Fire, vol.9, no.1, pp.43-1-43-24, January, 2026.

Wildfire Mitigation in Small-to-Medium-Scale Industrial Hubs Using Cost-Effective Optimized Wireless Sensor Networks

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Abstract-

Wildfires are increasingly recognized as a climatological hazard, able to threaten industrial and critical infrastructure safety and operations and lead to Natech disasters. Future projections of exacerbated fire regimes increase the likelihood of Natech disasters, therefore increasing expected direct damage costs, clean-up costs, and long-term economic losses due to business interruption and environmental remediation. While large industrial complexes, such as oil, gas, and chemical facilities have sufficient resources for the implementation of effective prevention and mitigation plans, small-to-medium-sized industrial hubs are particularly vulnerable due to their scattered distribution and limited resources for investing in comprehensive fire prevention systems. This study targets the vulnerability of these communities by proposing the deployment of Wireless Sensor Networks (WSNs) as cost-effective Early Wildfire Detection Systems (EWDSs) to safeguard wildland and industrial domains. The proposed approach leverages wildland–industrial interface (WII) geospatial data, simulated wildfire dynamics data, and mathematical optimization to maximize detection efficiency at minimal cost. The WII delimits the boundary where the presence of wildland fires impacts industrial activity, thus representing a proxy for potential Natech disasters. The methodology is tested in Cocentaina, Spain, a municipality characterized by a highly flammable Mediterranean landscape and medium-scale industrial parks. Results reveal the complex trade-offs between detection characteristics and the degree of protection in the combined wildland and WII areas, enabling stakeholders to make informed decisions. This methodology is easily replicable for any municipality and industrial installation, or for generic wildland–human interface (WHI) scenarios, provided there is access to wildfire dynamics data and geospatial boundaries delimiting the areas to protect.

Index Terms- wildland–industrial interface (WII); Natech; wildfires; vulnerable communities; geospatial information; GIS; simulations; optimization; Wireless Sensor Network (WSN)

Citation:
Gómez, J.L.; Marcoulaki, E.; Cantizano, A.; Konstantinidou, M.; Caro, R.; Castro, M. "Wildfire Mitigation in Small-to-Medium-Scale Industrial Hubs Using Cost-Effective Optimized Wireless Sensor Networks", Fire, vol.9, no.1, pp.43-1-43-24, January, 2026.