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KOREA UNIVERSITY

Integrating Human Domain Knowledge into Artificial Intelligence for Hybrid Forest Fire Prediction

: Case Studies from South Korea and Italy

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Postdoctoral Fellowship

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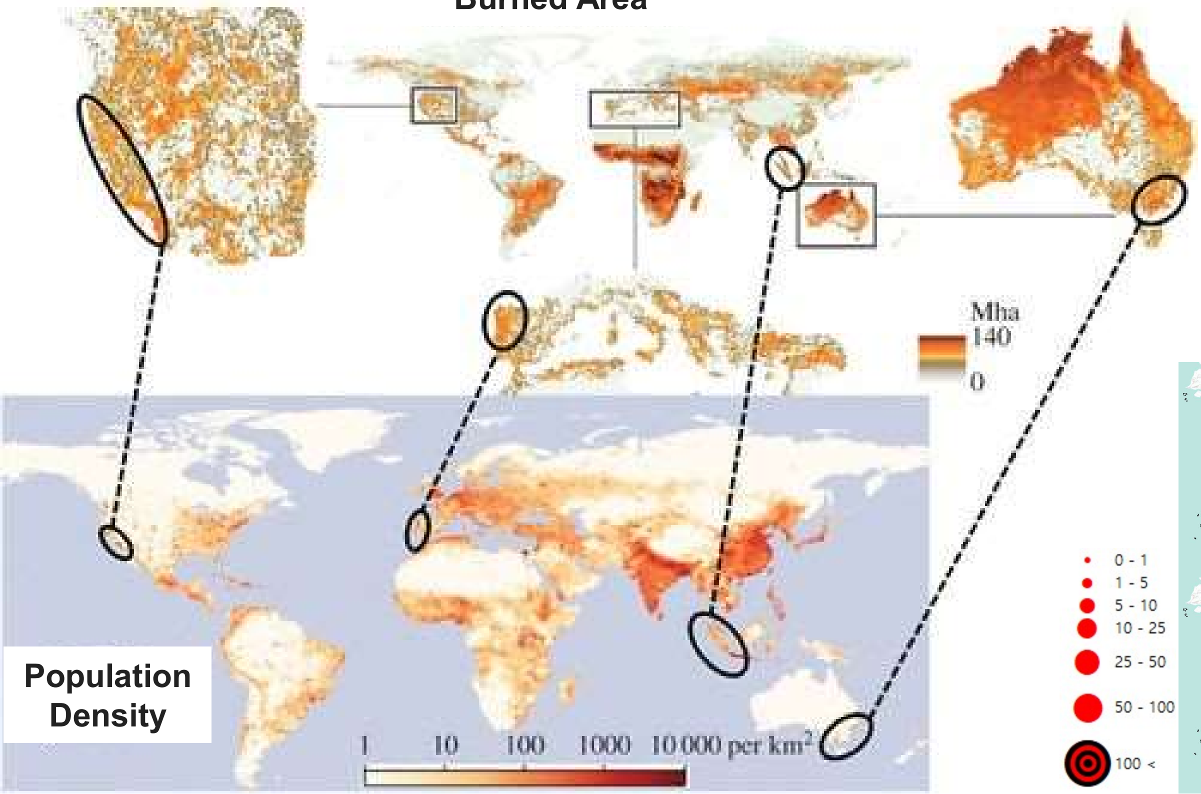
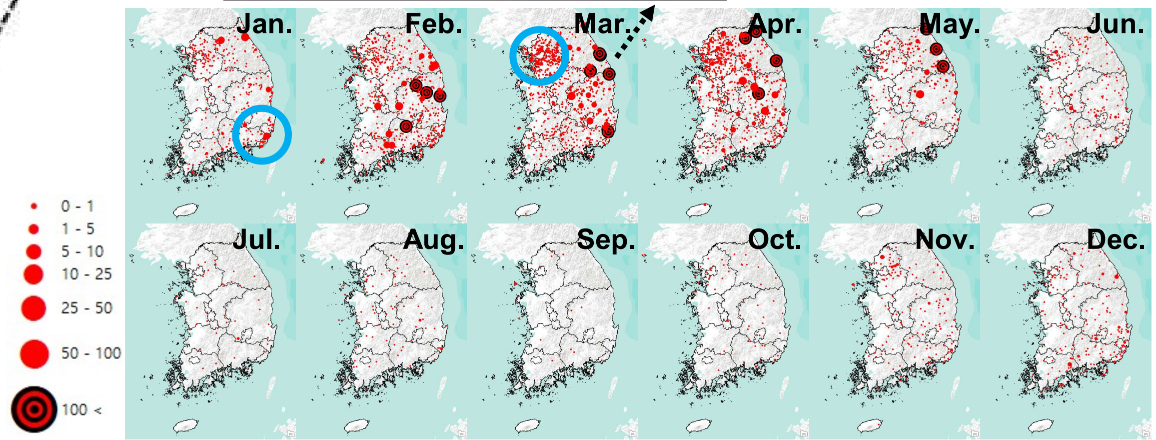
Forest Fire Dynamics
Interplay of Biophysical and Anthropogenic Factors

Burned Area



Doerr, S. H., & Santín, C. (2016)



Forest Fires in South Korea (2016.01-2022.03)

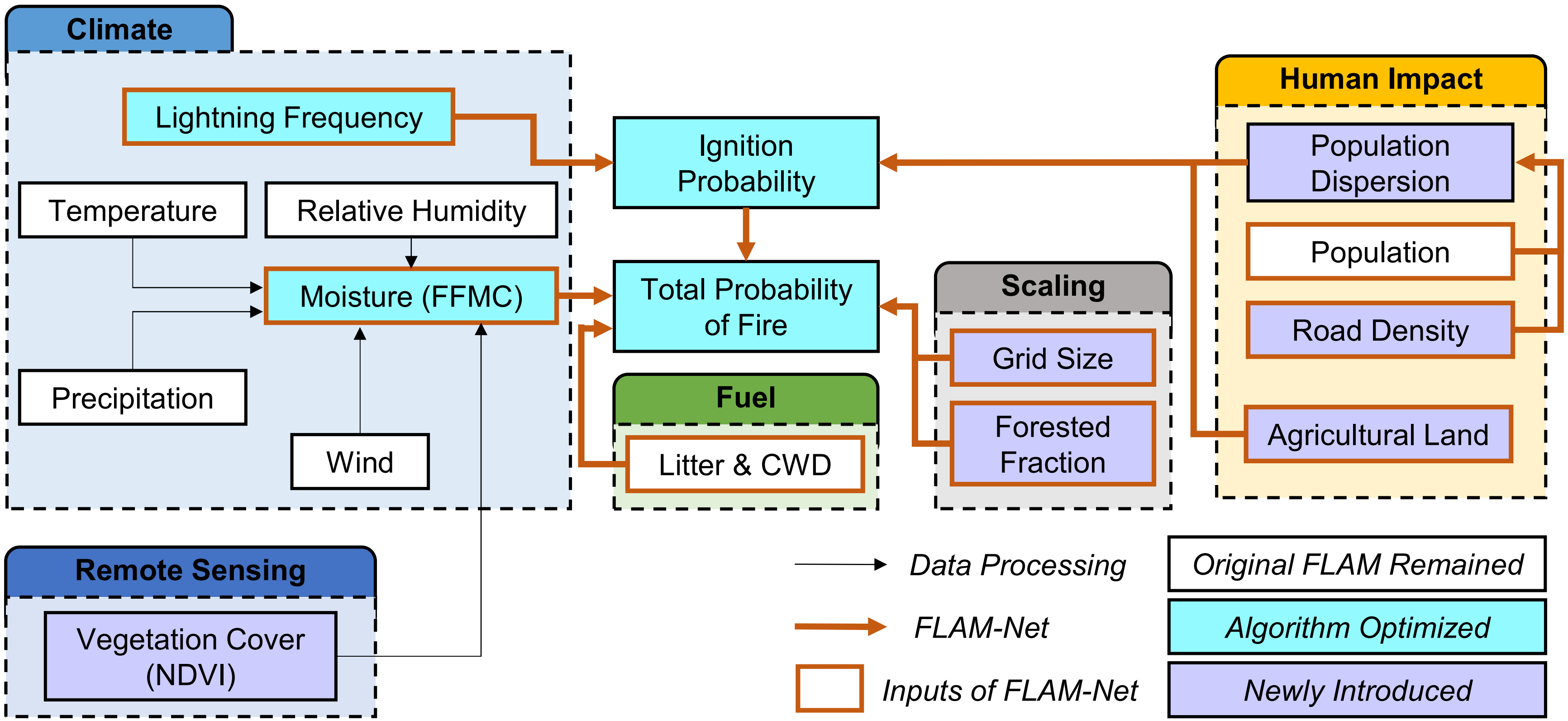
Comparison of Modelling Methods
Process-Based Model & Machine Learning

	Process-Based Model	>>> Hybrid <<< Machine Learning
Pros	• Already structured and guided by human knowledge. • Predictable for unseen dataset	• Powerful tool for solving complex problems • Efficient at optimization by its nature of end-to-end learning
Cons	• Decreasing performance when the problem is too complex for modeling • Setting appropriate parameters is time-consuming	• Need large amount of data for training • Unpredictable for unseen dataset

Transferring Human Knowledge into Artificial Intelligence

Model generalization *Training efficiency* *Interpretability*

Transferring IIASA's Forest Fire Model (FLAM) into the Neural Networks (FLAM-Net)



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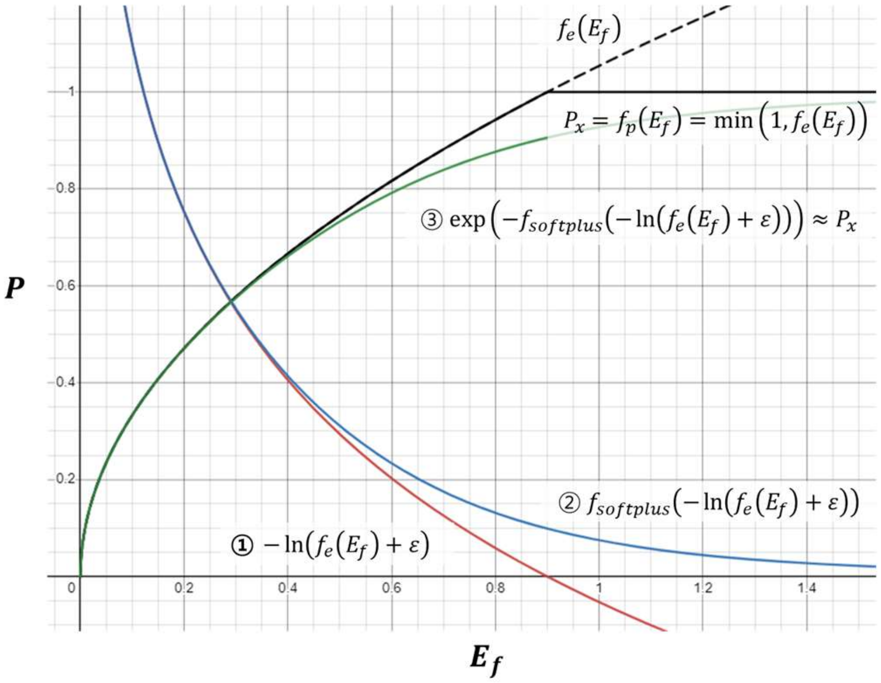
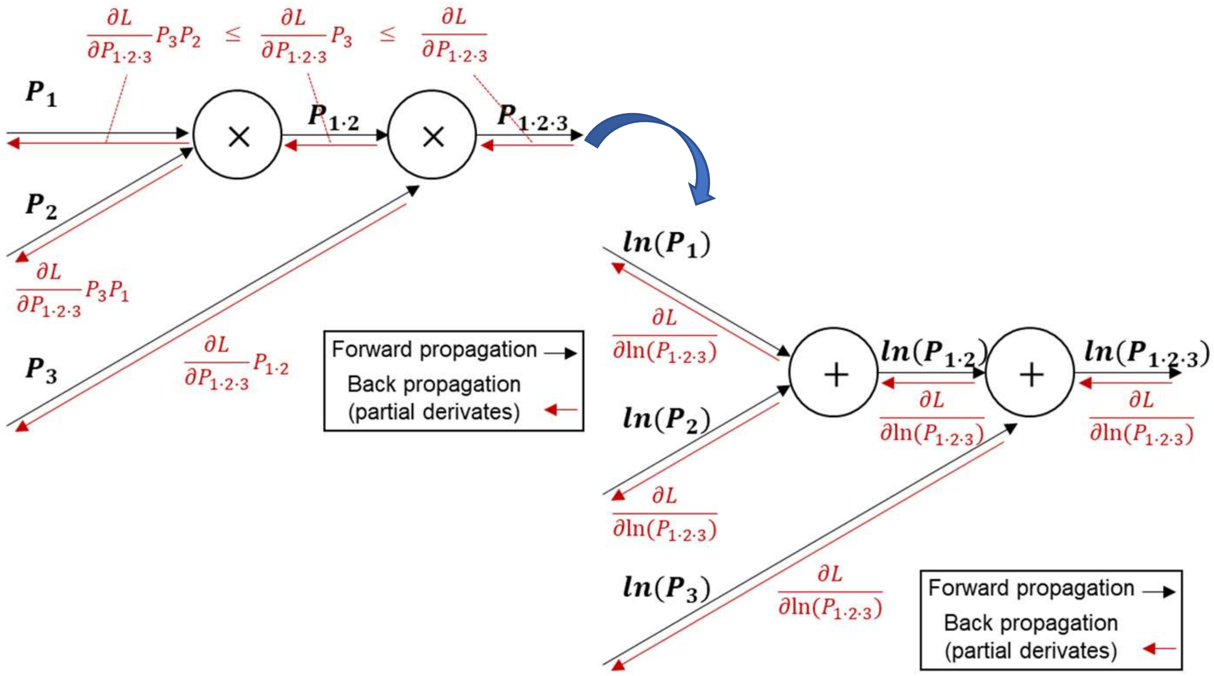
Preserving Gradients

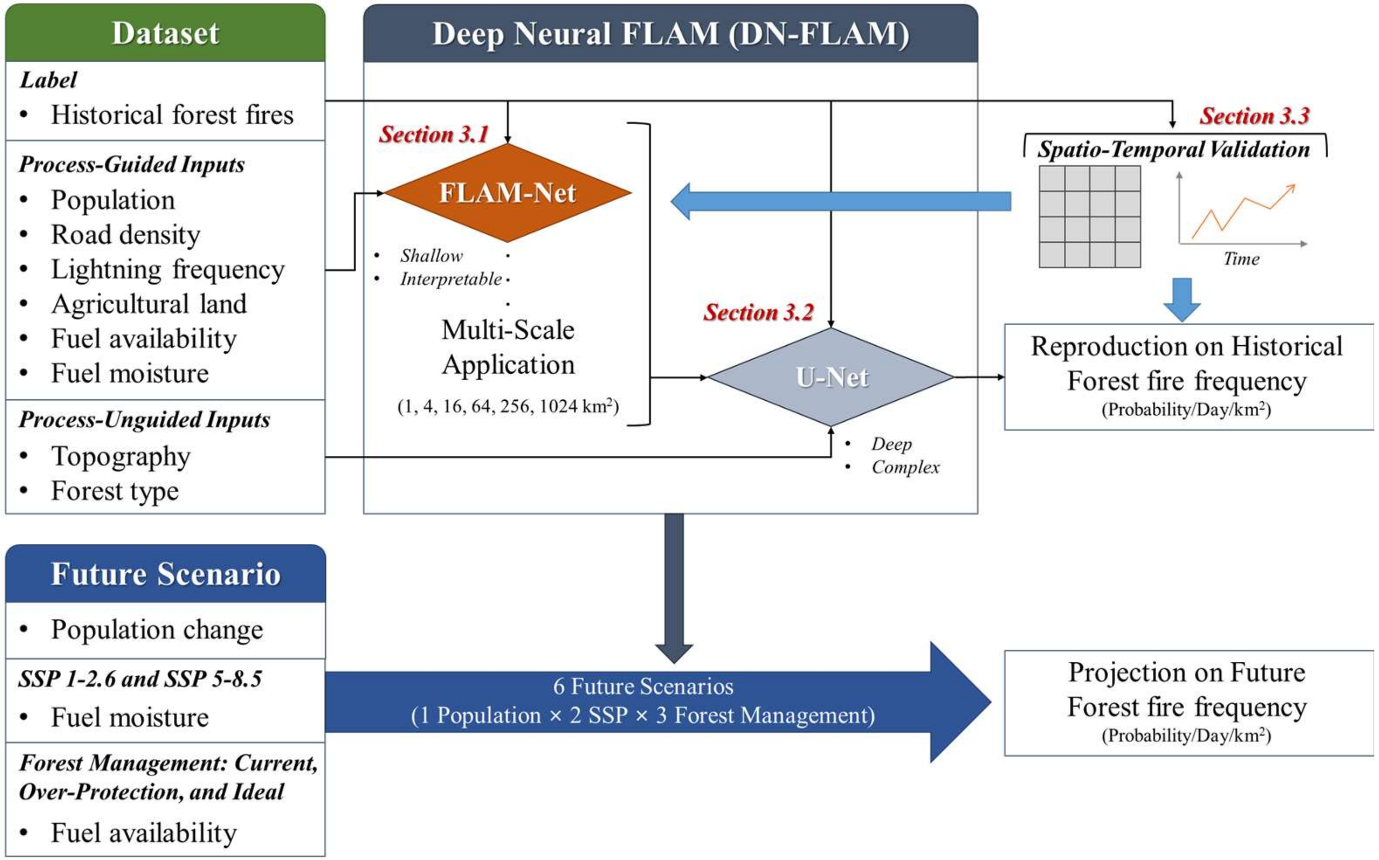


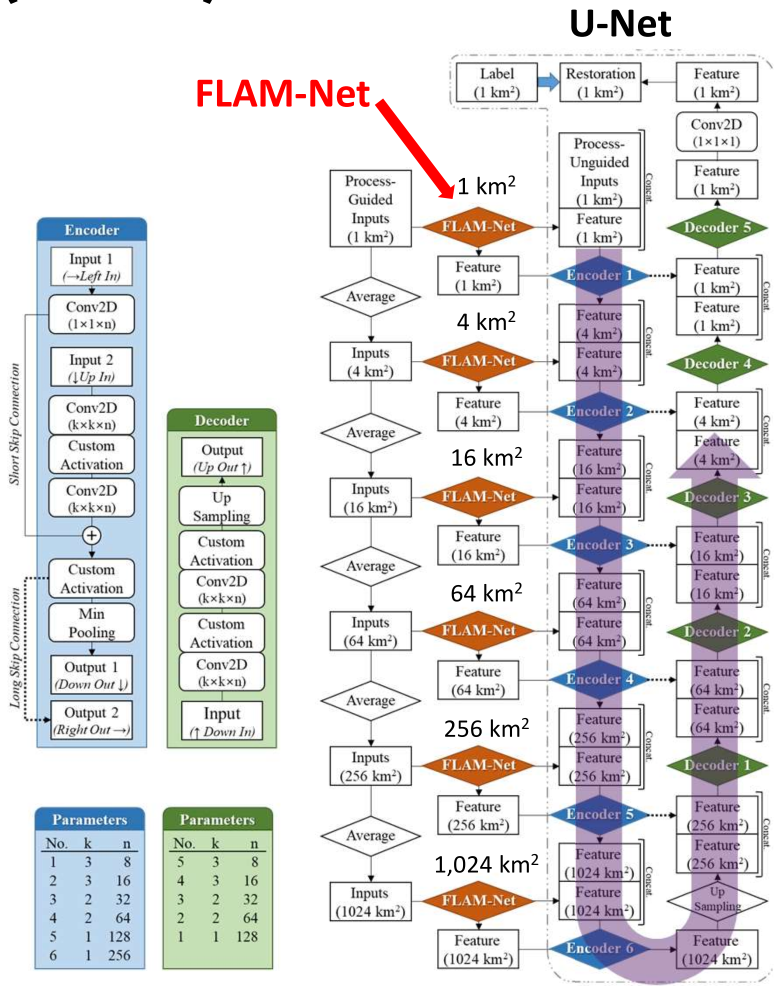
Log-Transformation on Probabilities



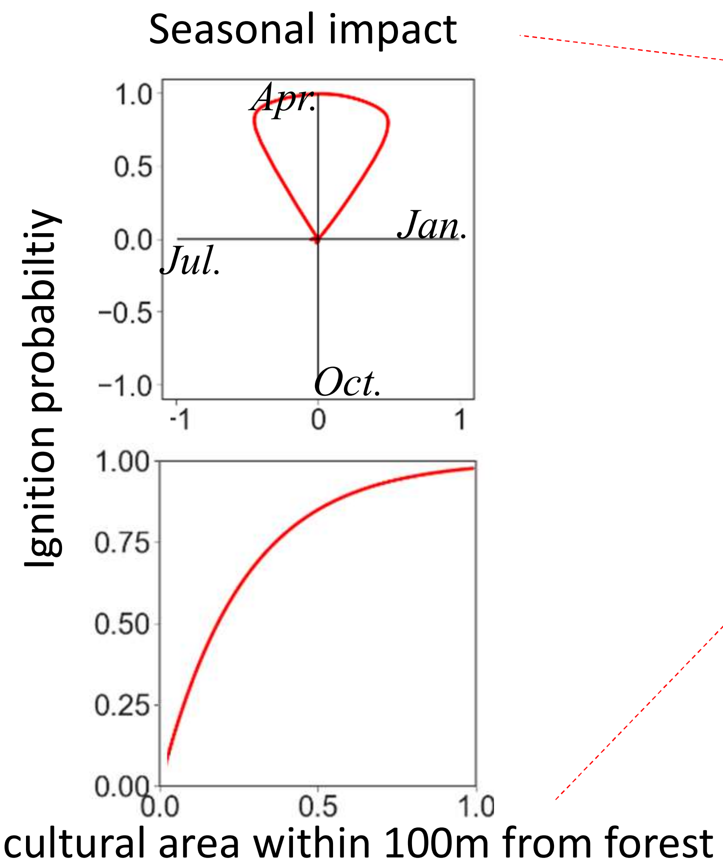
Log-transformation allows for expressing very small number, which has advantage on modeling disaster probability

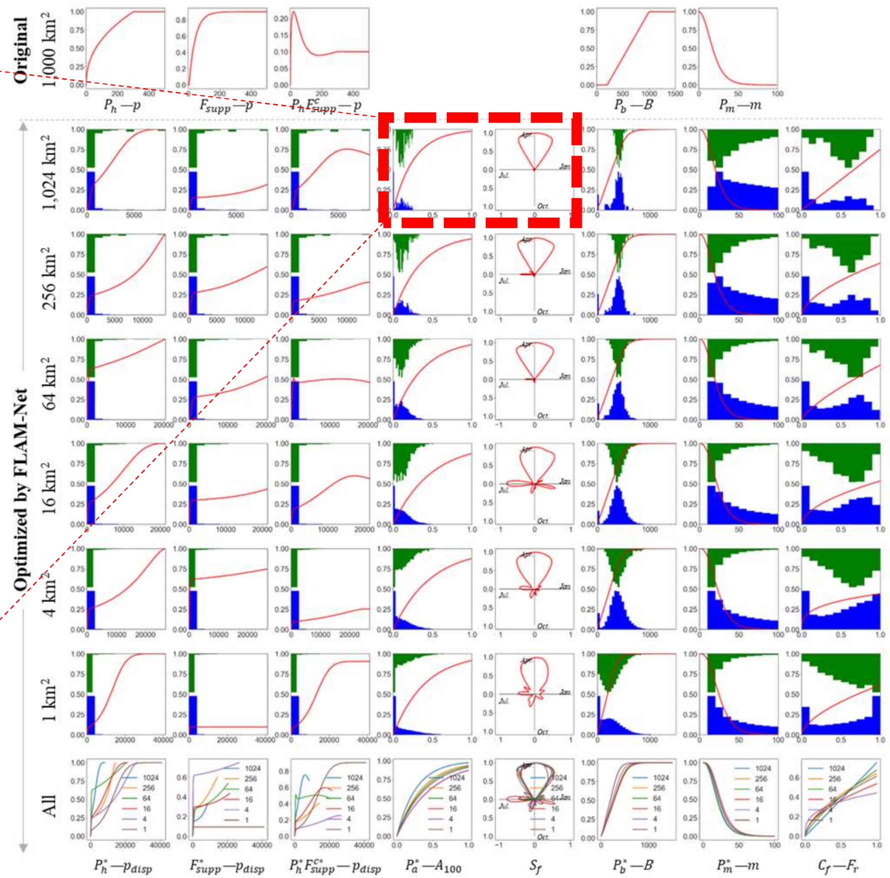
Transferring IIASA's Forest Fire Model (FLAM) into the Neural Networks (FLAM-Net)



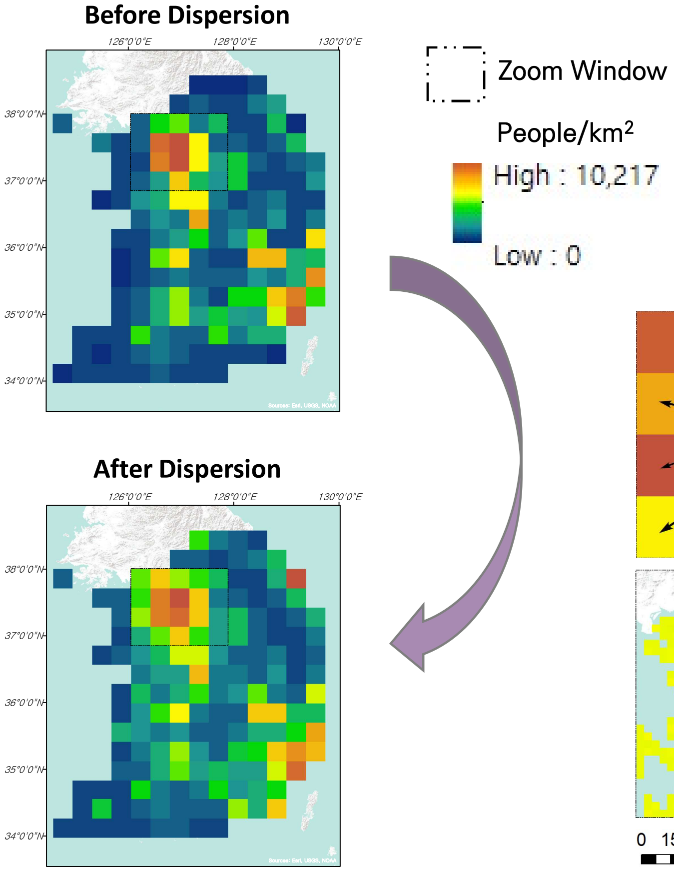


Parameter Optimization Results
Interpreting Biophysical & Anthropogenic Factors





Parameter Optimization Results
Interpreting Biophysical & Anthropogenic Factors

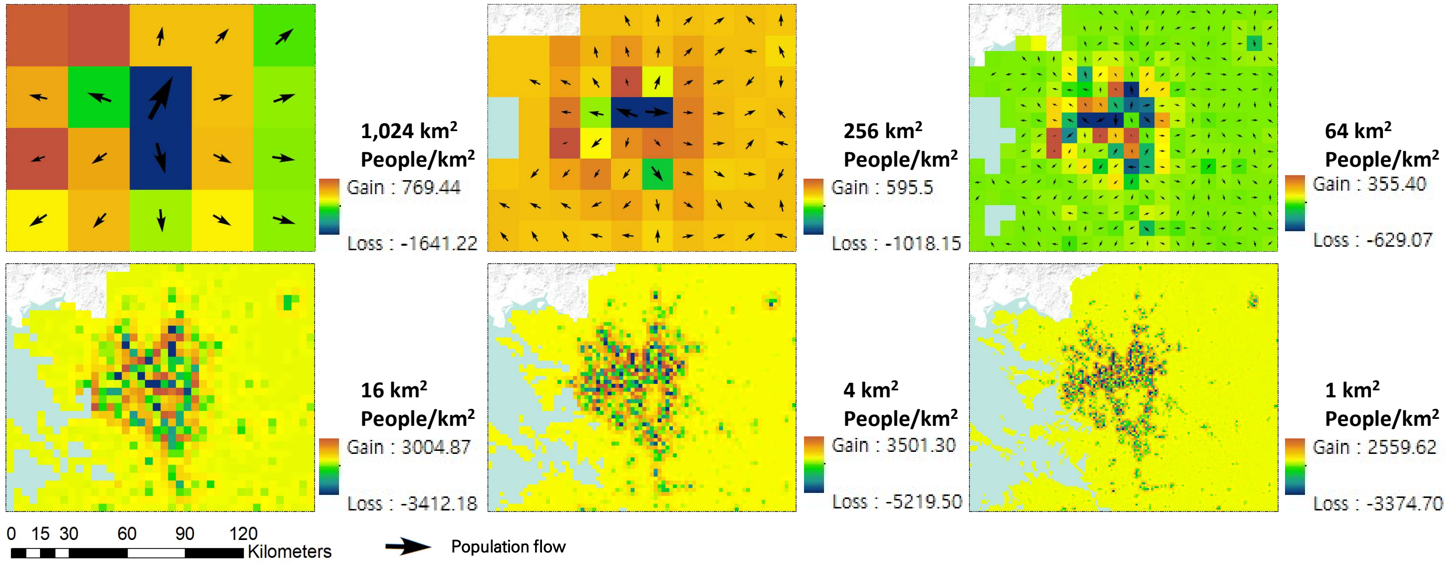


- Population dispersed from city center to the outskirts

→ Creating forest fire hotspots near metropolitan cities

- Dispersion rapidly decreases by distance

→ Needs further algorithm advancement by incorporating networks analysis



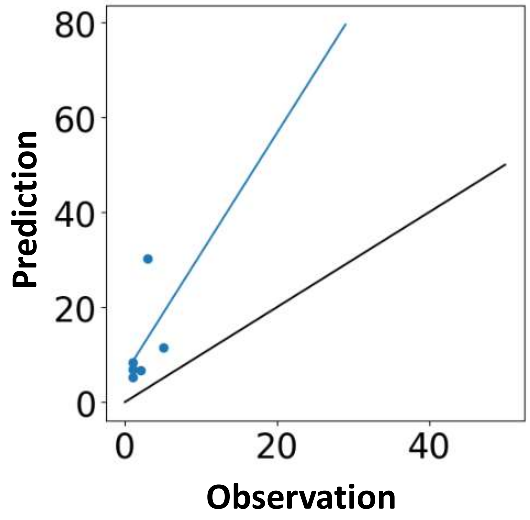
Month-Wise Validation

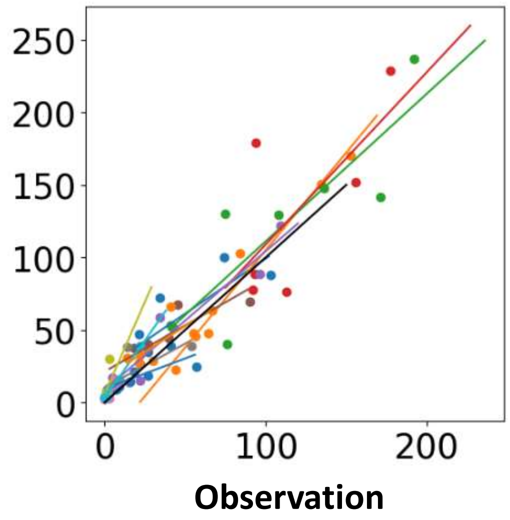
Pearson’s r

Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
0.789	0.986	0.854	0.694	0.959	0.871	0.726	0.785	0.431	0.987	0.757	0.698	0.795

There is a strong seasonal pattern of frequent forest fire in spring.
Does it merely reproduce this pattern?
Or able to differentiate among the same seasonality

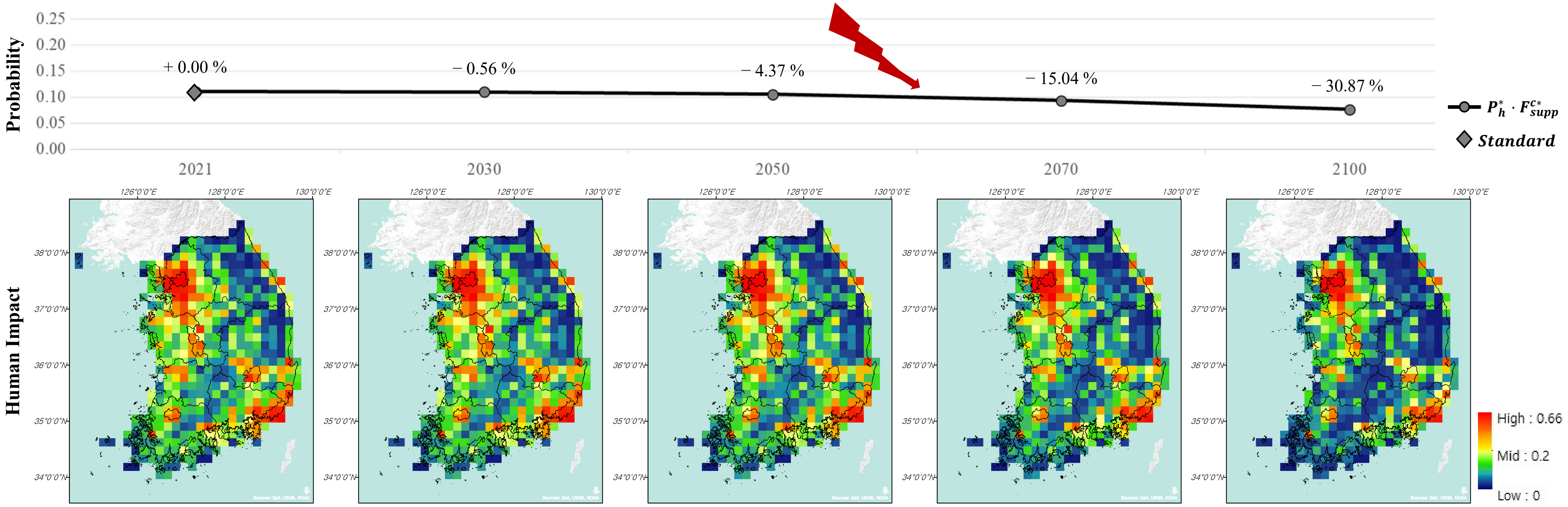
Overall high month-wise Pearson's r
Only 17 fire events observed over 6-year in September (smallest among the months)



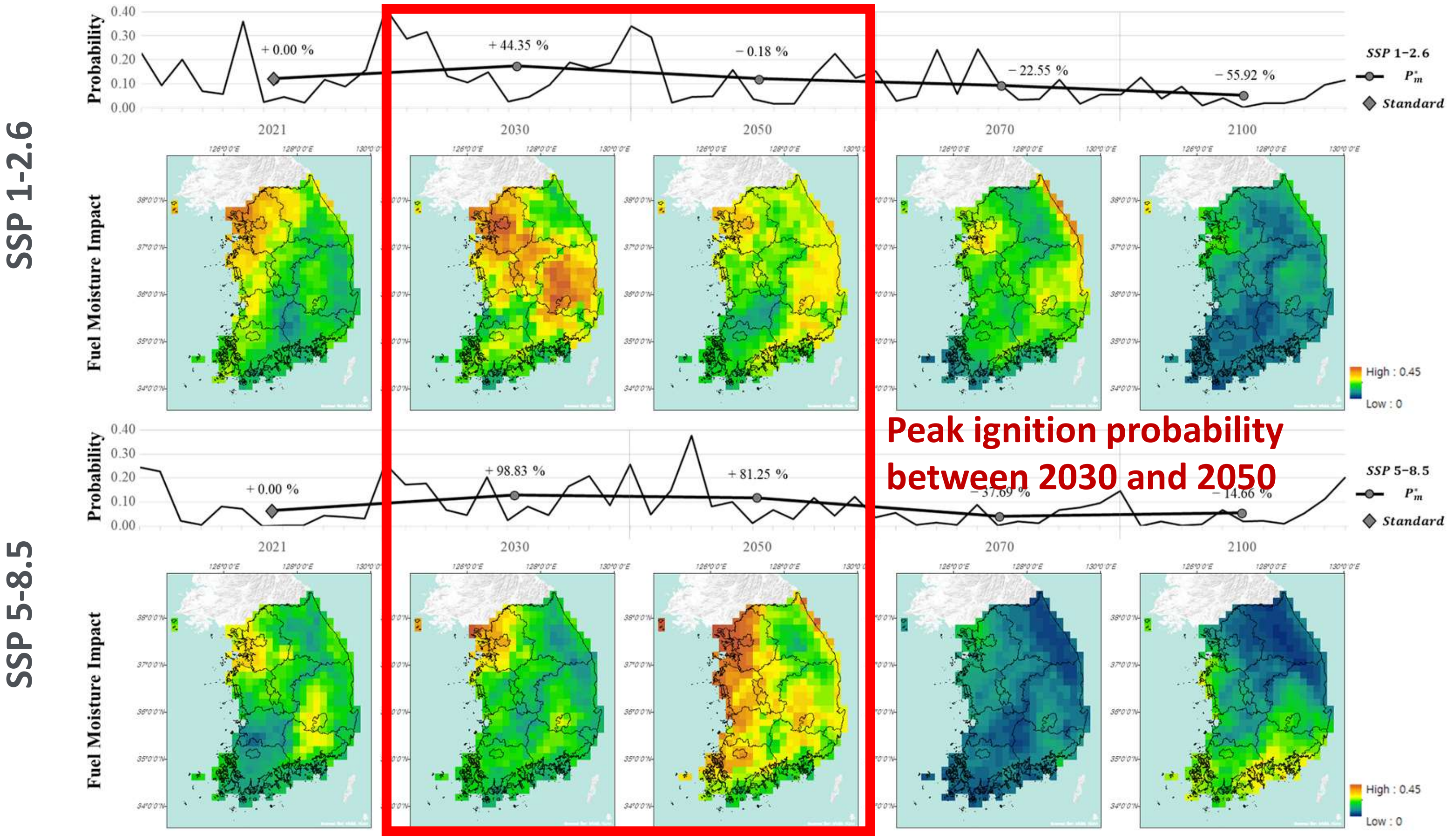


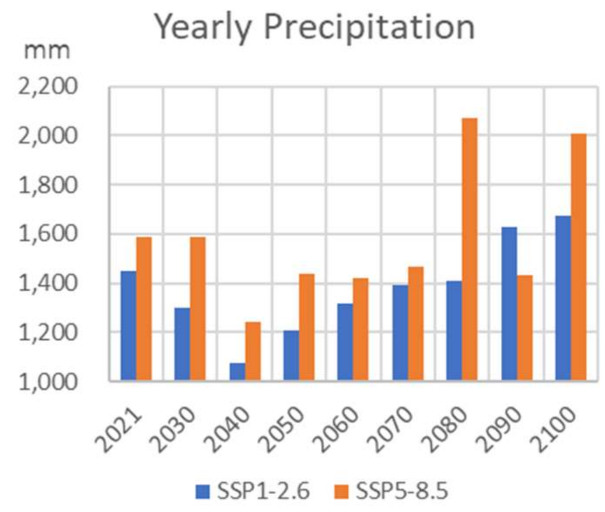
Future Projection
Impact of Population Density

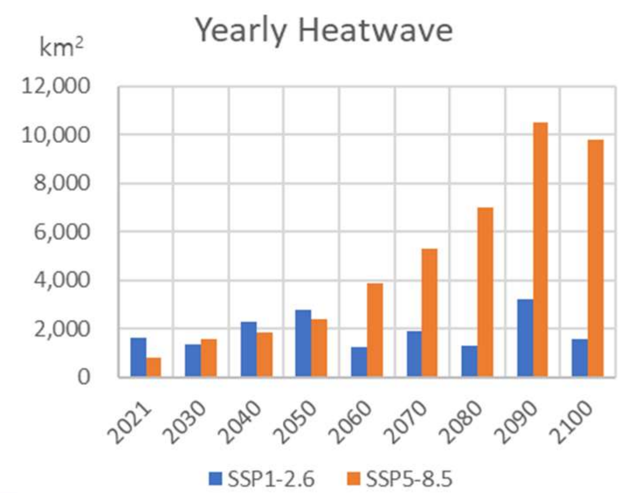
Rapidly decreasing population after 2050, while hotspots keep formed near metropolitan cities



Future Projection
Impact of Fuel Moisture (Climate Change)







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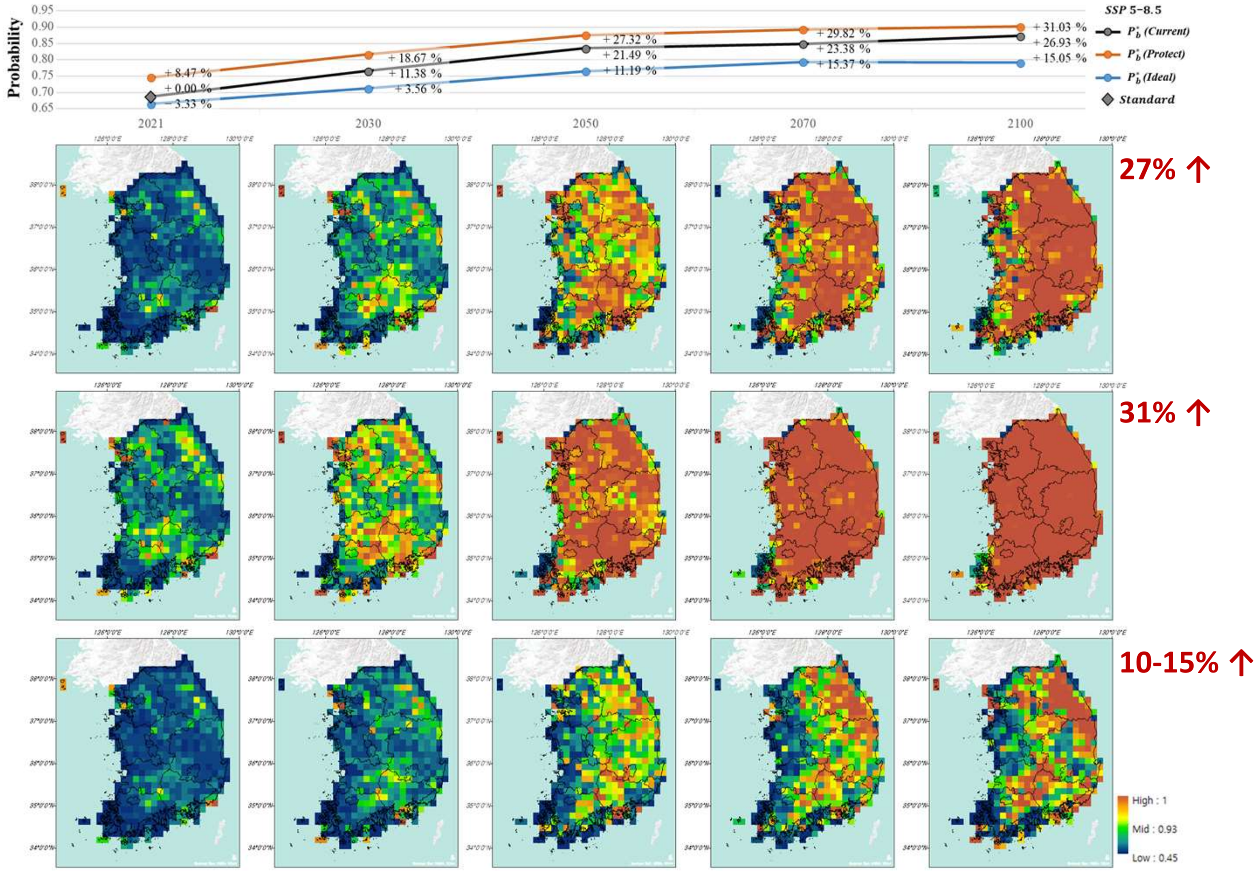
Future Projection
Impact of Fuel Load (Forest Management)

SSP 5-8.5



Current Management

- Clear-cut of 15,000 ha per year (legal final cutting age)
- Thinning practices at a rate of 30% of AGB across 165,000 ha per year

No Management

- No clear-cut
- No thinning practices

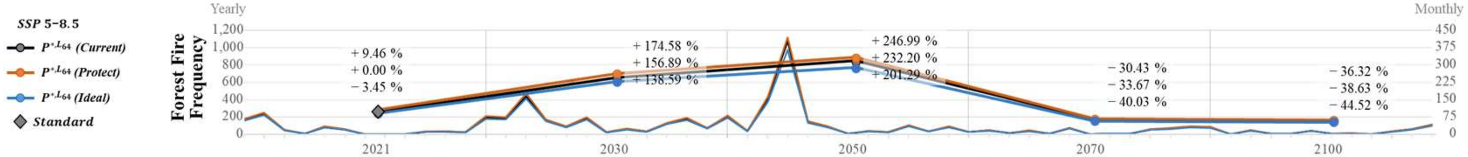
National Management Plan (6th) in the Future

- Clear-cut of 35,000 ha per year
- Thinning practices at a rate of 30% of AGB across 165,000 ha per year

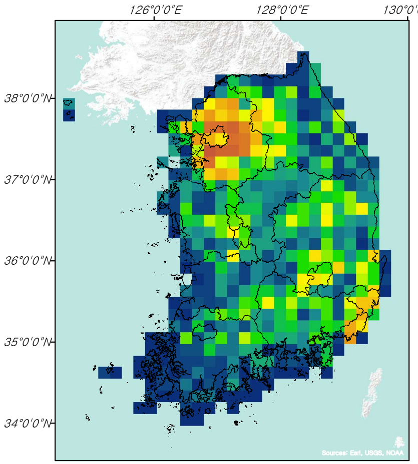
Future Projection on Fire Frequency

Peak fire frequency between 2030 and 2050

SSP 5-8.5



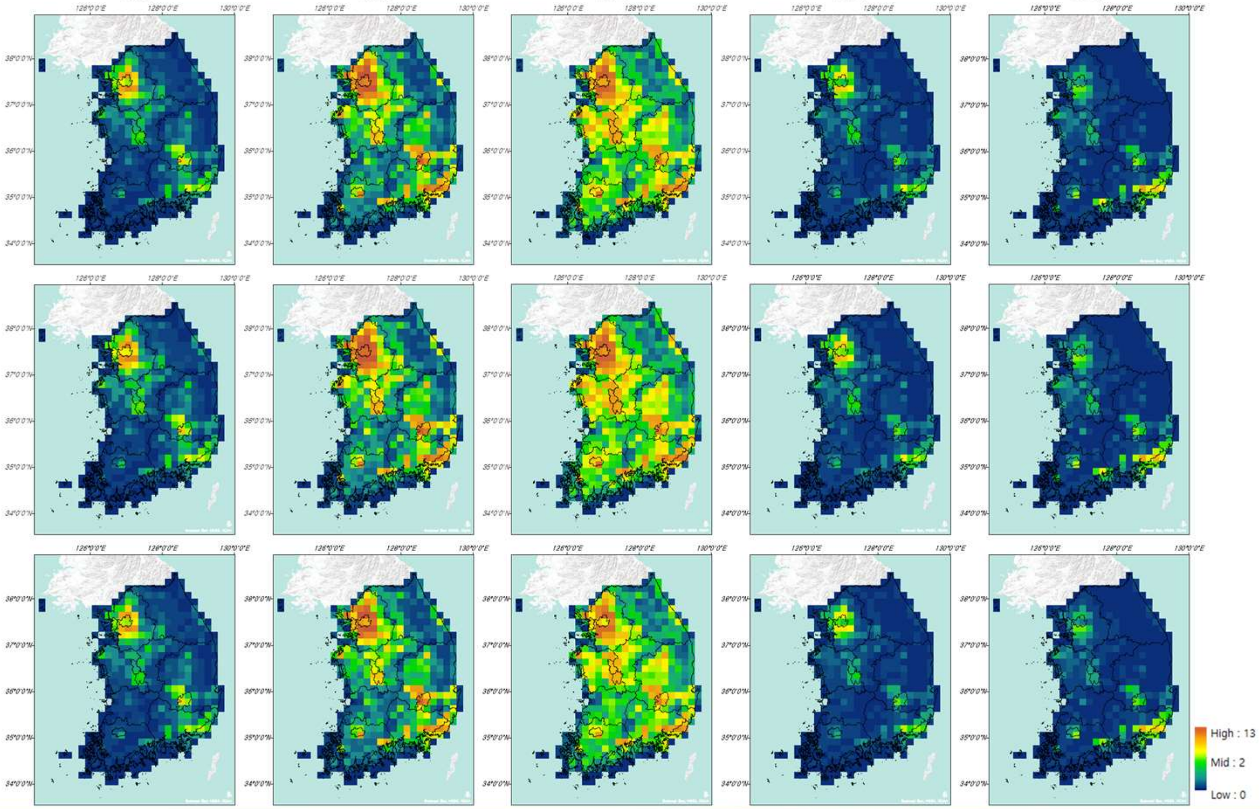
Historical



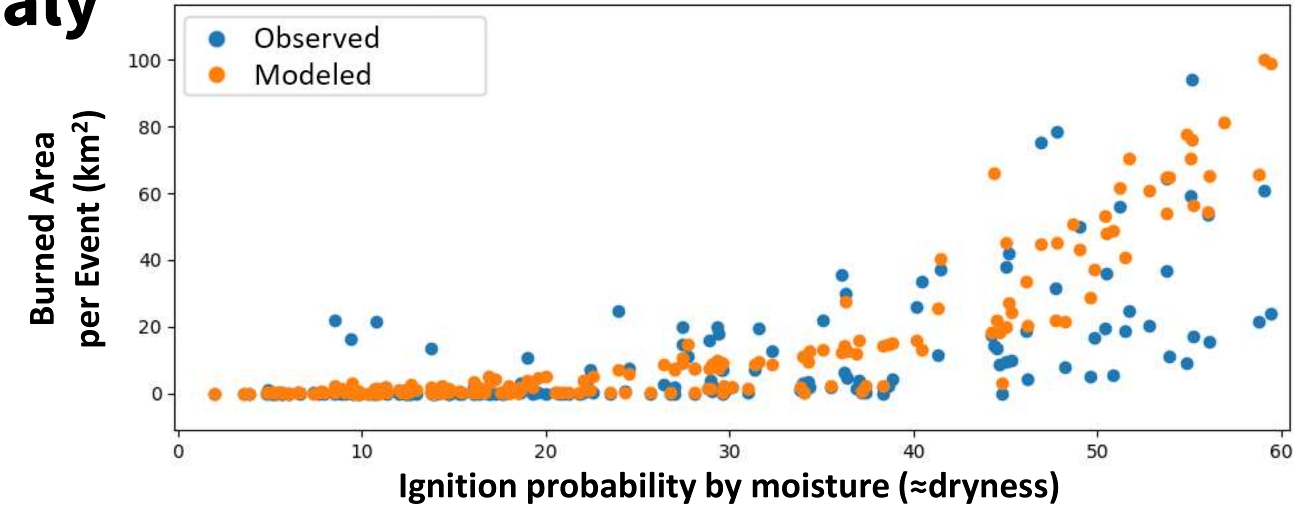
Current Management

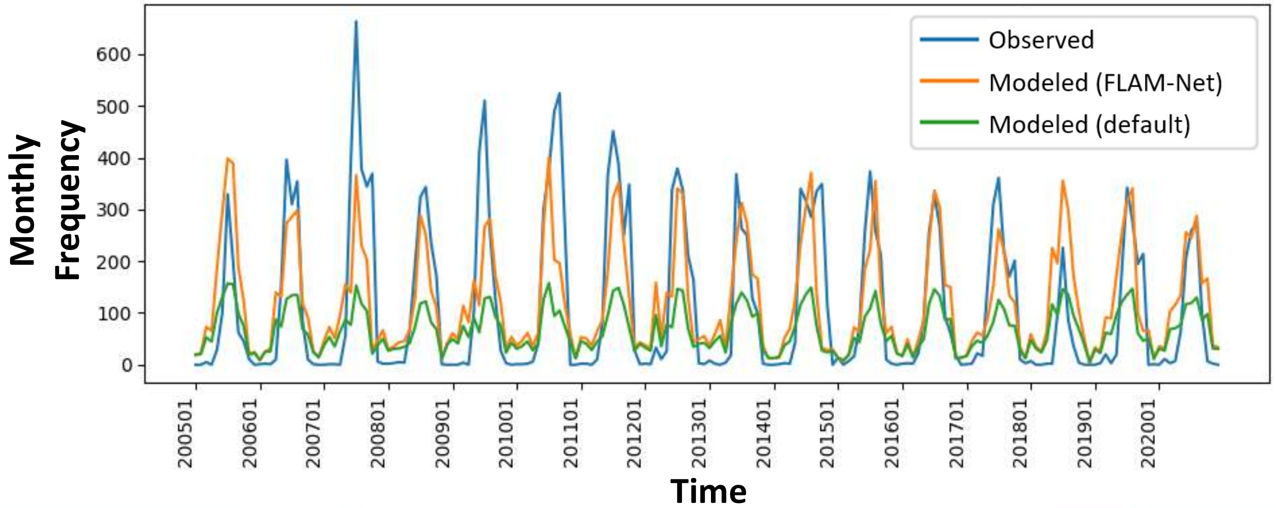
No Management

National Management Plan (6th)



The Case of Sardinia, Italy





Conclusion

IIASA's FLAM incorporates process-based algorithms for interpreting biophysical and anthropogenic factors affecting forest fires.

FLAM-Net effectively integrates FLAM processes into a machine-learning framework, augmented with additional algorithms tailored to national contexts.
i.e. agricultural burning and its seasonal patterns, as well as a diverse range of fire hotspots near metropolitan cities in South Korea.

The optimization of FLAM-Net yields interpretable insights into future fire frequency*, while enhancing its applicability through end-to-end optimization capabilities.
*** FLAM includes algorithms for estimating burned area, while FLAM-Net was examined only for frequency.**

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Thank you.

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