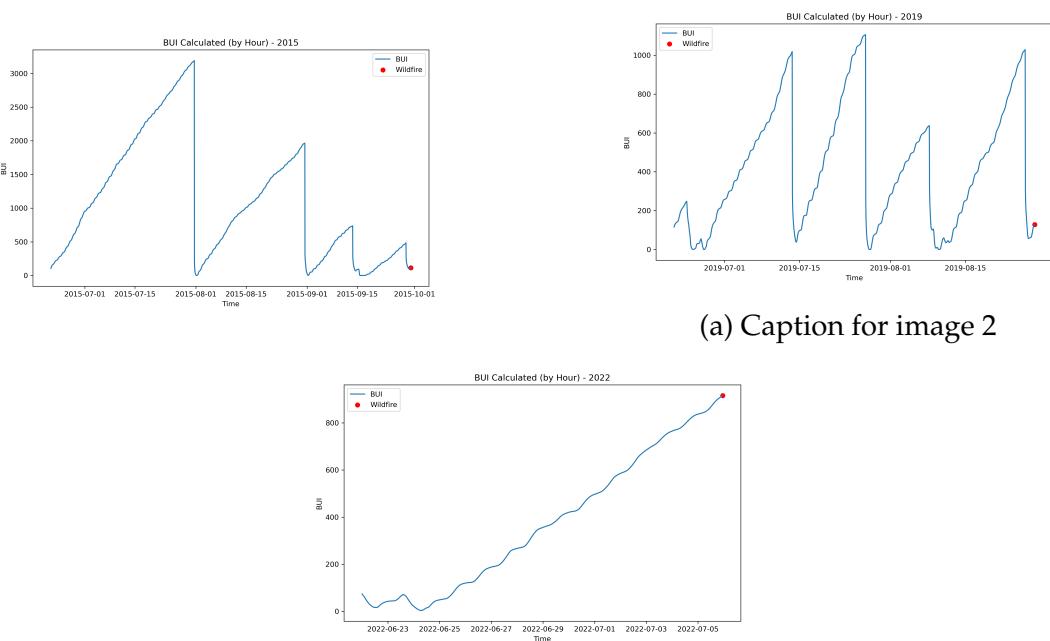


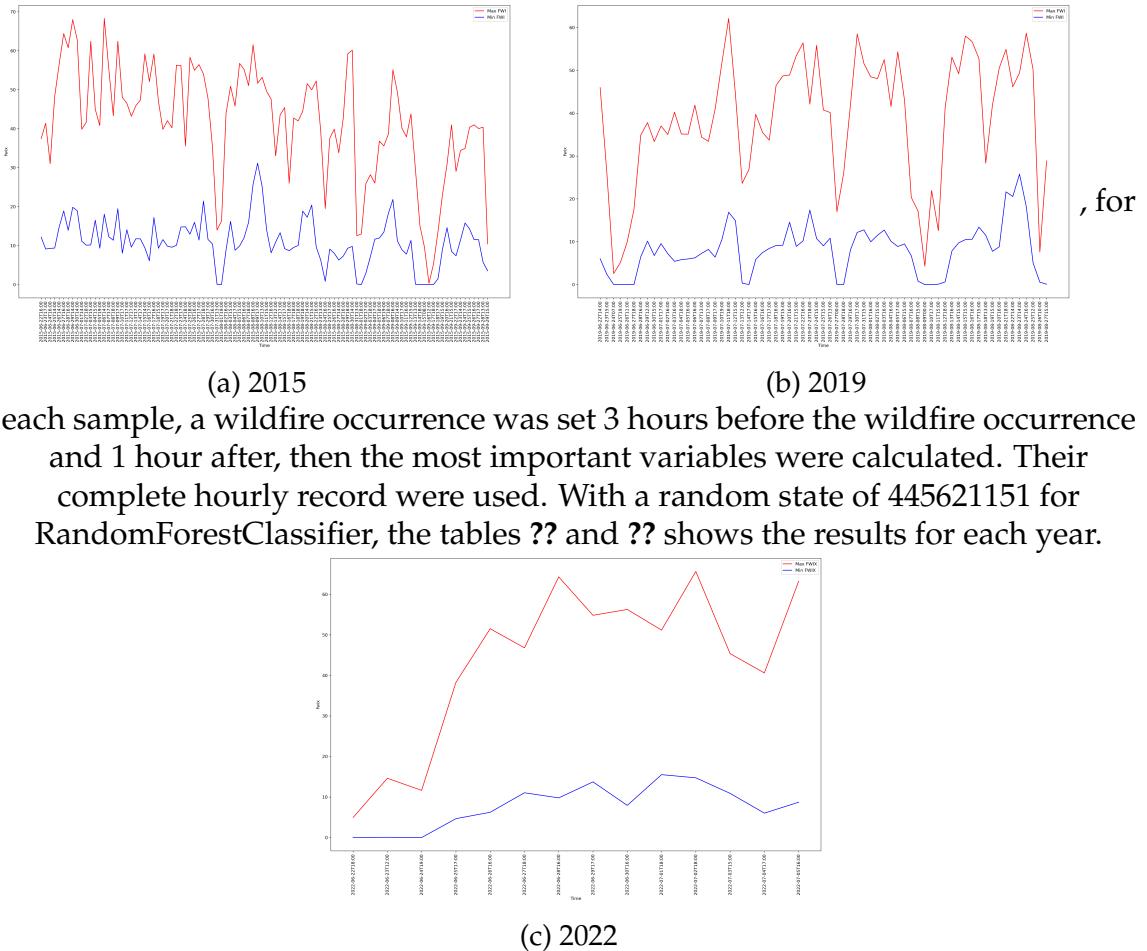
Figure 1.20: Calculated hourly BUI value for 2015, 2019, and 2022



(a) Caption for image 2

1.6 Evolution of maximum and minimum daily values of FWI variables

Figure 1.21: Daily max and min FWI values



each sample, a wildfire occurrence was set 3 hours before the wildfire occurrence and 1 hour after, then the most important variables were calculated. Their complete hourly record were used. With a random state of 445621151 for RandomForestClassifier, the tables ?? and ?? shows the results for each year.

Figure 1.22: Daily max and min FFMC values

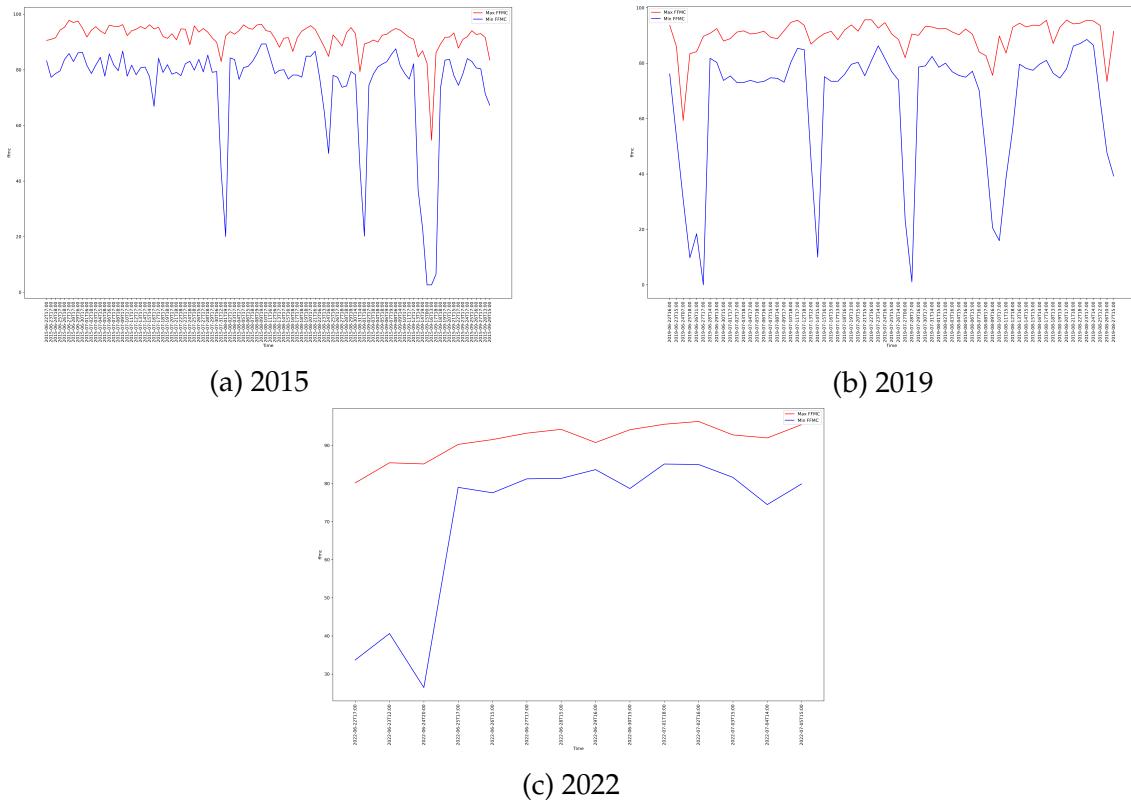


Figure 1.23: Daily max and min DMC values

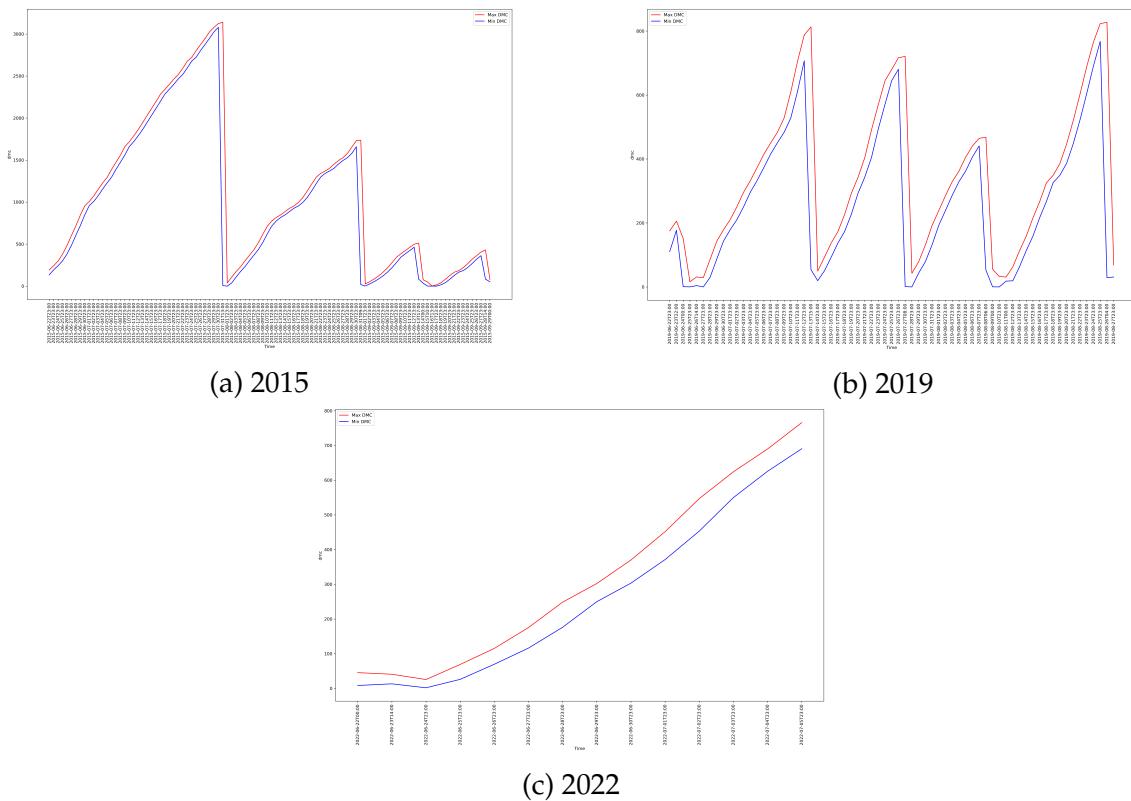


Figure 1.24: Daily max and min DC values

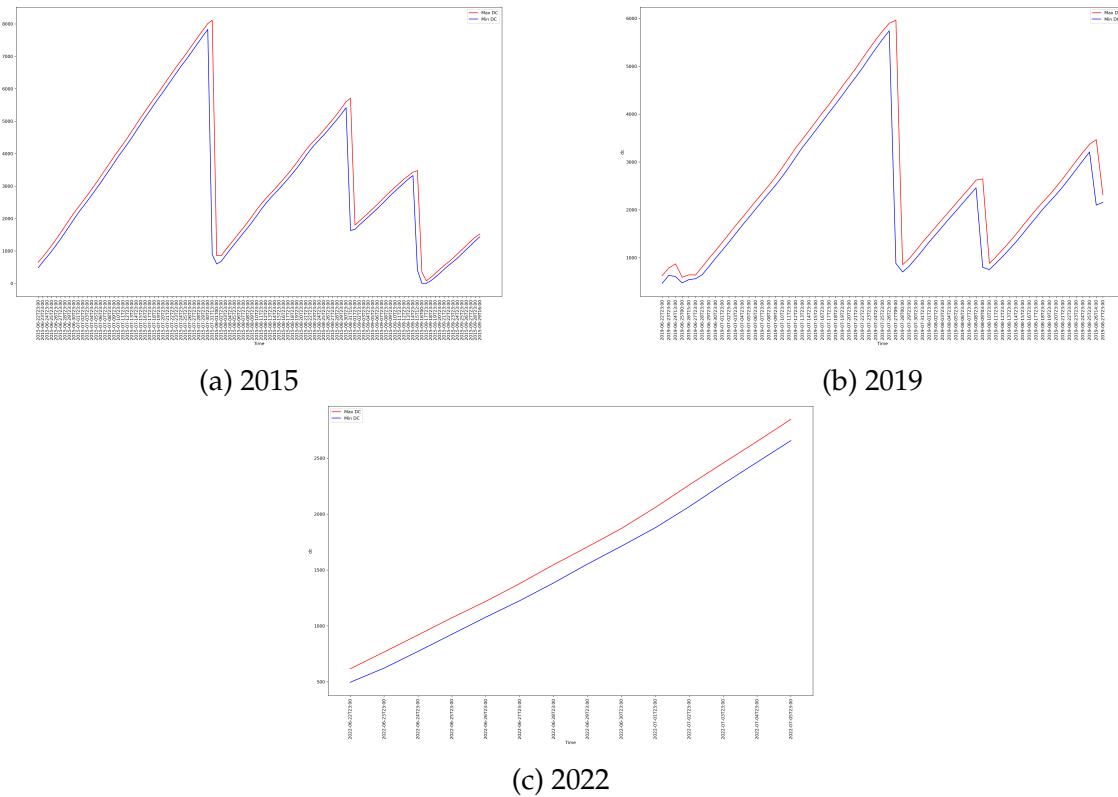


Figure 1.25: Daily max and min ISI values

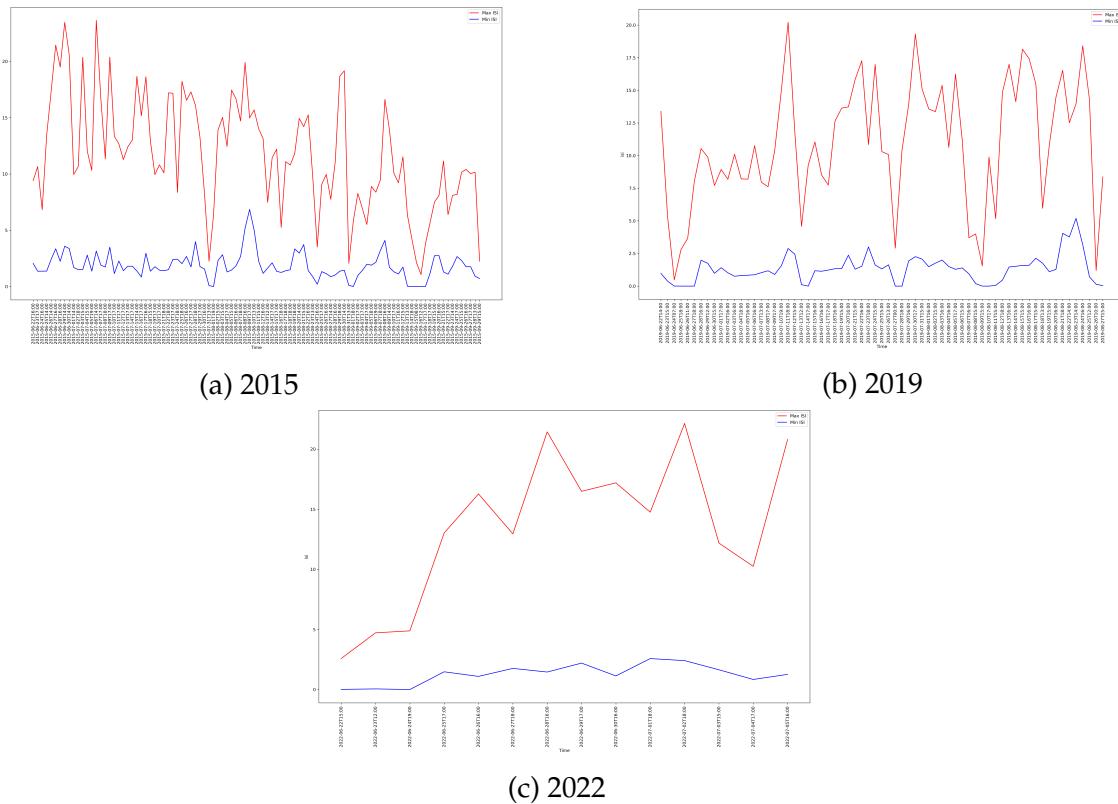
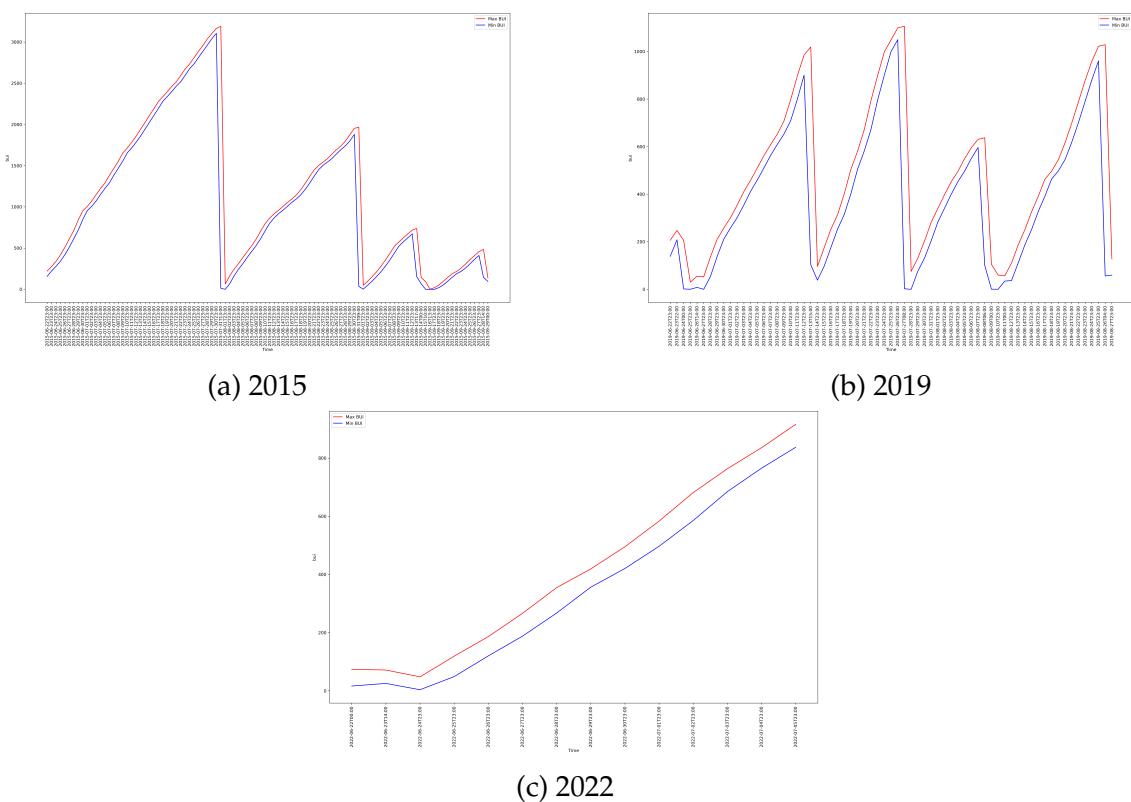


Figure 1.26: Daily max and min BUI values



1.7 Before, after and daily maximum value

Figure 1.27: Before, after and daily FWI maximum value

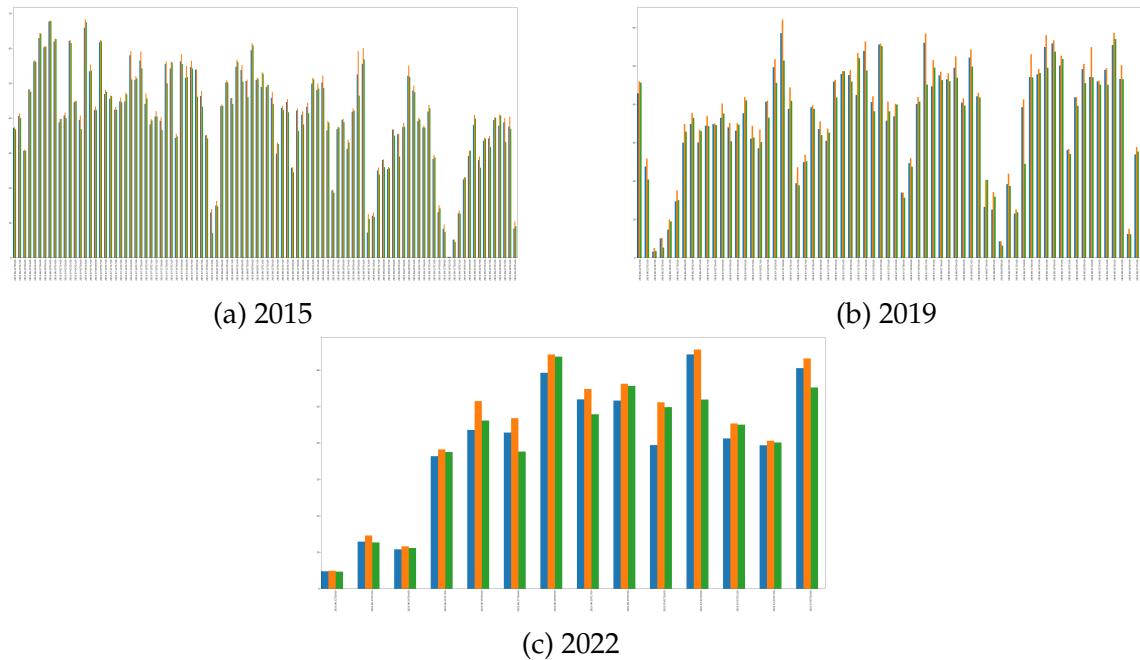


Figure 1.28: Before, after and daily FFMC maximum value

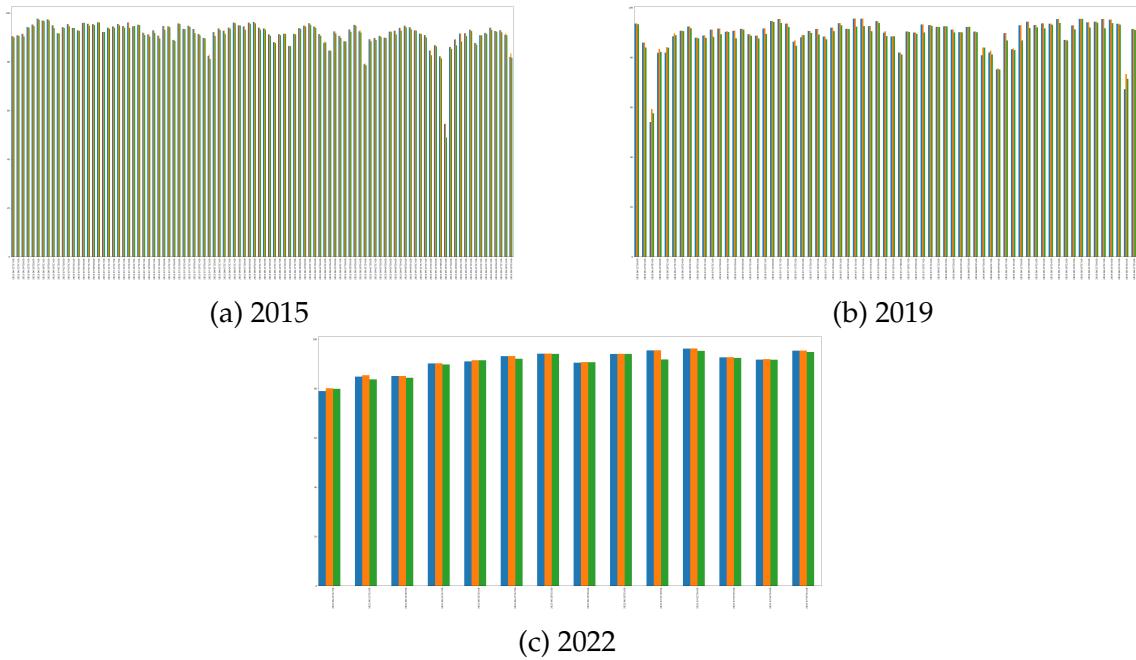


Figure 1.29: Before, after and daily DMC maximum value

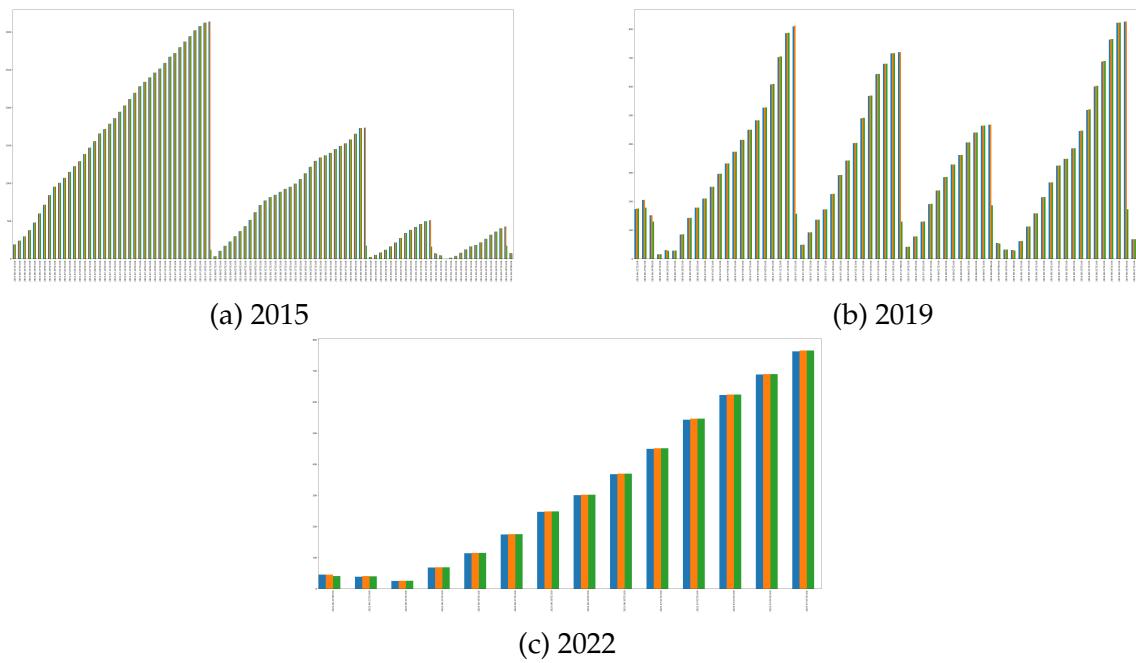


Figure 1.30: Before, after and daily DC maximum value

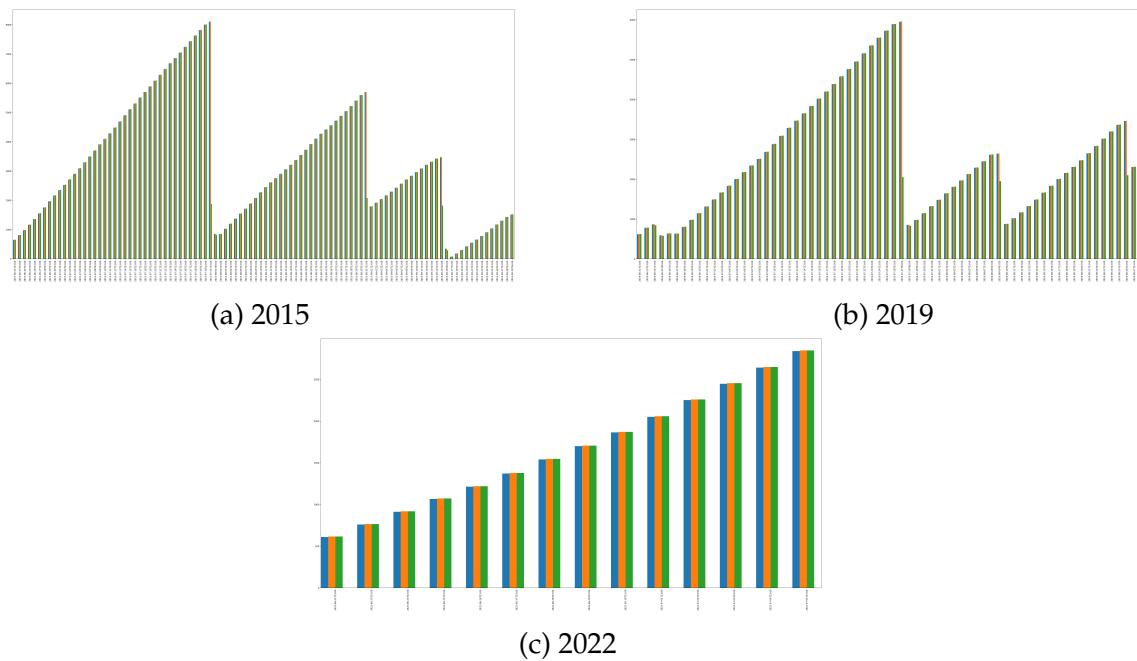


Figure 1.31: Before, after and daily ISI maximum value

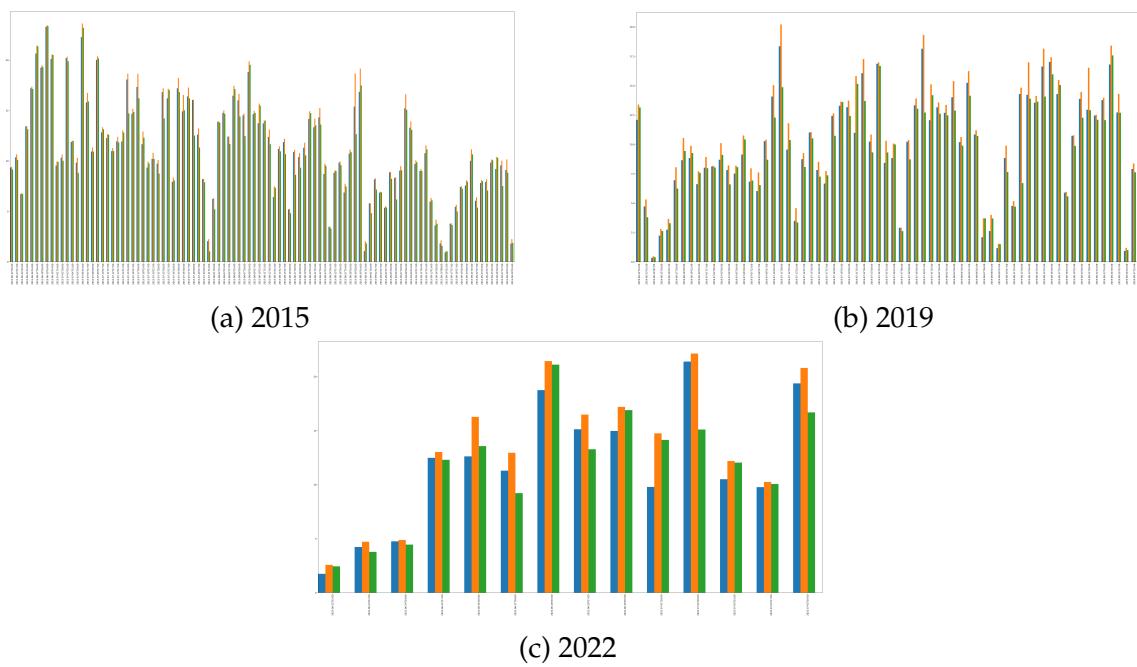
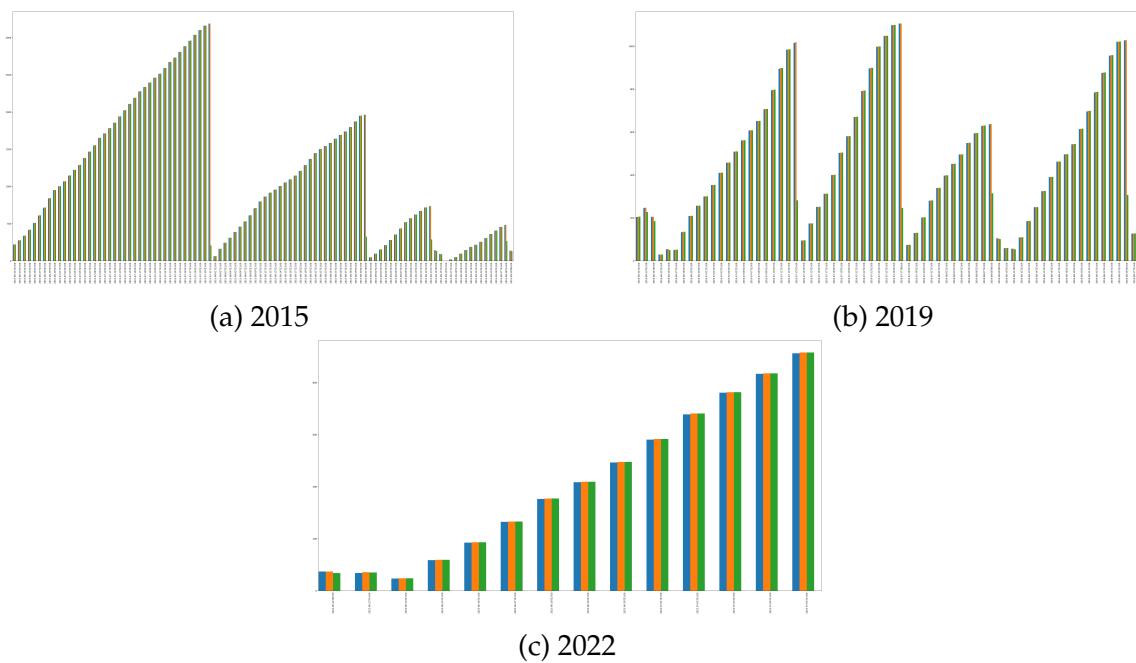


Figure 1.32: Before, after and daily BUI maximum value



1.8 Difference between the daily maximum and minimum values of the FWI variables

Figure 1.33: Daily difference of max and min FWI values

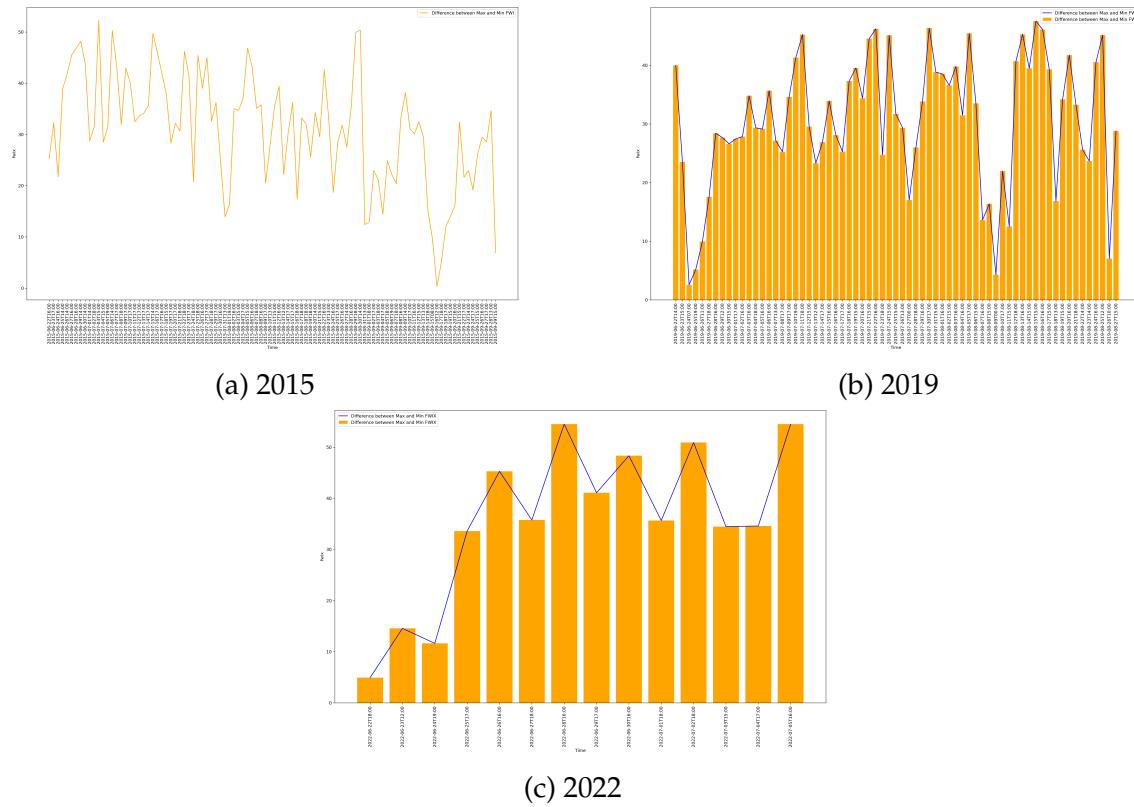


Figure 1.34: Daily difference of max and min FFMC values

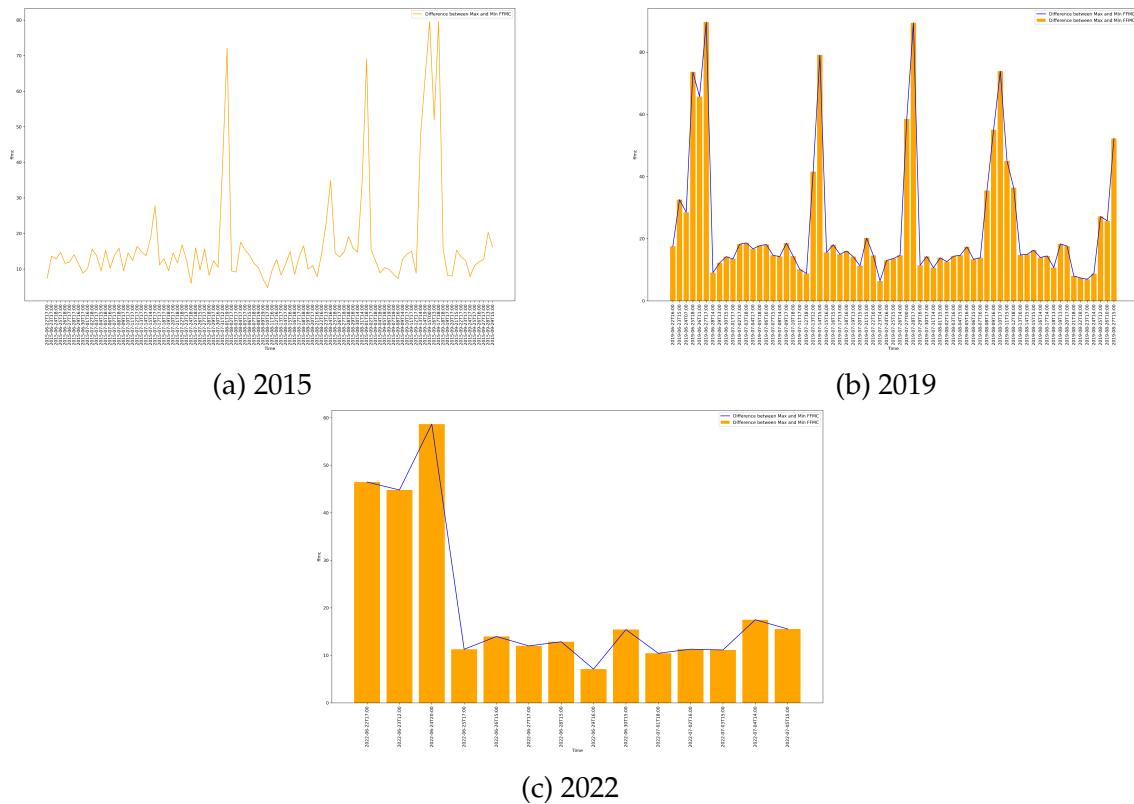


Figure 1.35: Daily difference of max and min DMC values

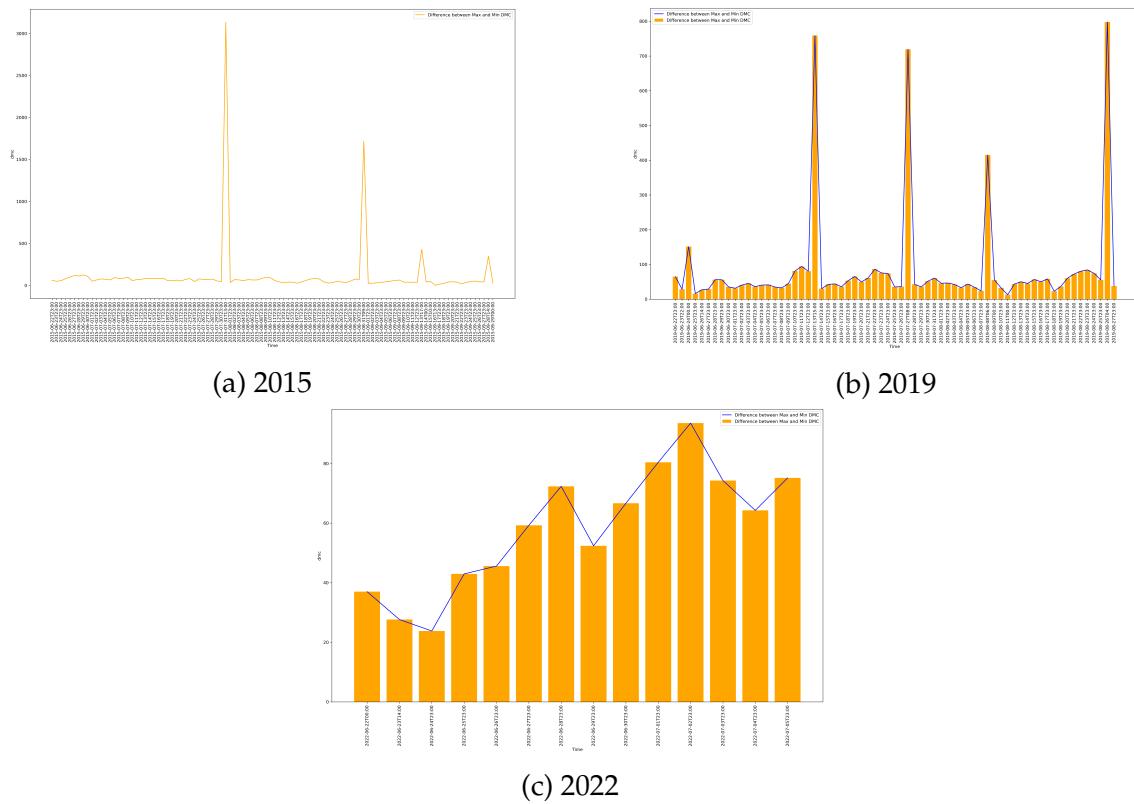


Figure 1.36: Daily difference of max and min DC values

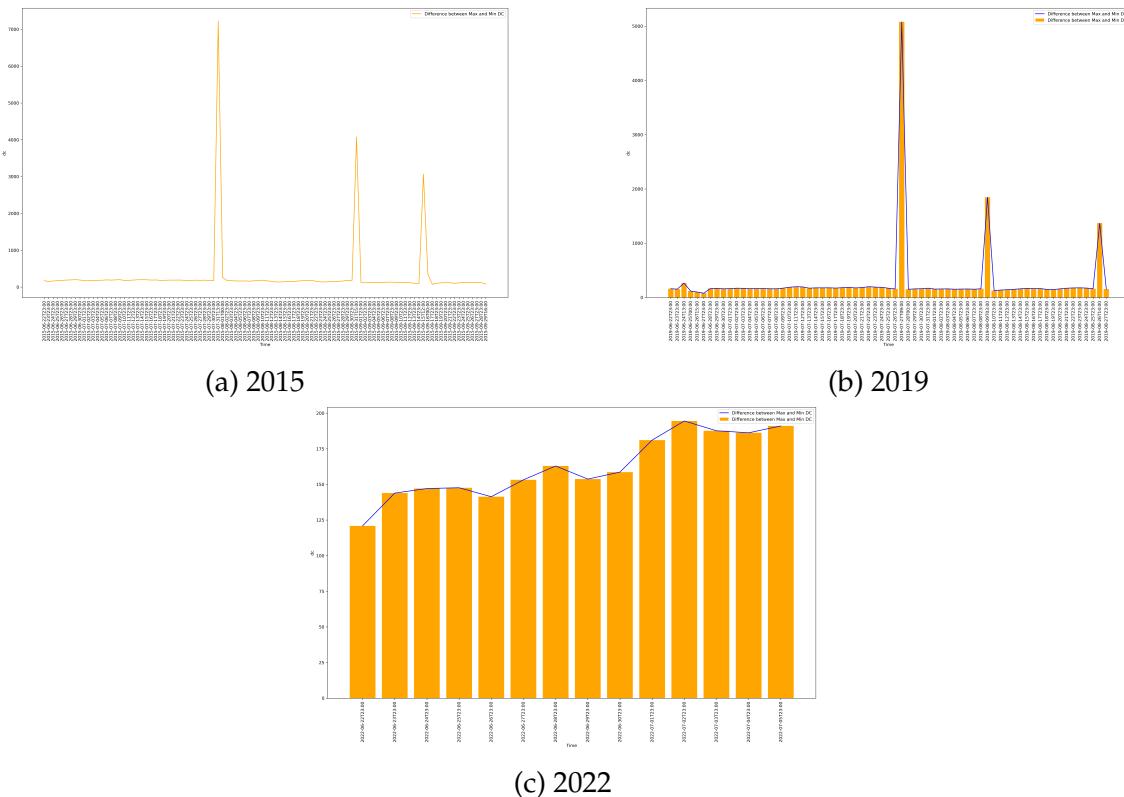


Figure 1.37: Daily difference of max and min ISI values

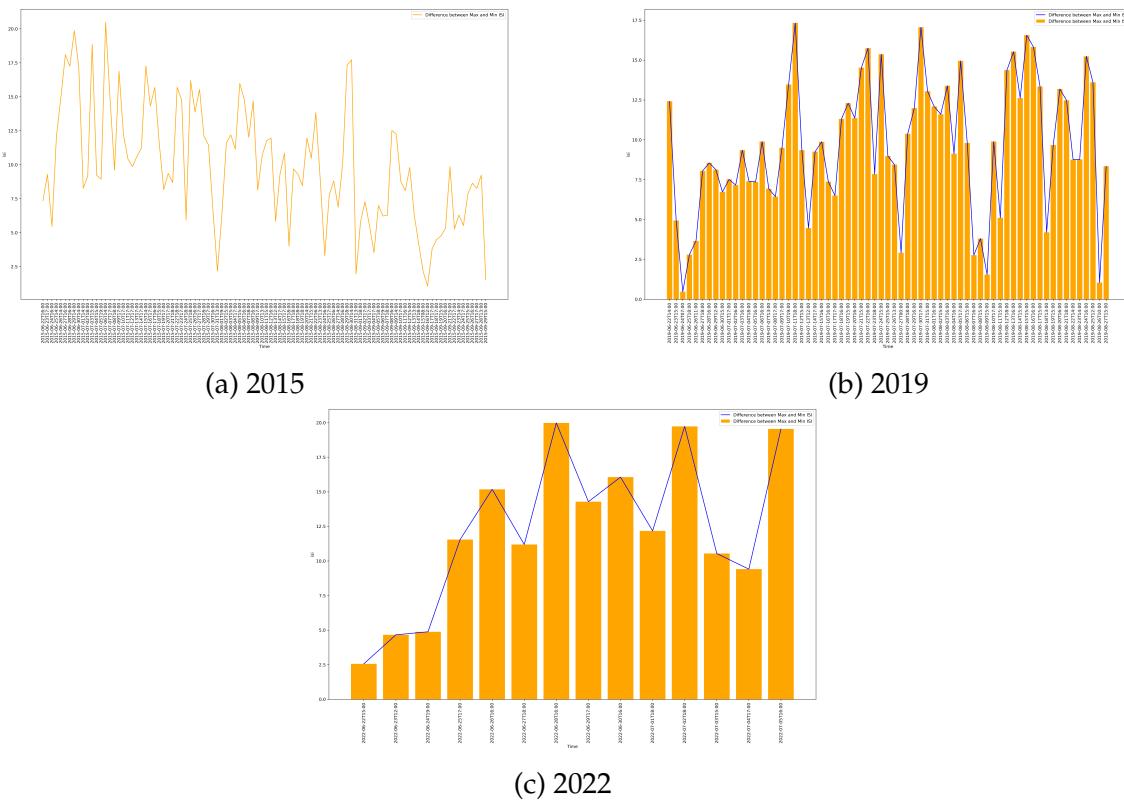
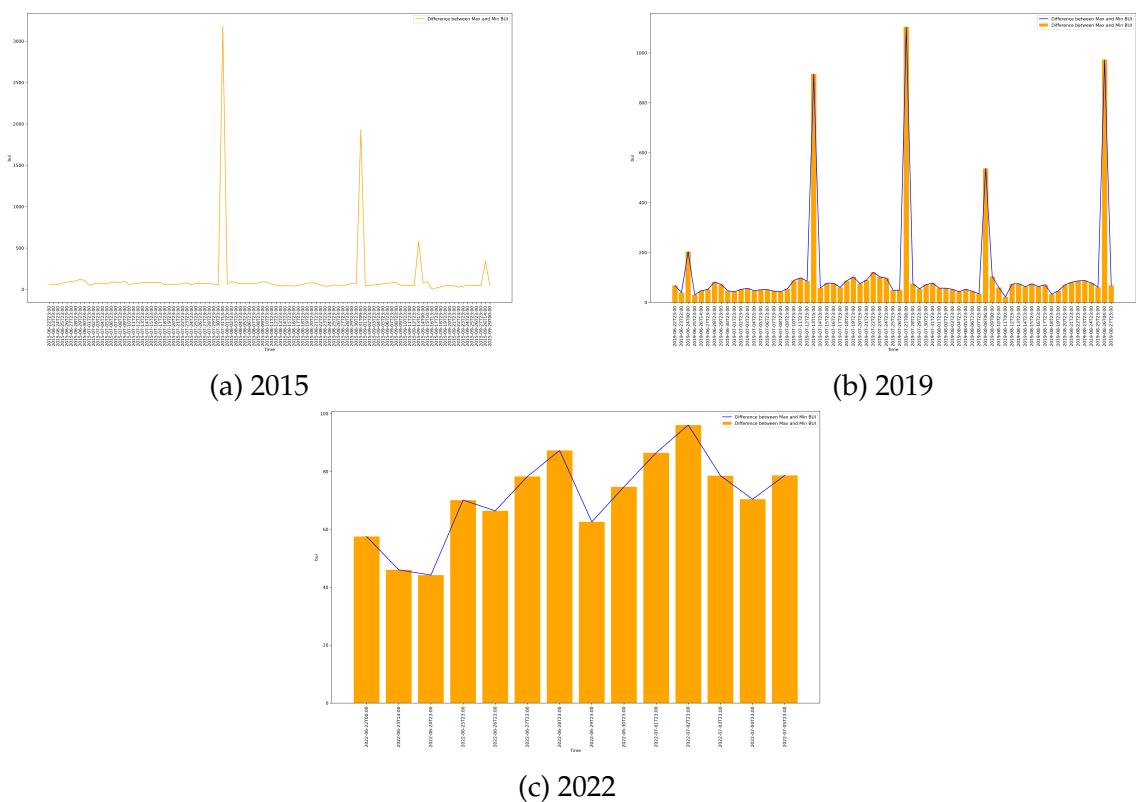


Figure 1.38: Daily difference of max and min BUI values



1.9 3-day time frame mean block tendency graphs of FWI variables

Figure 1.39: FWI mean tendency graph

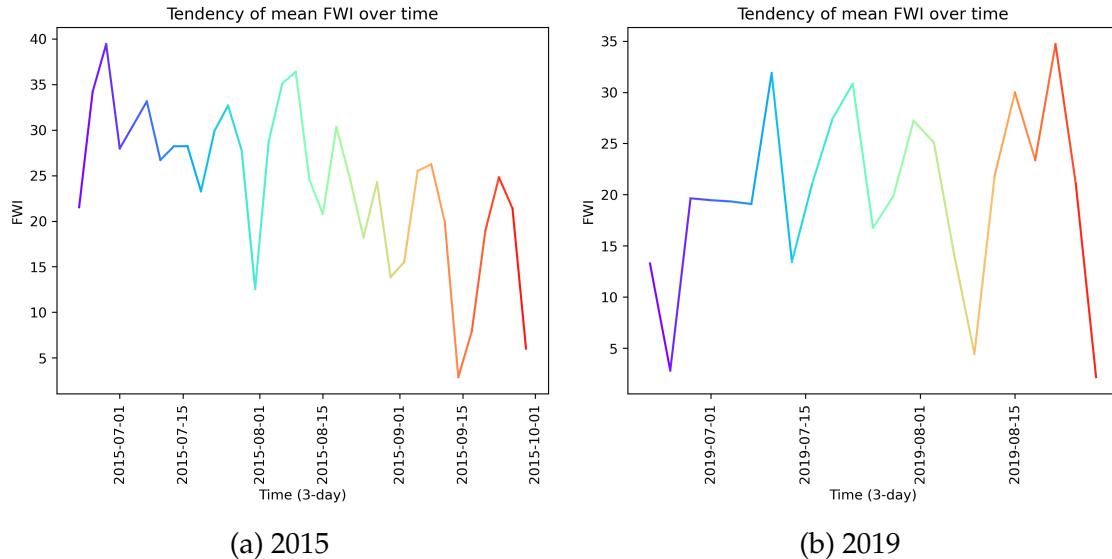


Figure 1.40: FFMC mean tendency graph

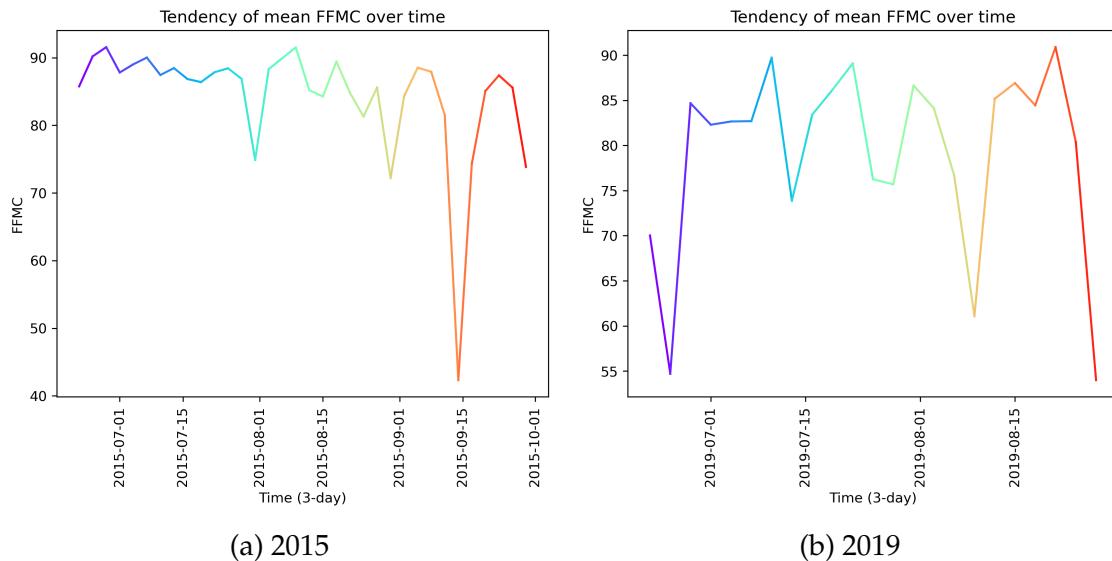


Figure 1.41: DMC mean tendency graph

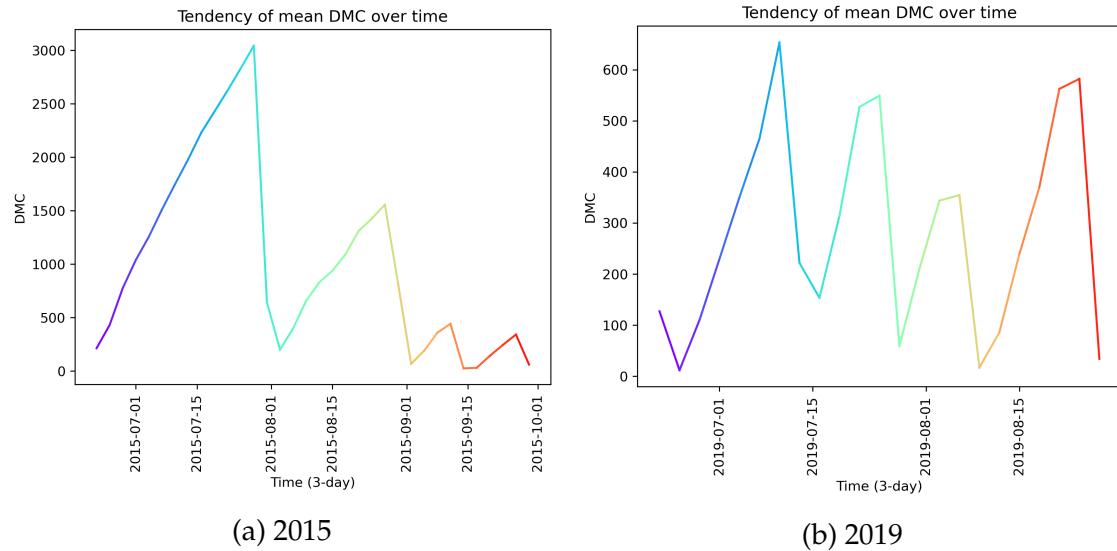


Figure 1.42: DC mean tendency graph

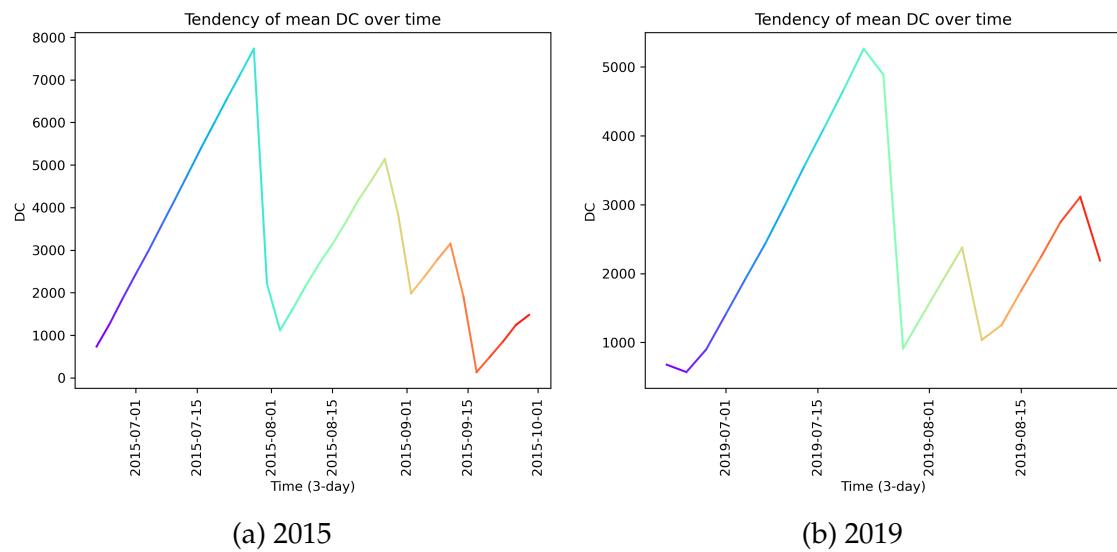


Figure 1.43: ISI mean tendency graph

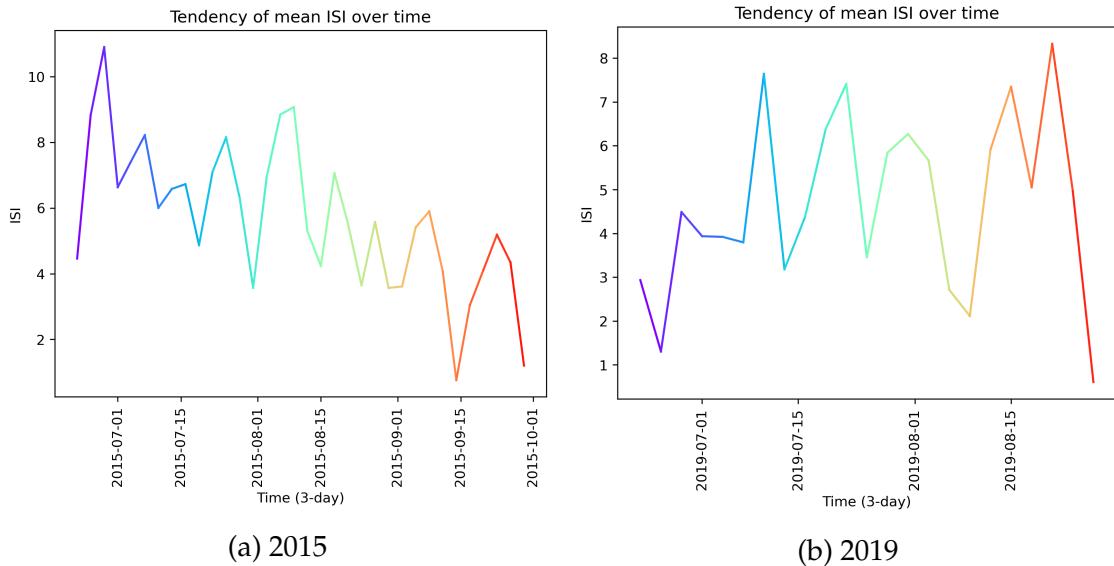
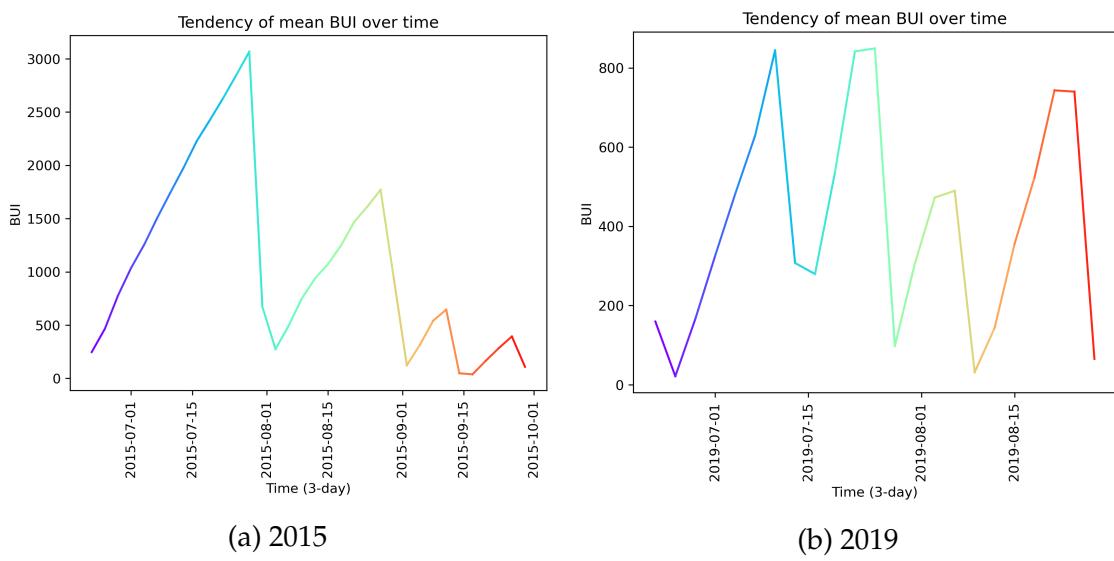


Figure 1.44: BUI mean tendency graph



1.10 Comparison of mean FWI variables 15 days prior to the wildfire

Figure 1.45: FWI values 15 days prior to wildfire

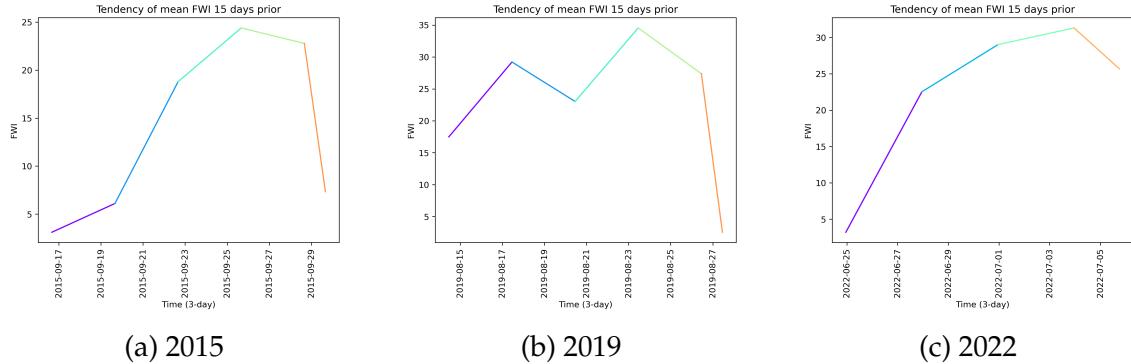


Figure 1.46: FFMC values 15 days prior to wildfire

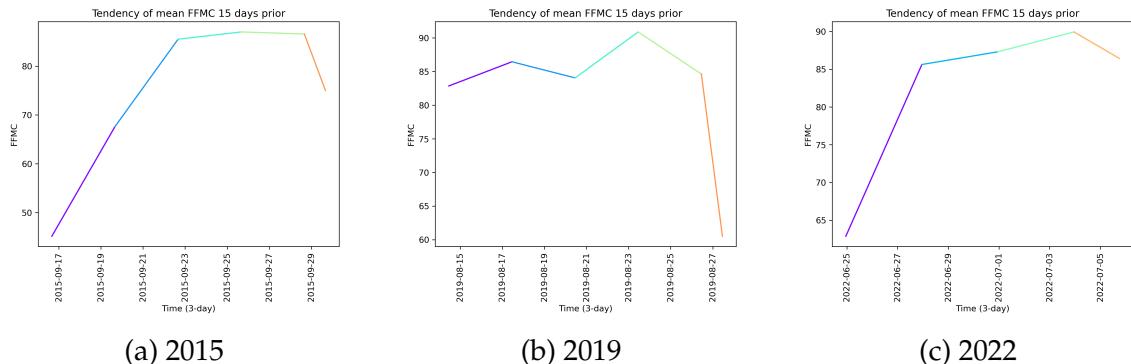


Figure 1.47: DMC values 15 days prior to wildfire

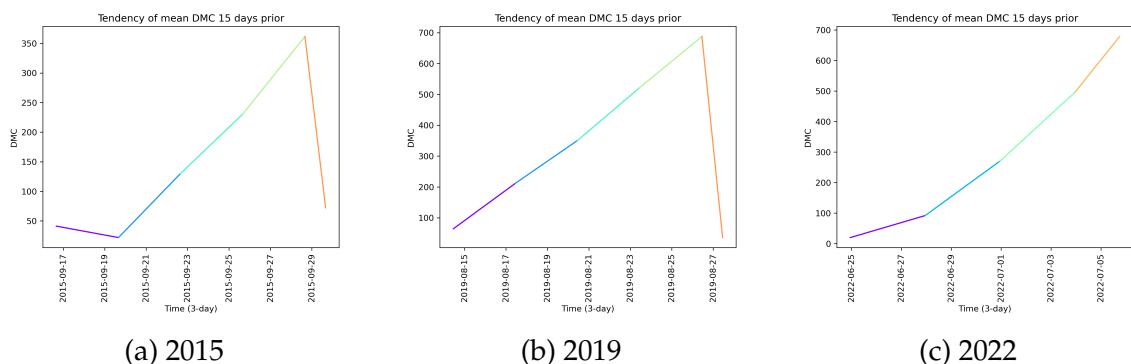


Figure 1.48: DC values 15 days prior to wildfire

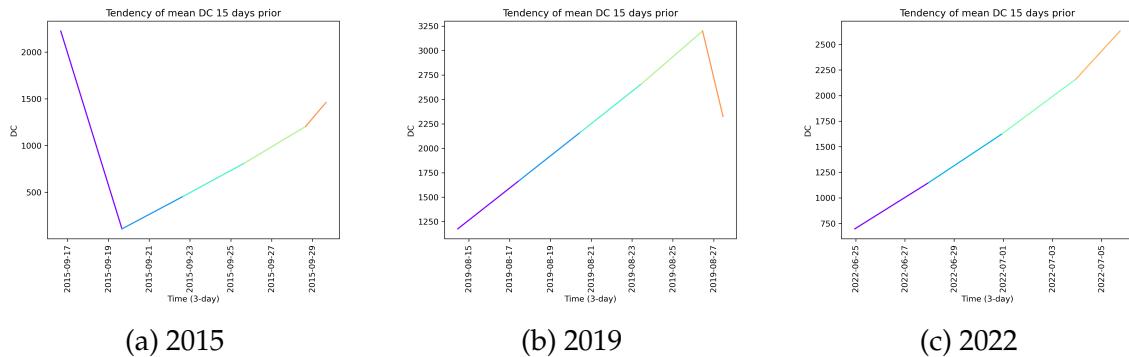


Figure 1.49: ISI values 15 days prior to wildfire

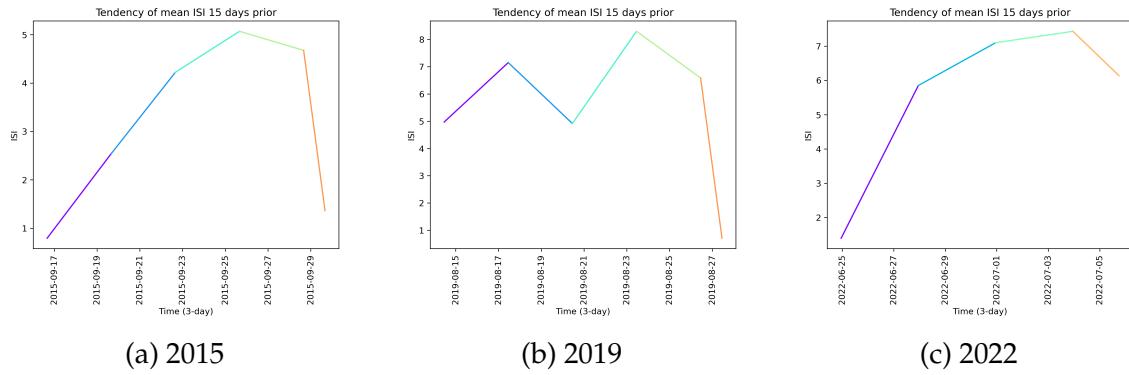
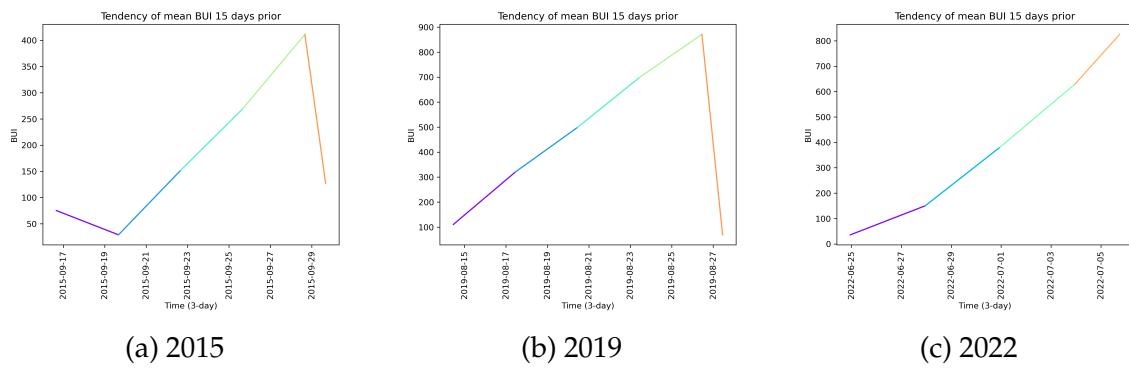


Figure 1.50: BUI values 15 days prior to wildfire



1.11 Comparison of mean FWI variables 3 days prior to the wildfire

Figure 1.51: FWI values 3 days prior to wildfire

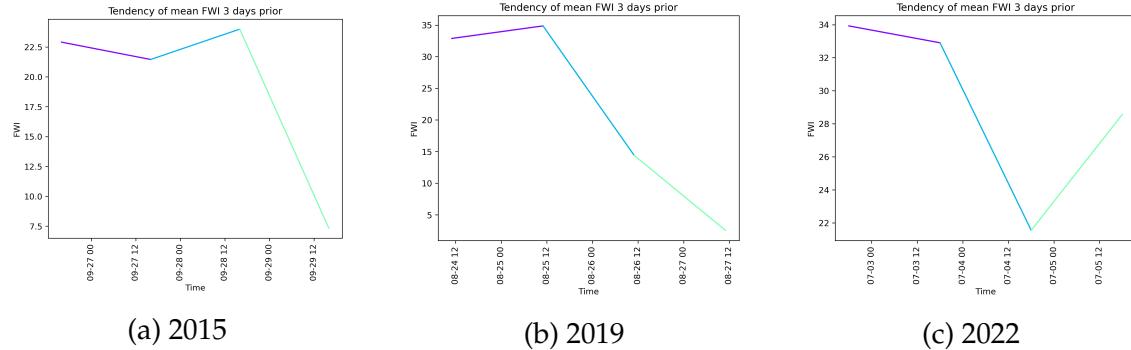


Figure 1.52: FFMC values 3 days prior to wildfire

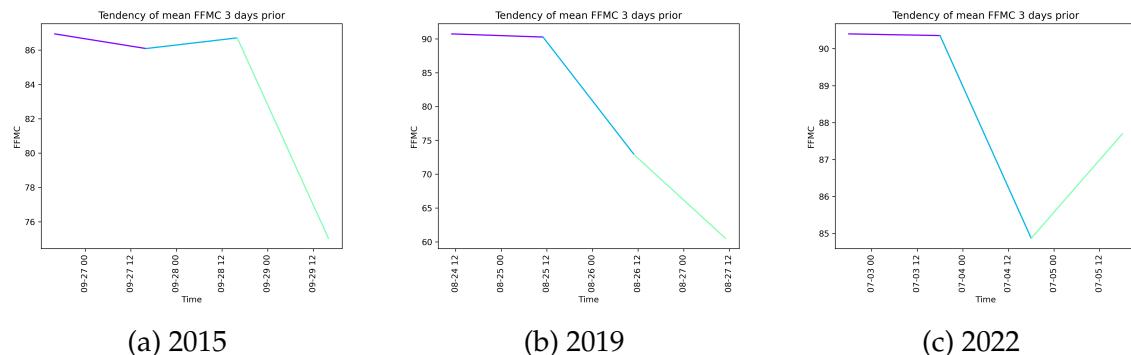


Figure 1.53: DMC values 3 days prior to wildfire

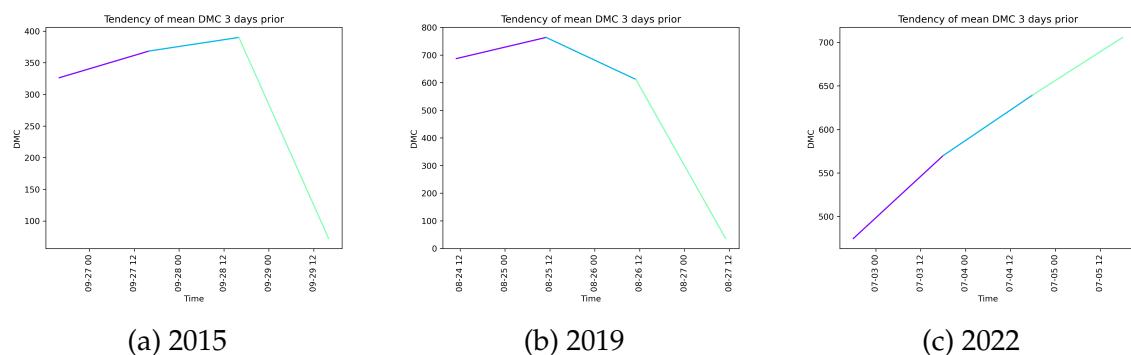


Figure 1.54: DC values 3 days prior to wildfire

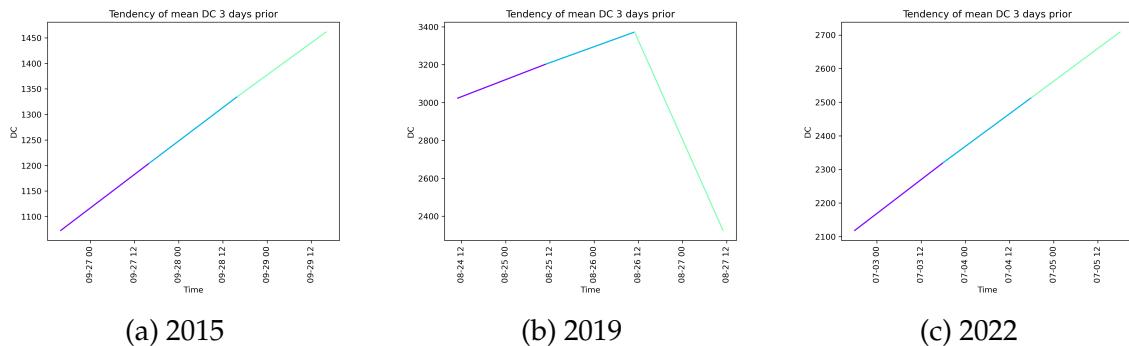


Figure 1.55: ISI values 3 days prior to wildfire

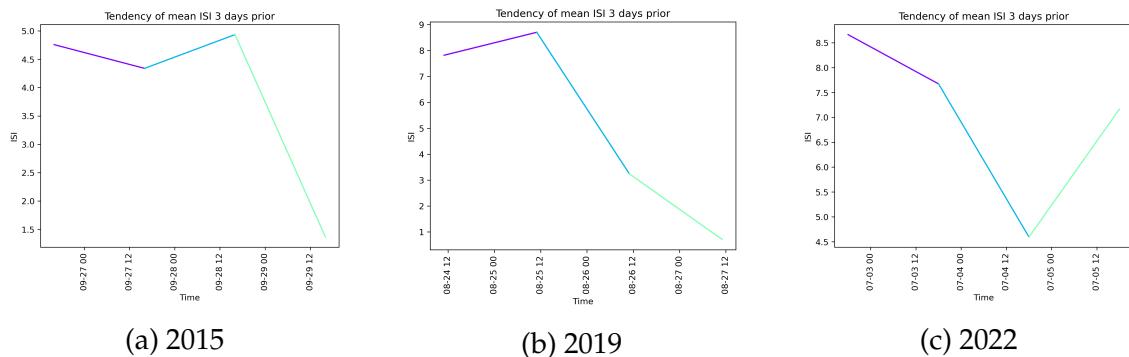
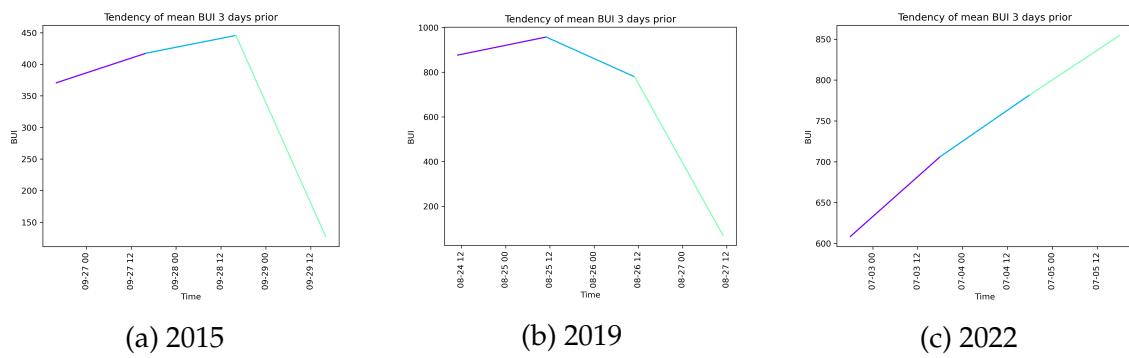


Figure 1.56: BUI values 3 days prior to wildfire



1.12 Polyfit FWI trend Analysis

1.12.1 All-time FWI trend with 3-days polyfit block

Figure 1.57: All-time FWI polyfit trend

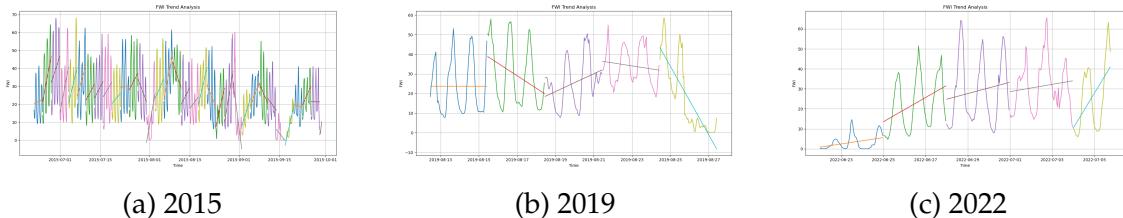


Figure 1.58: All-time FFMC polyfit trend

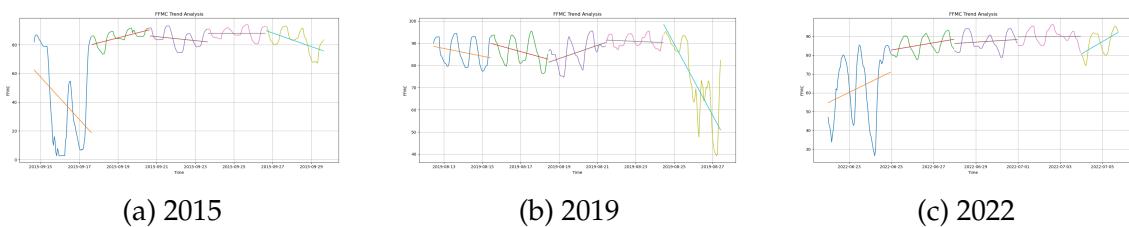
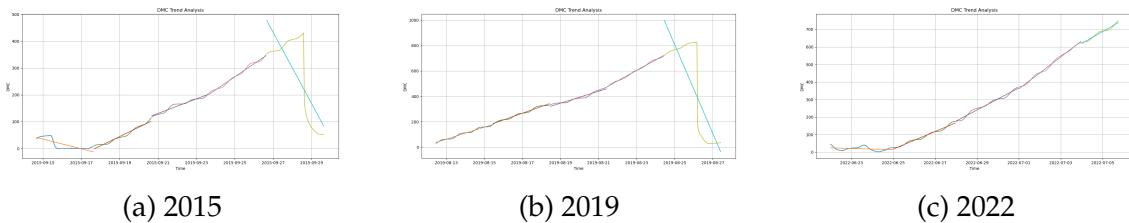


Figure 1.59: All-time DMC polyfit trend



1.12.2 15-days polyfit trend

15 dias com declive da reta para 3 dias.

1.13 15-days Weather Variables

1.14 3-days Weather variables

Figure 1.60: All-time DC polyfit trend

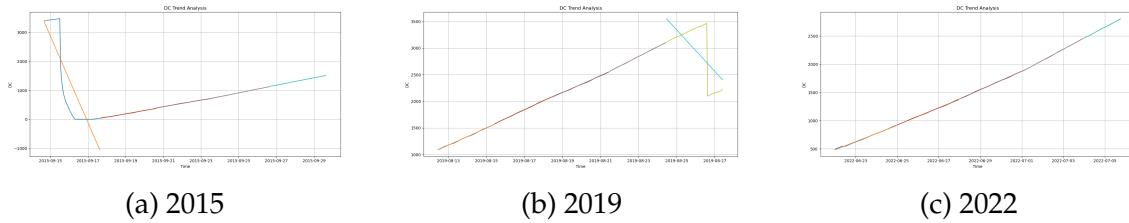


Figure 1.61: All-time ISI polyfit trend

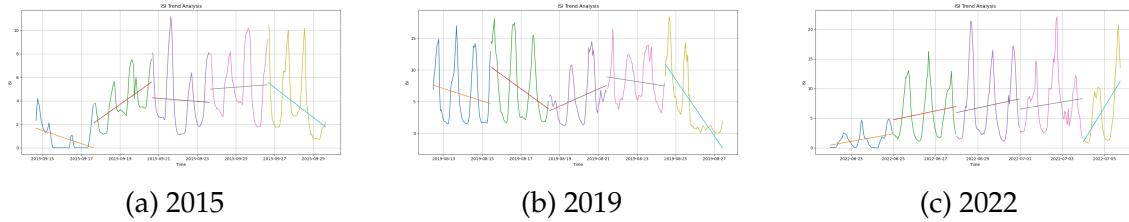


Figure 1.62: 15-days FWI polyfit trend

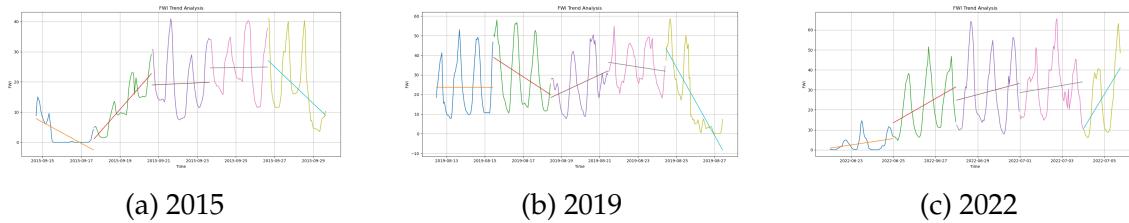


Figure 1.63: 15-days FFMC polyfit trend

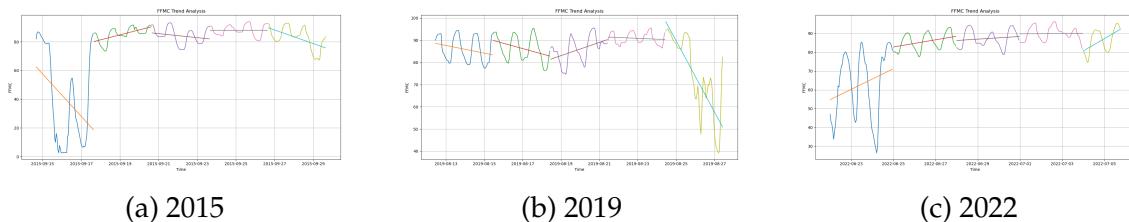


Figure 1.64: 15-days DMC polyfit trend

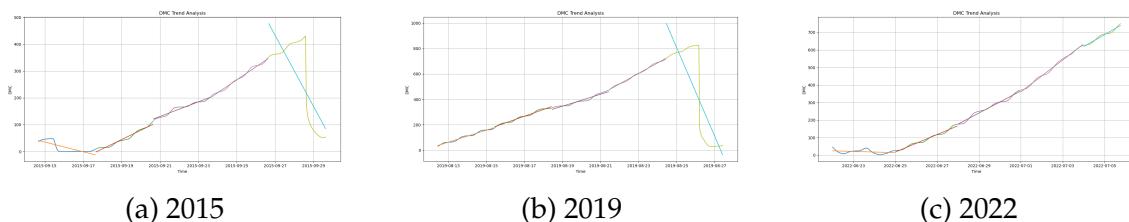


Figure 1.65: 15-days DC polyfit trend

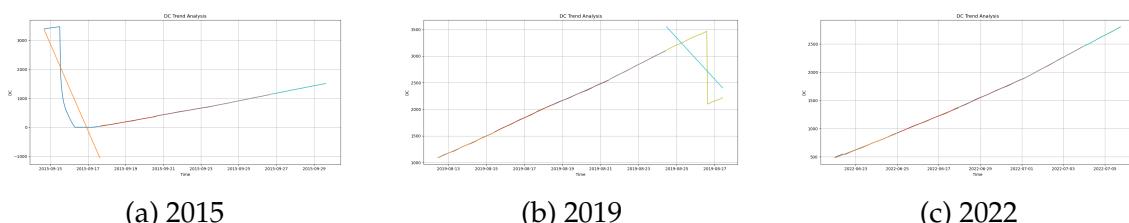


Figure 1.66: 15-days ISI polyfit trend

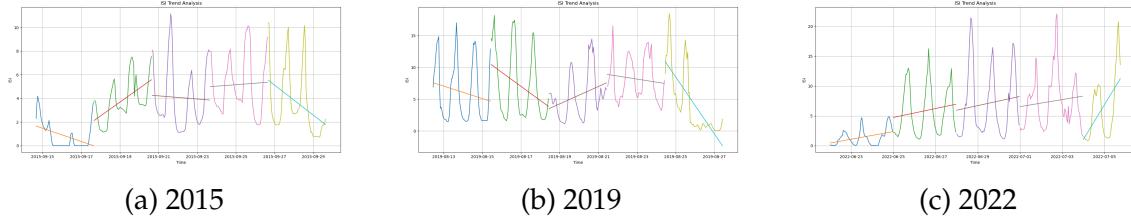


Figure 1.67: 15-days BUI polyfit trend

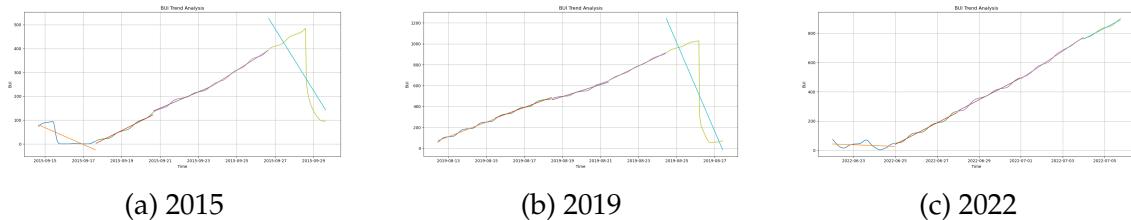


Figure 1.68: 15-days temperature, humidity, and dew

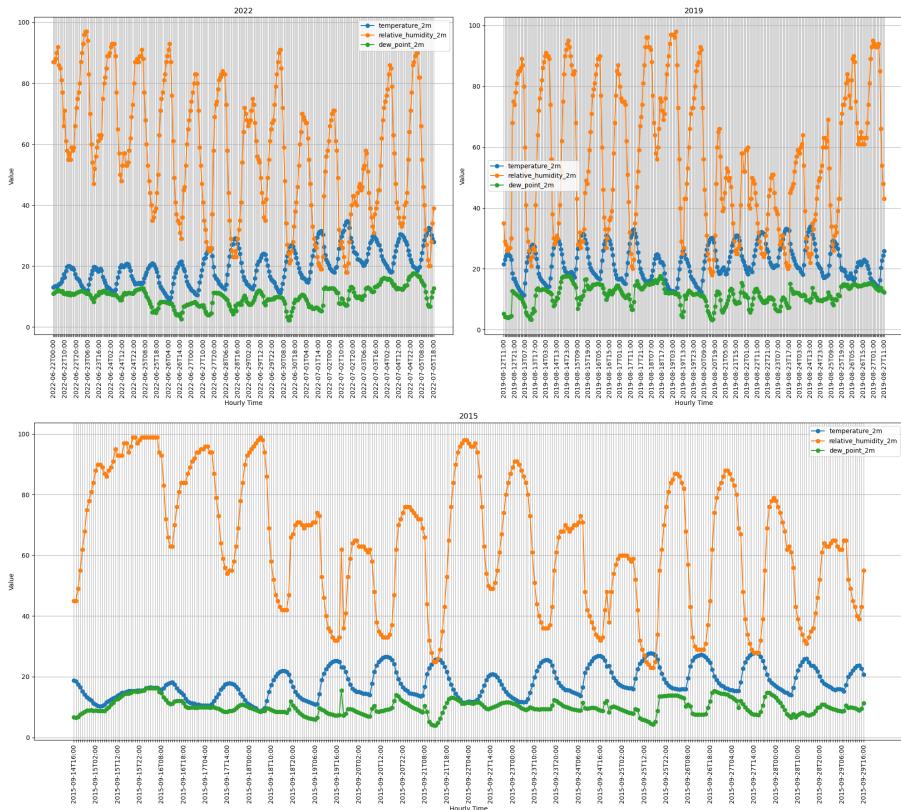


Figure 1.69: 15-days soil temperature at different depths

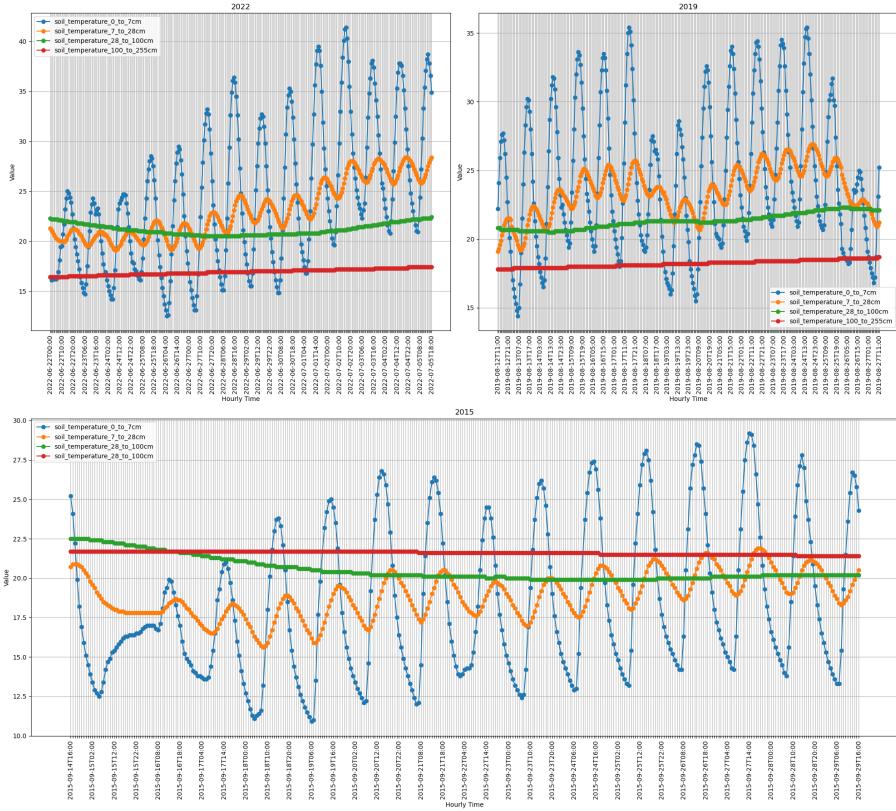


Figure 1.70: 15-days soil moisture at different depths

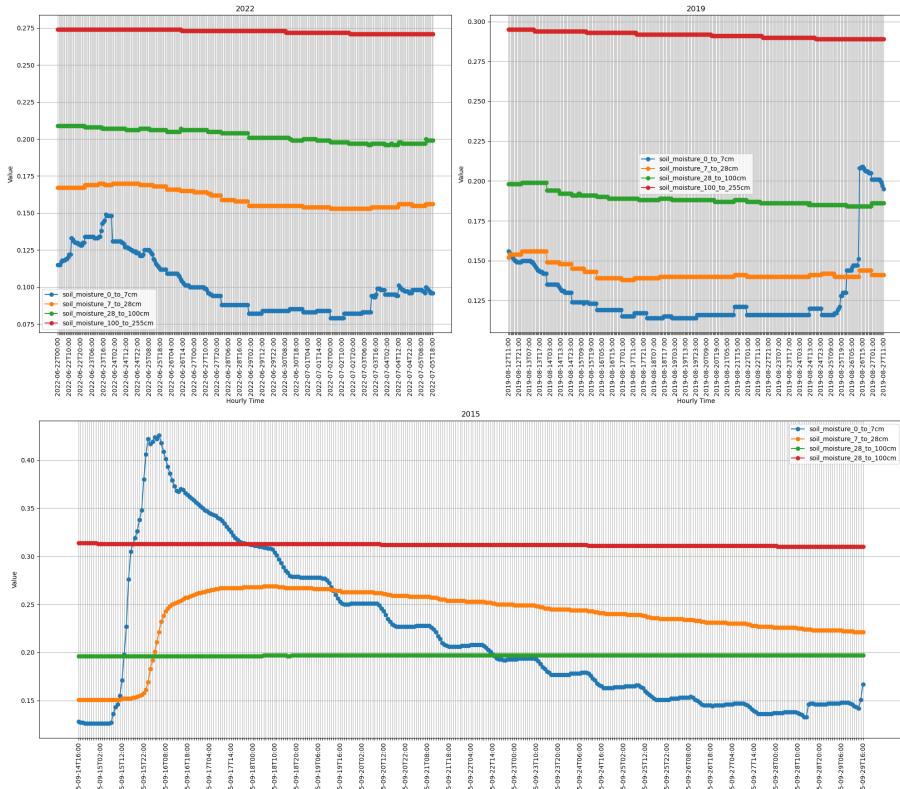


Figure 1.71: 15-days precipitation and pressure

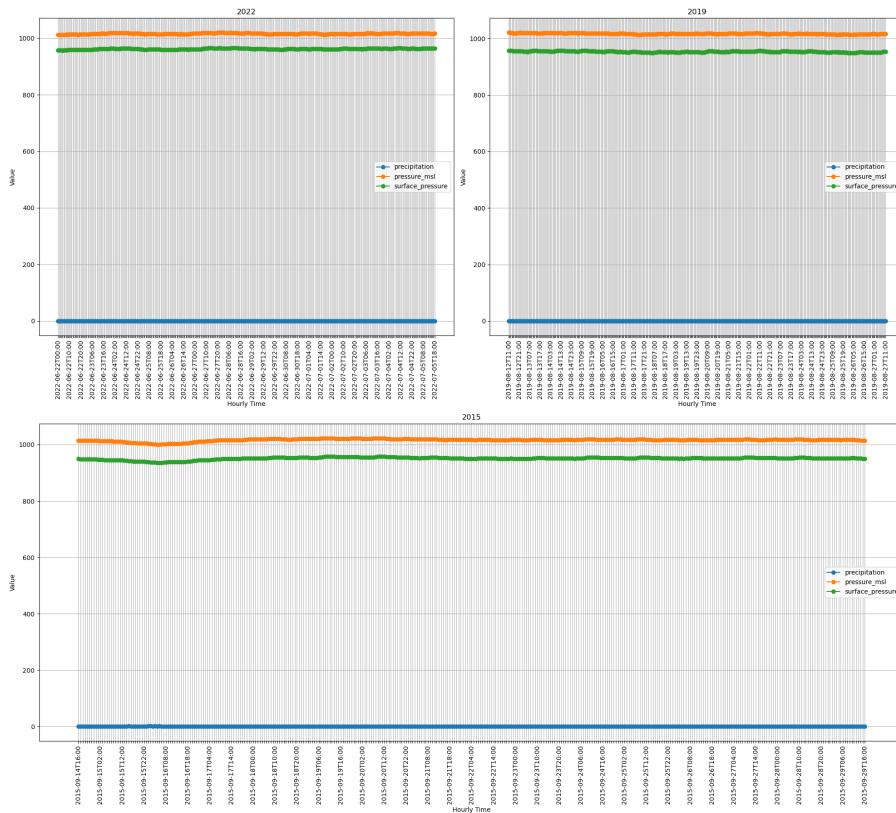


Figure 1.72: 15-days wind gusts, evapotranspiration, and vapour pressure deficit

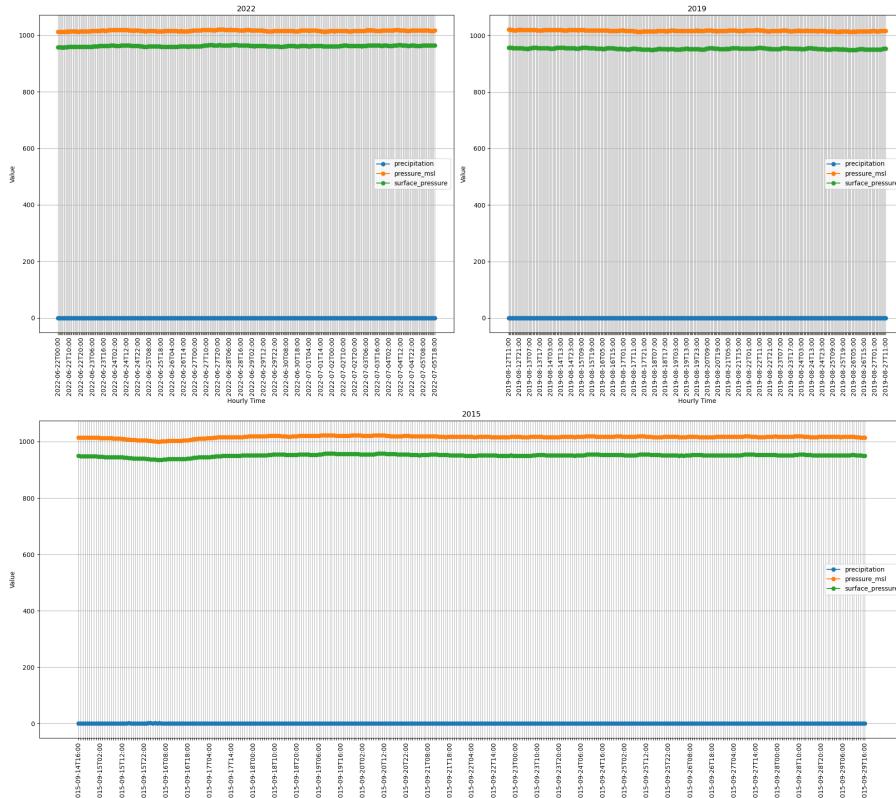


Figure 1.73: 3-days temperature, humidity, and dew

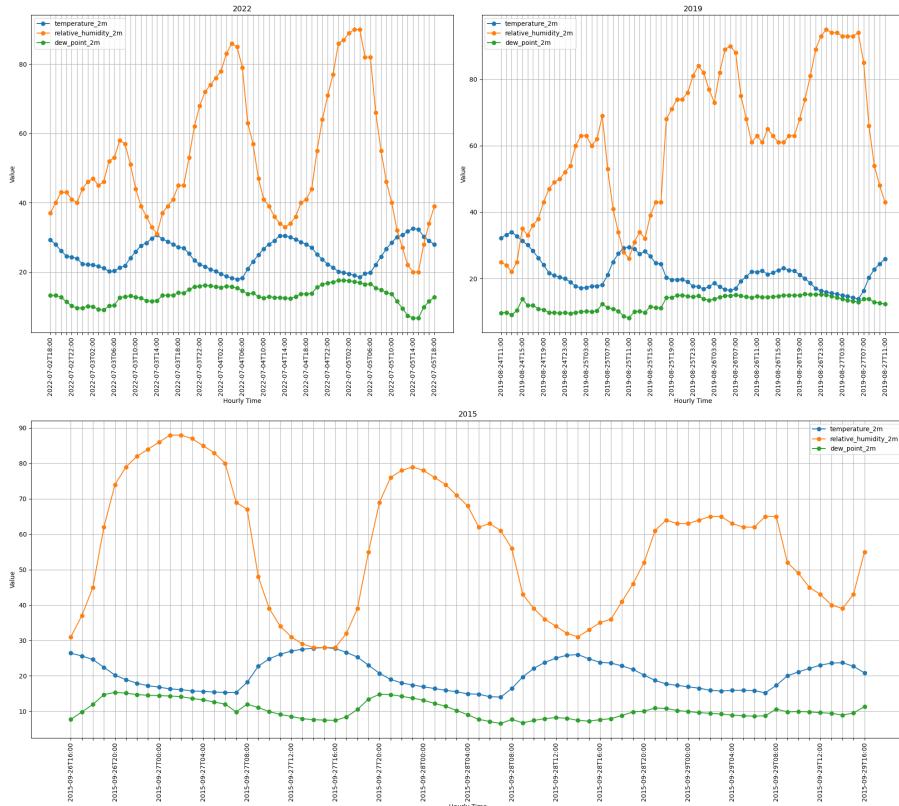


Figure 1.74: 3-days soil temperature at different depths

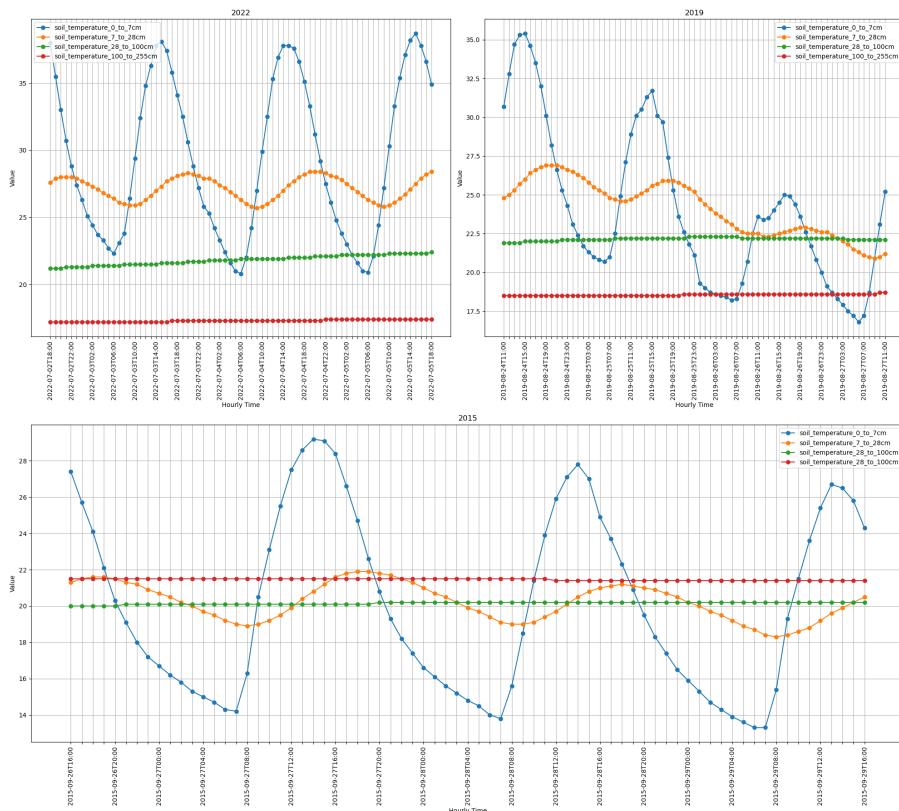


Figure 1.75: 3-days soil moisture at different depths

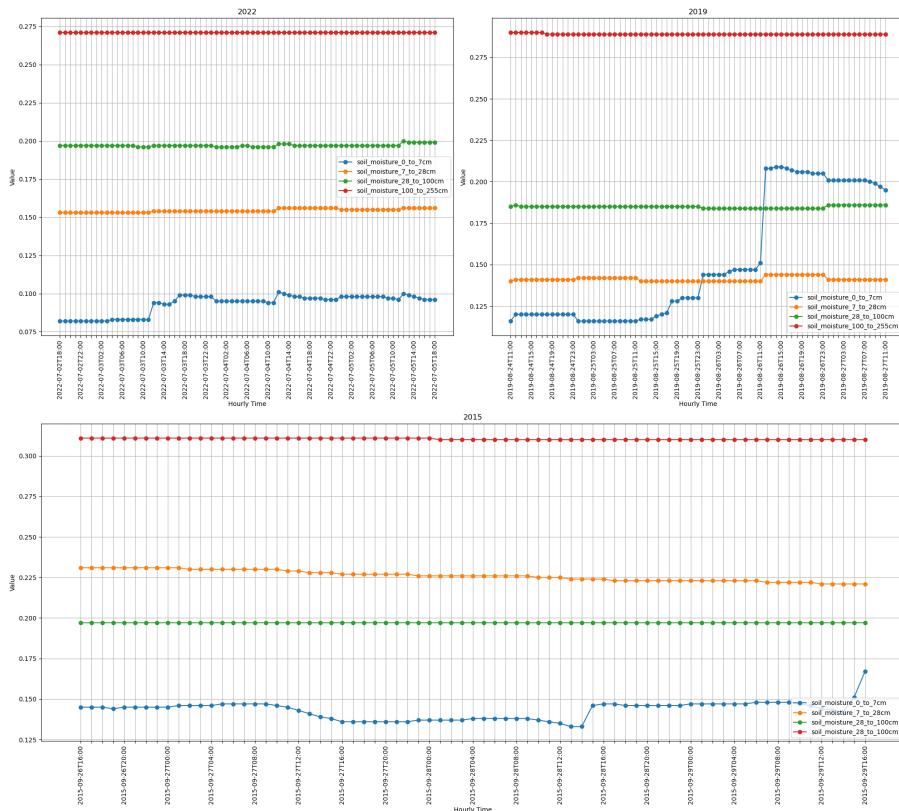


Figure 1.76: 3-days precipitation and pressure

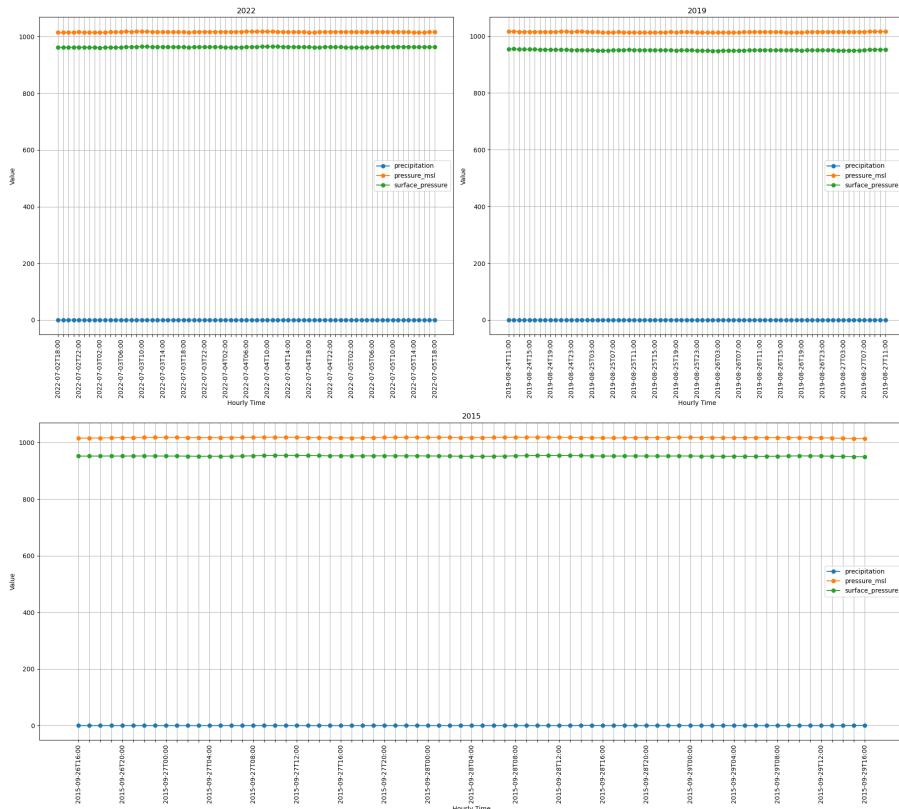


Figure 1.77: 3-days wind gusts, evapotranspiration, and vapour pressure deficit

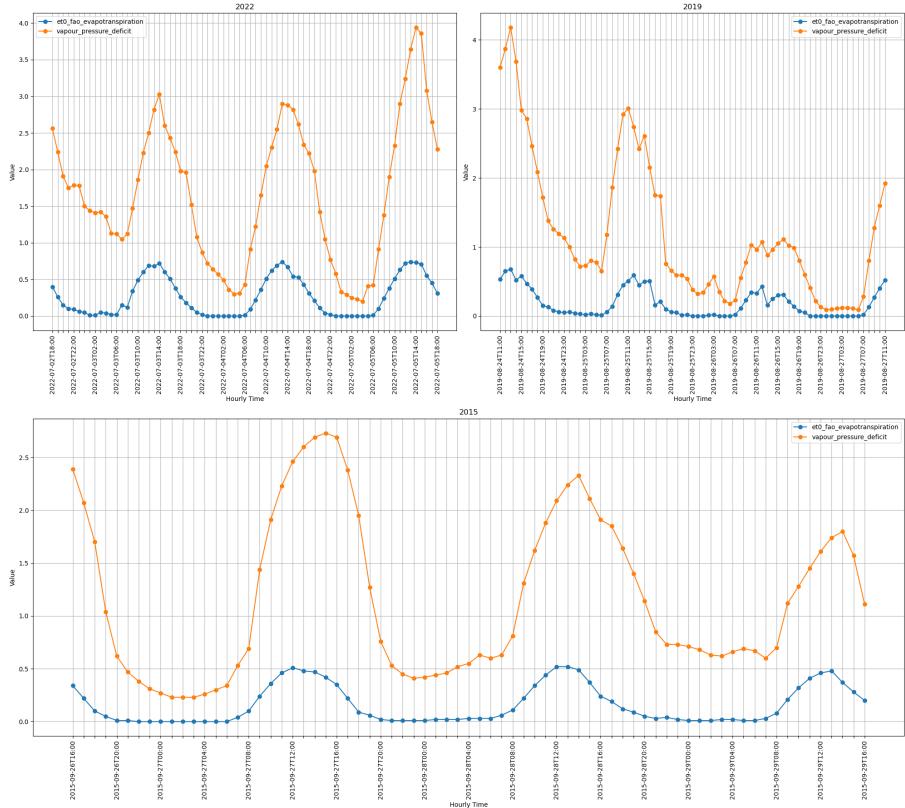


Figure 1.78: 3-days shortwave, direct, and diffuse radiation

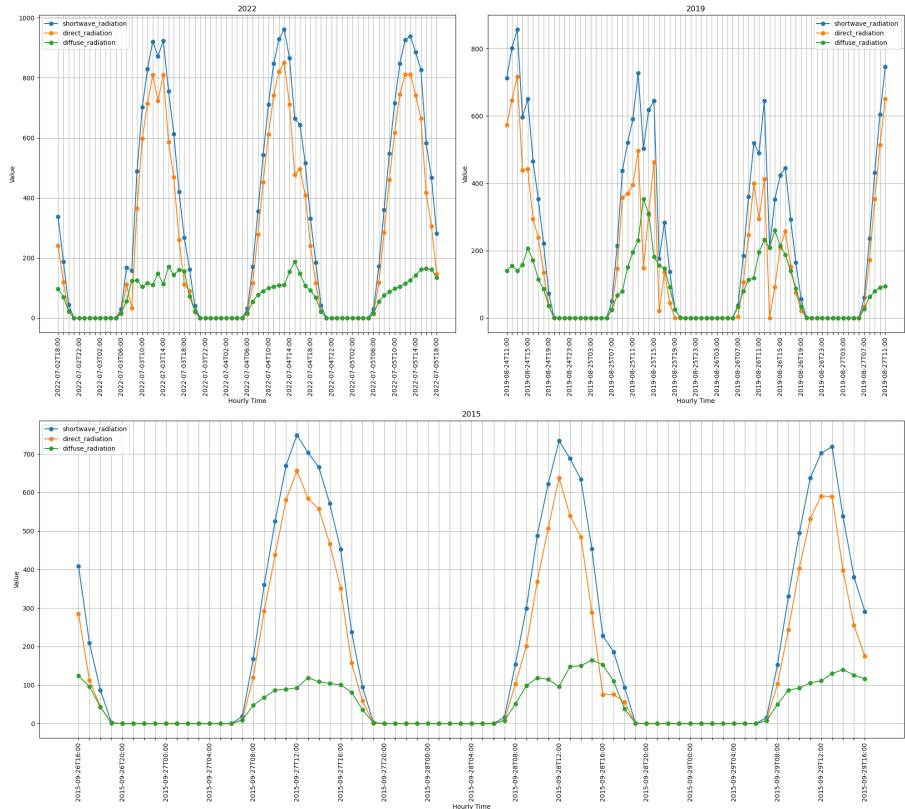


Figure 1.79: 3-days direct, global, and instant irrardice

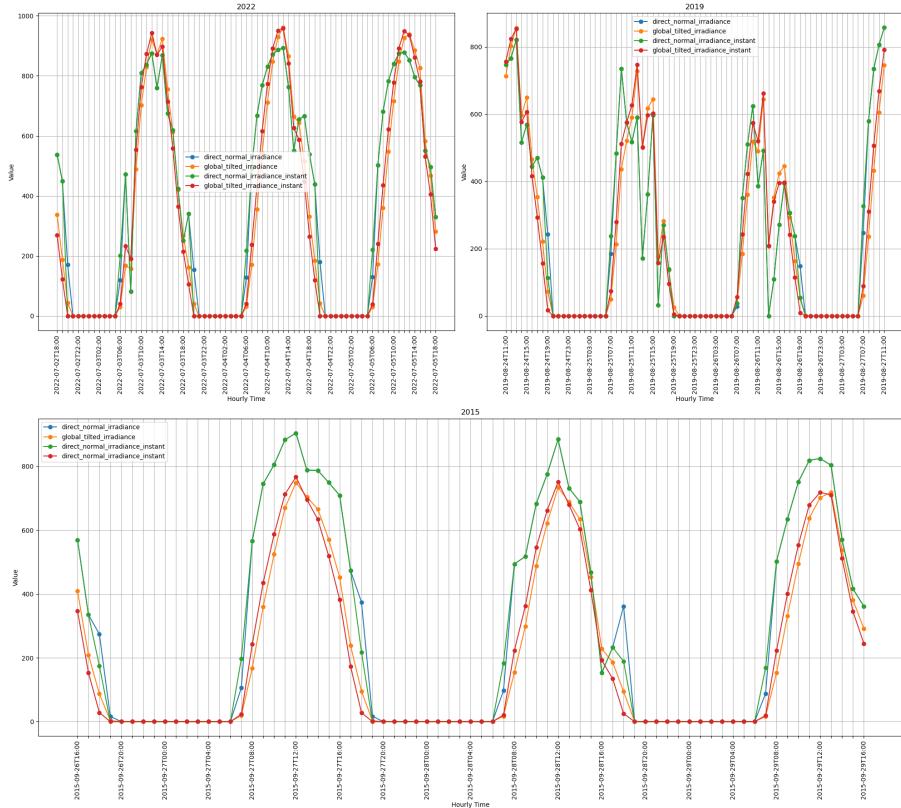


Figure 1.80: 3-days cloud covers at different heights

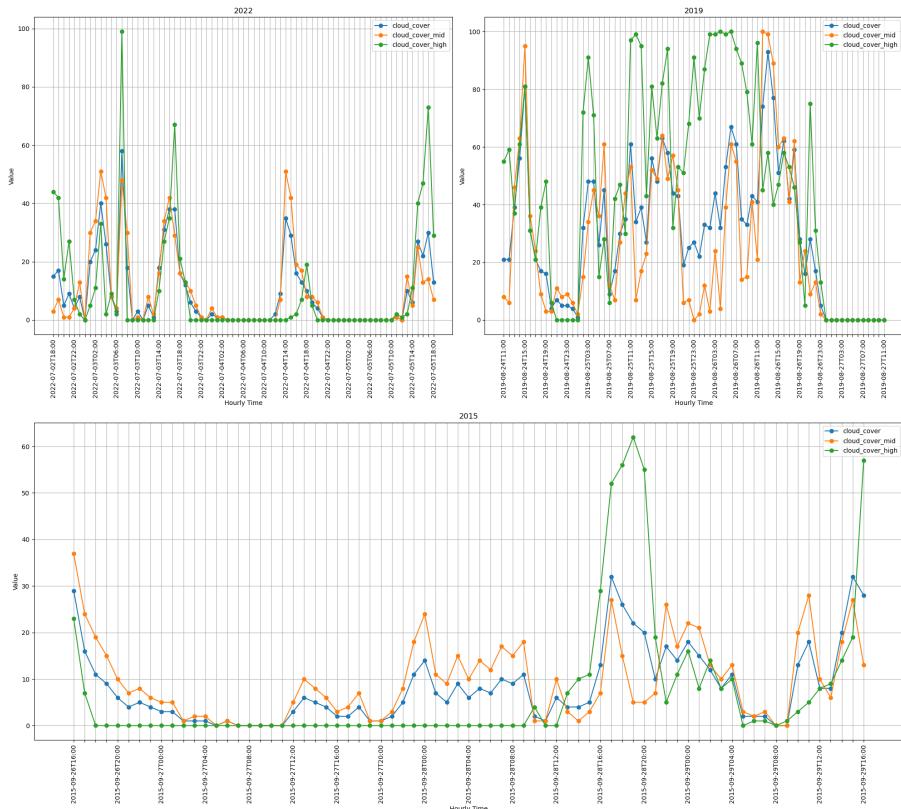


Figure 1.81: 3-days terrestrial, direct, and instant radiation

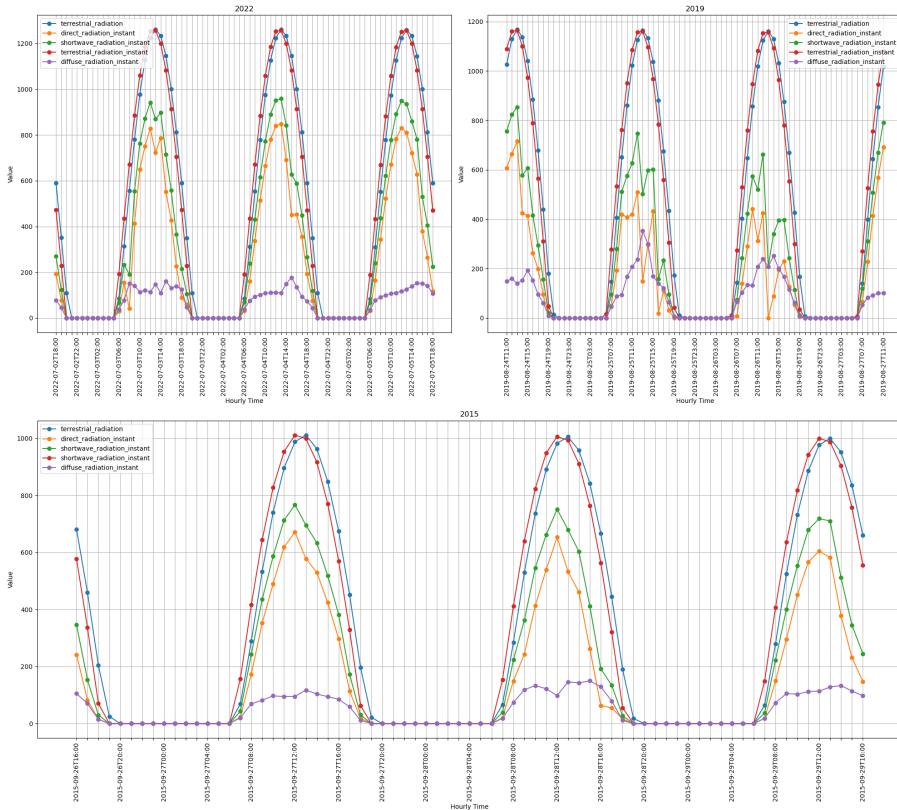
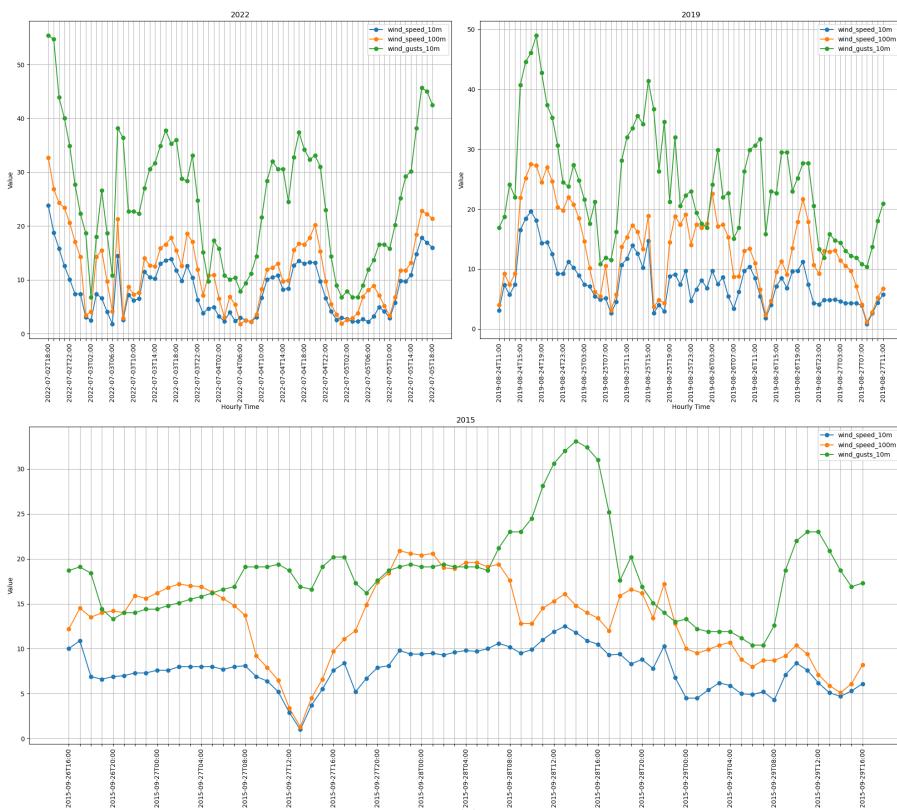


Figure 1.82: 3-days wind speed at different heights



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