

Supplementary Material

Pyros: a raster–vector spatial simulation model for predicting wildland surface fire spread and growth

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Supplementary Tables S1-S8

Table S1. Metrics for case no-wind no-slope: dead fuel moisture and fuel models.

Case no-wind no-slope	Metric	MF Dead 10h 0.05	MF Dead 10h 0.10	MF Dead 10h 0.15	MF Dead 10h 0.20	MF Dead 10h 0.25
Fuel model 1	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.942	0.951	0.954	0.962	0.959
	F ₁ -score	0.970	0.975	0.977	0.981	0.979
Fuel model 2	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.962	0.953	0.968	0.955	0.960
	F ₁ -score	0.981	0.976	0.984	0.977	0.980
Fuel model 3	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.945	0.954	0.959	0.964	0.965
	F ₁ -score	0.972	0.977	0.979	0.982	0.982
Fuel model 4	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.956	0.956	0.955	0.954	0.957
	F ₁ -score	0.978	0.977	0.977	0.976	0.978
Fuel model 5	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.951	0.941	0.943	0.949	0.949
	F ₁ -score	0.975	0.969	0.971	0.974	0.974
Fuel model 6	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.952	0.960	0.951	0.954	0.964
	F ₁ -score	0.975	0.979	0.975	0.976	0.982
Fuel model 8	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.053	0.019	0.029	0.013	0.016
	F ₁ -score	0.102	0.038	0.056	0.026	0.031
Fuel model 9	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.949	0.928	0.908	0.871	0.854
	F ₁ -score	0.974	0.963	0.952	0.931	0.921
Fuel model 10	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.913	0.906	0.923	0.896	0.885
	F ₁ -score	0.955	0.951	0.960	0.945	0.939

Table S2. Metrics for case no-wind no-slope: live fuel moisture and fuel models.

Case no-wind no-slope	Metric	MF Live 10h 0.05	MF Live 10h 0.10	MF Live 10h 0.15	MF Live 10h 0.20	MF Live 10h 0.25
Fuel model 1	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.947	0.947	0.947	0.947	0.947
	F ₁ -score	0.973	0.973	0.973	0.973	0.973
Fuel model 2	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.966	0.944	0.948	0.952	0.960
	F ₁ -score	0.983	0.971	0.973	0.976	0.980
Fuel model 3	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.951	0.951	0.951	0.951	0.951
	F ₁ -score	0.975	0.975	0.975	0.975	0.975
Fuel model 4	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.936	0.955	0.959	0.954	0.945
	F ₁ -score	0.967	0.977	0.979	0.976	0.972
Fuel model 5	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.963	0.958	0.952	0.918	0.897
	F ₁ -score	0.981	0.978	0.975	0.957	0.946
Fuel model 6	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.956	0.956	0.956	0.956	0.956
	F ₁ -score	0.977	0.977	0.977	0.977	0.977
Fuel model 8	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.039	0.039	0.039	0.039	0.039
	F ₁ -score	0.075	0.075	0.075	0.075	0.075
Fuel model 9	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.935	0.935	0.935	0.935	0.935
	F ₁ -score	0.967	0.967	0.967	0.967	0.967
Fuel model 10	Precision	1.000	1.000	1.000	1.000	0.999
	Recall	0.948	0.940	0.906	0.885	0.815
	F ₁ -score	0.973	0.969	0.951	0.939	0.898

Table S3. Metrics for case slope no-wind: slope and fuel models.

Case slope no-wind	Metric	Slope 0.0 [deg]	Slope 10.0 [deg]	Slope 20.0 [deg]	Slope 30.0 [deg]	Slope 40.0 [deg]
Fuel model 1	Precision	0.999	1.000	1.000	1.000	1.000
	Recall	0.976	0.977	0.991	0.994	0.978
	F ₁ -score	0.987	0.988	0.995	0.997	0.989
Fuel model 2	Precision	0.998	1.000	0.999	1.000	1.000
	Recall	0.935	0.928	0.985	0.987	0.993
	F ₁ -score	0.965	0.963	0.992	0.993	0.996
Fuel model 3	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.973	0.982	0.989	0.994	0.985
	F ₁ -score	0.987	0.991	0.994	0.997	0.992
Fuel model 4	Precision	0.998	0.999	1.000	1.000	1.000
	Recall	0.988	0.980	0.990	0.995	0.994
	F ₁ -score	0.993	0.990	0.995	0.997	0.997
Fuel model 5	Precision	1.000	0.999	1.000	0.999	1.000
	Recall	0.912	0.922	0.969	0.989	0.988
	F ₁ -score	0.954	0.959	0.984	0.994	0.994
Fuel model 6	Precision	0.999	0.997	1.000	0.999	1.000
	Recall	0.943	0.958	0.977	0.988	0.992
	F ₁ -score	0.970	0.977	0.988	0.993	0.996
Fuel model 8	Precision	1.000	1.000	1.000	0.989	0.998
	Recall	0.077	0.103	0.238	0.772	0.844
	F ₁ -score	0.143	0.186	0.385	0.867	0.915
Fuel model 9	Precision	1.000	1.000	0.997	1.000	0.999
	Recall	0.844	0.673	0.882	0.942	0.973
	F ₁ -score	0.915	0.805	0.936	0.970	0.986
Fuel model 10	Precision	0.986	1.000	0.998	0.998	0.997
	Recall	0.930	0.715	0.873	0.958	0.975
	F ₁ -score	0.957	0.834	0.932	0.978	0.986

Table S4. Case wind no-slope: wind speed at 10 m and fuel models.

Case wind no-slope	Metric	Wind Speed 0.0 [m s ⁻¹]	Wind Speed 2.0 [m s ⁻¹]	Wind Speed 4.0 [m s ⁻¹]	Wind Speed 6.0 [m s ⁻¹]	Wind Speed 8.0 [m s ⁻¹]
Fuel model 1	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.983	0.988	0.994	0.989	0.965
	F ₁ -score	0.992	0.994	0.997	0.994	0.982
Fuel model 2	Precision	1.000	0.999	1.000	1.000	1.000
	Recall	0.935	0.967	0.985	0.989	0.995
	F ₁ -score	0.967	0.983	0.992	0.995	0.997
Fuel model 3	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.977	0.991	0.990	0.977	0.953
	F ₁ -score	0.988	0.995	0.995	0.989	0.976
Fuel model 4	Precision	0.998	1.000	1.000	1.000	1.000
	Recall	0.987	0.992	0.994	0.989	0.969
	F ₁ -score	0.993	0.996	0.997	0.994	0.984
Fuel model 5	Precision	1.000	0.998	1.000	1.000	1.000
	Recall	0.918	0.982	0.985	0.992	0.995
	F ₁ -score	0.957	0.990	0.992	0.996	0.997
Fuel model 6	Precision	0.998	0.999	1.000	1.000	1.000
	Recall	0.958	0.981	0.986	0.991	0.996
	F ₁ -score	0.978	0.990	0.993	0.995	0.998
Fuel model 8	Precision	1.000	1.000	1.000	0.994	1.000
	Recall	0.077	0.079	0.550	0.755	0.786
	F ₁ -score	0.143	0.147	0.710	0.859	0.880
Fuel model 9	Precision	1.000	0.984	0.999	0.997	0.997
	Recall	0.849	0.762	0.878	0.961	0.972
	F ₁ -score	0.918	0.859	0.935	0.978	0.984
Fuel model 10	Precision	0.997	0.999	1.000	1.000	0.998
	Recall	0.879	0.802	0.938	0.960	0.977
	F ₁ -score	0.935	0.890	0.968	0.979	0.987

Table S5. Case cross-slope wind: wind speed and direction.

Case cross-slope wind	Metric	Wind Speed 2.0 [m s ⁻¹]	Wind Speed 4.0 [m s ⁻¹]	Wind Speed 6.0 [m s ⁻¹]	Wind Speed 8.0 [m s ⁻¹]	Wind Speed 10.0 [m s ⁻¹]
Wind Dir 0.0 [deg]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.990	0.994	0.990	0.995	0.993
	F ₁ -score	0.995	0.997	0.995	0.997	0.997
Wind Dir 45.0 [deg]	Precision	0.999	1.000	1.000	1.000	1.000
	Recall	0.993	0.991	0.994	0.997	0.995
	F ₁ -score	0.996	0.996	0.997	0.998	0.997
Wind Dir 90.0 [deg]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.989	0.994	0.990	0.995	0.994
	F ₁ -score	0.995	0.997	0.995	0.998	0.997
Wind Dir 135.0 [deg]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.988	0.994	0.995	0.994	0.997
	F ₁ -score	0.994	0.997	0.997	0.997	0.998
Wind Dir 180.0 [deg]	Precision	1.000	0.999	1.000	1.000	1.000
	Recall	0.985	0.990	0.993	0.994	0.996
	F ₁ -score	0.992	0.995	0.997	0.997	0.998
Wind Dir 225.0 [deg]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.959	0.983	0.993	0.992	0.995
	F ₁ -score	0.979	0.991	0.996	0.996	0.997
Wind Dir 270.0 [deg]	Precision	0.999	0.999	1.000	1.000	1.000
	Recall	0.986	0.991	0.994	0.994	0.996
	F ₁ -score	0.993	0.995	0.997	0.997	0.998
Wind Dir 315.0 [deg]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.988	0.994	0.996	0.994	0.997
	F ₁ -score	0.994	0.997	0.998	0.997	0.998

Table S6. Case cross-slope wind: aspect and wind direction.

Case cross-slope wind	Metric	Aspect 60.0 [deg]	Aspect 120.0 [deg]	Aspect 180.0 [deg]	Aspect 240.0 [deg]	Aspect 300.0 [deg]
Wind Dir 60.0 [deg]	Precision	1.000	1.000	0.999	0.999	1.000
	Recall	0.988	0.988	0.988	0.986	0.989
	F ₁ -score	0.994	0.994	0.993	0.993	0.994
Wind Dir 120.0 [deg]	Precision	1.000	1.000	1.000	1.000	0.999
	Recall	0.988	0.988	0.986	0.988	0.986
	F ₁ -score	0.994	0.994	0.994	0.994	0.992
Wind Dir 180.0 [deg]	Precision	1.000	1.000	1.000	1.000	0.999
	Recall	0.988	0.988	0.986	0.988	0.986
	F ₁ -score	0.994	0.994	0.992	0.992	0.994
Wind Dir 240.0 [deg]	Precision	0.999	1.000	1.000	1.000	1.000
	Recall	0.985	0.988	0.988	0.989	0.988
	F ₁ -score	0.992	0.994	0.994	0.994	0.994
Wind Dir 300.0 [deg]	Precision	1.000	0.999	0.999	1.000	1.000
	Recall	0.988	0.987	0.987	0.988	0.988
	F ₁ -score	0.994	0.993	0.994	0.994	0.994

Table S7. Metrics for case downslope wind: slope and wind speed.

Case downslope wind	Metric	Slope 0.0 [deg]	Slope 10.0 [deg]	Slope 20.0 [deg]	Slope 30.0 [deg]	Slope 40.0 [deg]
Wind Speed 0.0 [m s ⁻¹]	Precision	0.998	1.000	0.999	1.000	1.000
	Recall	0.936	0.927	0.984	0.989	0.994
	F ₁ -score	0.966	0.962	0.991	0.994	0.997
Wind Speed 2.0 [m s ⁻¹]	Precision	0.999	0.998	0.997	0.999	1.000
	Recall	0.965	0.975	0.982	0.988	0.991
	F ₁ -score	0.982	0.987	0.989	0.993	0.995
Wind Speed 4.0 [m s ⁻¹]	Precision	1.000	0.999	1.000	1.000	1.000
	Recall	0.985	0.990	0.971	0.959	0.988
	F ₁ -score	0.992	0.994	0.985	0.979	0.994
Wind Speed 6.0 [m s ⁻¹]	Precision	1.000	1.000	1.000	1.000	0.998
	Recall	0.989	0.993	0.984	0.982	0.981
	F ₁ -score	0.995	0.996	0.992	0.991	0.989
Wind Speed 8.0 [m s ⁻¹]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.995	0.994	0.995	0.993	0.986
	F ₁ -score	0.997	0.997	0.997	0.996	0.993
Wind Speed 10.0 [m s ⁻¹]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.997	0.994	0.996	0.994	0.994
	F ₁ -score	0.998	0.997	0.998	0.997	0.997

Table S8. Case cross-slope wind: slope and wind direction.

Case cross-slope wind	Metric	Slope 0.0 [deg]	Slope 10.0 [deg]	Slope 20.0 [deg]	Slope 30.0 [deg]	Slope 40.0 [deg]
Wind Dir 0.0 [deg]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.977	0.973	0.986	0.989	0.994
	F ₁ -score	0.988	0.986	0.993	0.994	0.997
Wind Dir 45.0 [deg]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.973	0.986	0.985	0.988	0.995
	F ₁ -score	0.986	0.993	0.992	0.994	0.997
Wind Dir 90.0 [deg]	Precision	1.000	1.000	1.000	1.000	1.000
	Recall	0.977	0.973	0.987	0.989	0.993
	F ₁ -score	0.988	0.986	0.994	0.995	0.996
Wind Dir 135.0 [deg]	Precision	1.000	0.997	0.999	1.000	1.000
	Recall	0.973	0.992	0.987	0.988	0.990
	F ₁ -score	0.986	0.995	0.993	0.994	0.995
Wind Dir 180.0 [deg]	Precision	1.000	0.998	0.999	0.999	1.000
	Recall	0.977	0.984	0.980	0.989	0.993
	F ₁ -score	0.988	0.991	0.989	0.994	0.996
Wind Dir 225.0 [deg]	Precision	1.000	1.000	1.000	0.999	1.000
	Recall	0.972	0.973	0.945	0.985	0.988
	F ₁ -score	0.985	0.986	0.971	0.992	0.994
Wind Dir 270.0 [deg]	Precision	1.000	0.998	0.999	0.999	1.000
	Recall	0.977	0.984	0.981	0.991	0.993
	F ₁ -score	0.988	0.991	0.990	0.995	0.996
Wind Dir 315.0 [deg]	Precision	1.000	0.998	0.999	1.000	1.000
	Recall	0.974	0.991	0.988	0.987	0.991
	F ₁ -score	0.987	0.995	0.993	0.994	0.995

Supplementary Figures S1-S7.

Figure S1. Case no-wind no-slope: dead fuel moisture and fuel models. Input variables: dead fuel moisture fraction varies from 0.05 to 0.25; live fuel moisture fraction is 1; fuel models are referred to Rothermel (1972) and Anderson (1982). Simulation parameters: 1 m spatial resolution; 20 epochs of 6 min length.

Figure S2. Case no-wind no-slope: live fuel moisture and fuel models. Input variables: dead fuel moisture fraction is 0.05; live fuel moisture fraction varies from 0.5 to 2.5; fuel models are referred to Rothermel (1972) and Anderson (1982). Simulation parameters: 1 m spatial resolution; 20 epochs of 6 min length.

Figure S3. Case slope no-wind: slope and fuel models. Input variables: dead fuel moisture fraction is 0.05; live fuel moisture fraction is 1; slope varies between 0 and 40 degrees; aspect is 45 degrees azimuthal; fuel models are referred to Rothermel (1972) and Anderson (1982). Simulation parameters: 1 m spatial resolution; 10 epochs of 3 min length.

Figure S4. Case wind no-slope: wind speed at 10 m and fuel models. Input variables: dead fuel moisture fraction is 0.05; live fuel moisture fraction is 1; wind speed at 10 m varies between 0 and 8 m s⁻¹; wind direction is 45 degrees azimuthal; fuel models are referred to Rothermel (1972) and Anderson (1982). Simulation parameters: 1 m spatial resolution; 10 epochs of 3 min length.

Figure S5. Case cross-slope wind: wind speed and direction. Input variables: dead fuel moisture fraction is 0.05; live fuel moisture fraction is 1; wind speed at 10 m varies between 2 and 10 m s⁻¹; wind direction varies between 0 and 315 degrees azimuthal; slope is 30 degrees; aspect is 45 degrees azimuthal; fuel model 2 (Rothermel 1972; Anderson 1982). Simulation parameters: 1 m spatial resolution; 10 epochs of 3 min length.

Figure S6. Case cross-slope wind: aspect and wind direction. Input variables: dead fuel moisture fraction is 0.05; live fuel moisture fraction is 1; wind speed at 10 m is 3 m s⁻¹; wind direction varies between 0 and 300 degrees azimuthal; slope is 30 degrees; aspect is 45 degrees azimuthal; fuel model 2 (Rothermel 1972; Anderson 1982). Simulation parameters: 1 m spatial resolution; 10 epochs of 3 min length.

Figure S7. Case downslope wind: slope and wind speed. Input variables: dead fuel moisture fraction is 0.05; live fuel moisture fraction is 1; wind speed at 10 m varies between is 0 and 10 m s⁻¹; wind direction is 45 degrees azimuthal; slope varies between 0 and 40 degrees; aspect is 45 degrees azimuthal; fuel model 2 (Rothermel 1972; Anderson 1982). Simulation parameters: 1 m spatial resolution; 10 epochs of 3 min length.













