



A review of Machine Learning Applications in Wildfire Science & Management

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Why do a review?

- What has been done and what methods were used?
- Do ML methods work better than other methods and for what tasks?
- Can we make use of existing success stories here in Canada?
- Identify gaps and challenges
- Find opportunities for future research



Our review

- Scoping review methodology (Arksey & O'Malley, 2005)
 - map out literature on research area
- Search Google and Scopus databases
- Additional referenced papers
- Include only journal papers and conference proceedings*
- Synthesize results



What is Machine Learning?

- [Implementation]

“A **computer program** is said to **learn** from experience E with respect to **some set of tasks** T and performance measure P if its performance at tasks in T , as measured by P , improves with experience E .”

Tim Mitchell, Machine Learning, 1997

- [Outcomes]

“Detect patterns in data, use the uncovered patterns to predict future data or other outcomes of interest”

Kevin Murphy, Machine Learning: A Probabilistic Perspective, 2012



The lay of the land...

Tree based methods

- Single trees (CART)
- Random Forest
- Boosted Regression trees
- Other ensemble methods

Neural networks

- Shallow networks
- Self-organizing maps
- CNN/Deep Learning
- NeuroFuzzy models

Reward based

- Reinforcement learning
- Genetic algorithms

Bayesian methods

- Bayesian networks
- Naive Bayes
- Maximum Entropy

Other

- K-means
- Support vector machine
- K-nearest neighbors
- + more



Data analytics & wildfires

eg. Fire Mapping,
Fuels characterization,
Impacts

Descriptive
What happened?

eg. controls on fire,
Fire Ecology

Diagnostic
Why did it happen?

Predictive
What will happen?

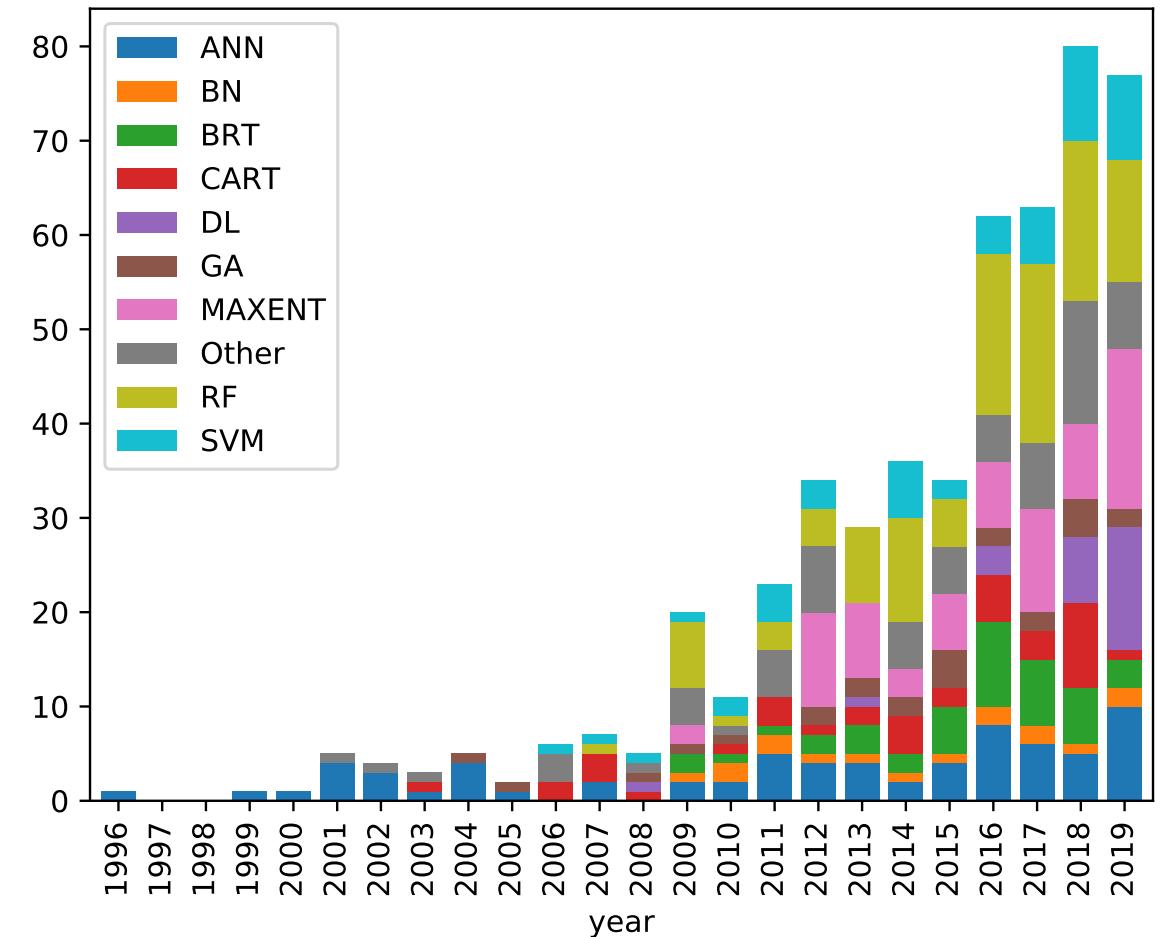
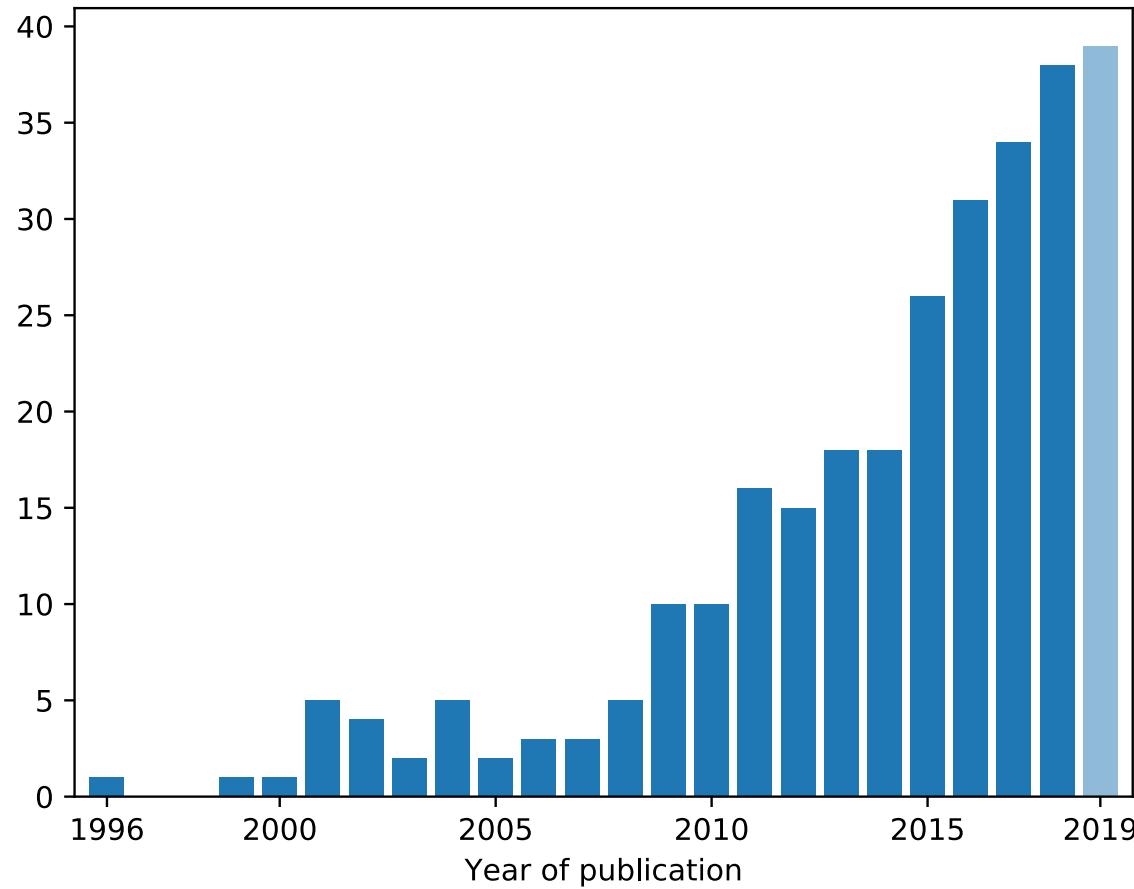
eg. Fire Susceptibility Mapping,
Fire Occurrence Prediction,
Fire Behaviour Prediction

Prescriptive
What do we do?

eg. Fire Management:
Policy and planning
Preparedness and Response
Fuels treatment



Review summary (currently 285 papers)



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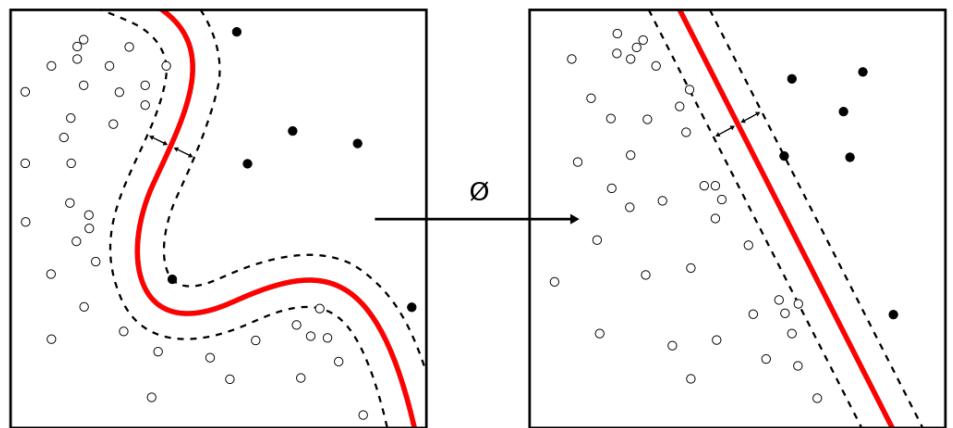
1. Fuels Characterization, Fire Detection And Mapping: 61 papers
2. Fire Weather And Climate Change: 20 papers
3. Fire Occurrence, Susceptibility and Risk: 123 papers
4. Fire Behaviour Prediction: 41 papers
5. Fire Effects: 33 papers
6. Fire Management: 14 papers



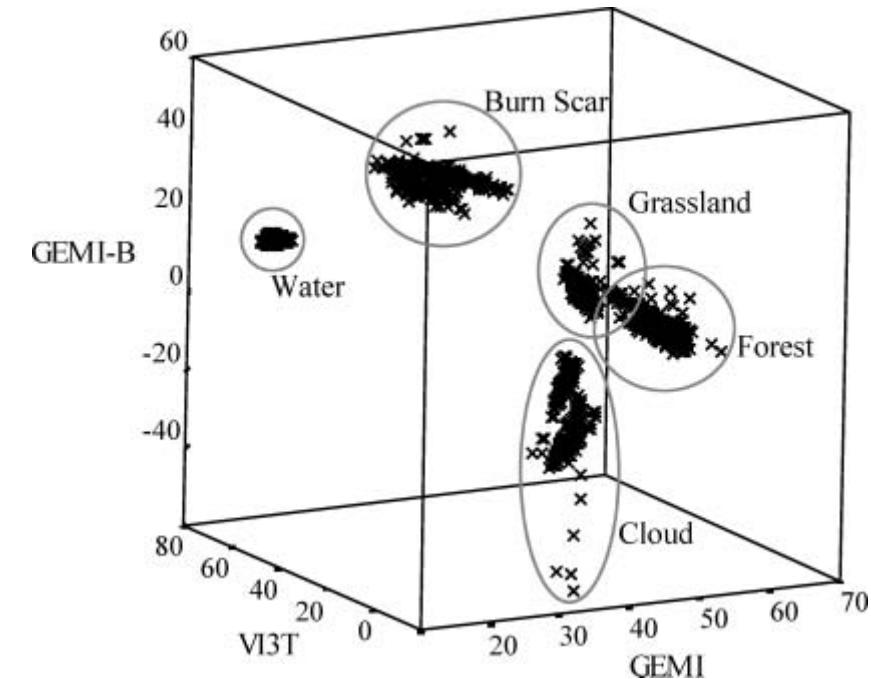
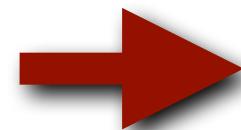
Section	Domain	BN	KM	CART	BRT	ANN	SVM	GA	EDT	KNN	MAXENT	DL	RF	Other
1.1	Fuels characterization	-	-	1	1	1	2	-	-	1	-	-	4	-
1.2	Fire detection	1	1	-	-	10	1	1	-	-	-	15	-	6
1.3	Fire mapping	-	1	1	1	6	11	-	2	1	1	1	1	7
2.1	Fire weather prediction	-	1	-	-	-	-	-	-	-	-	-	1	3
2.2	Lightning prediction	-	-	1	-	-	-	-	-	-	-	-	2	-
2.3	Climate change	-	-	2	5	2	1	-	1	-	7	1	5	-
3.1	Fire occurrence prediction	1	-	1	-	7	3	-	2	1	2	1	5	1
3.2	Landscape	-	1	1	-	1	1	-	-	-	1	2	2	1
3.3	Fire Susceptibility Mapping	2	1	8	8	16	12	3	1	-	27	1	26	6
3.4	Landscape controls on fire	2	1	14	19	10	10	3	1	1	30	1	37	4
4.1	Fire Spread and Growth	2	-	-	-	5	-	13	-	1	-	2	1	2
4.2	Burned area and fire severity prediction	1	-	6	1	8	7	1	-	2	-	1	5	7
5.1	Soil erosion and deposits	-	1	-	-	1	-	-	-	-	1	-	1	-
5.2	Smoke and particulate levels	-	-	-	-	1	1	-	1	-	-	-	3	3
5.3	Post-fire regeneration and ecology	-	-	2	5	1	1	1	-	-	1	-	11	2
5.4	Impacts on people and animals	2	-	1	-	-	-	-	-	-	1	-	-	-
6.1	Planning and policy	1	-	-	-	-	-	1	-	-	-	2	-	1
6.2	Fuel treatment	1	-	-	-	-	-	1	-	-	-	-	-	1
6.3	Wildfire preparedness and response	2	-	-	1	1	-	1	-	-	1	-	-	-
6.4	Social factors	1	-	-	-	-	-	-	-	-	-	-	-	-

Fire mapping with SVM (11 papers)

https://commons.wikimedia.org/wiki/File:Kernel_Machine.svg



eg. Bioinformatics,
face detection



Cao et al. (2009). An automatic method for burn scar mapping using support vector machines. International Journal of Remote Sensing, 30(3), 577–594

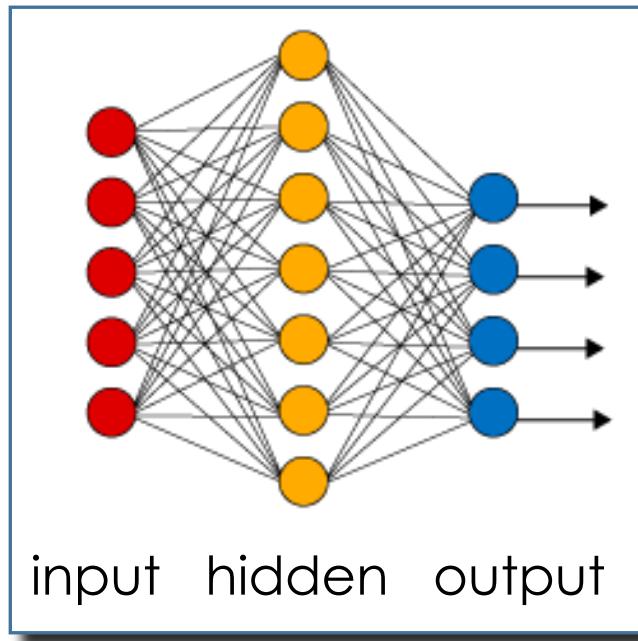


Natural Resources
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Ressources naturelles
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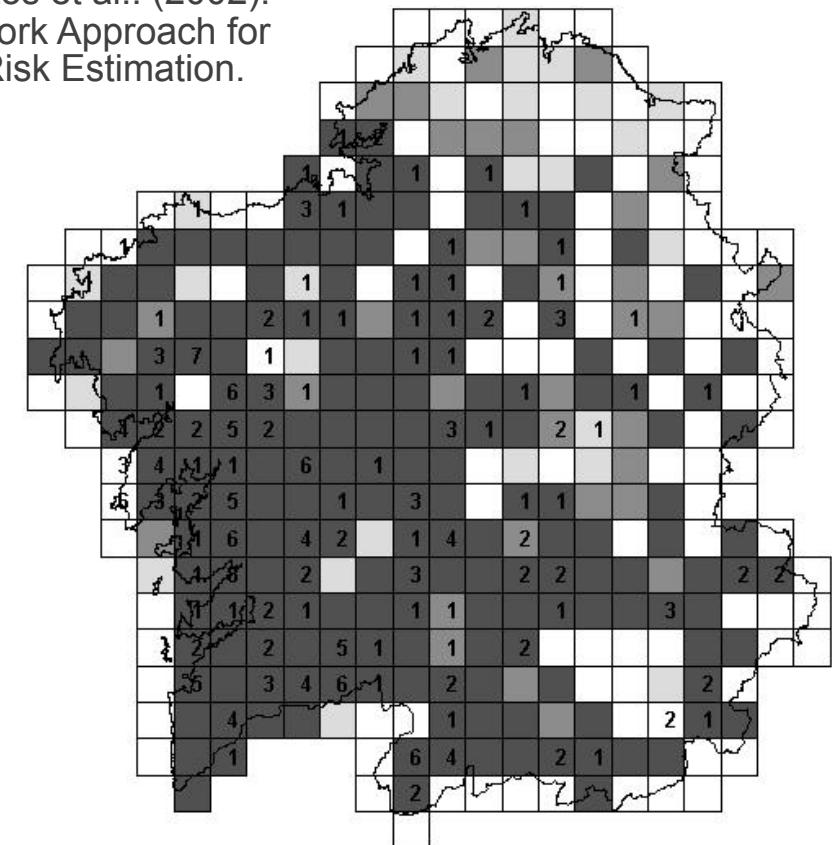
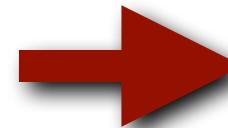
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Fire occurrence prediction with ANN (7 papers)



eg. Handwriting recognition, Medical diagnosis

Alonso-Betanzos et al.. (2002).
A Neural Network Approach for
Forestal Fire Risk Estimation.

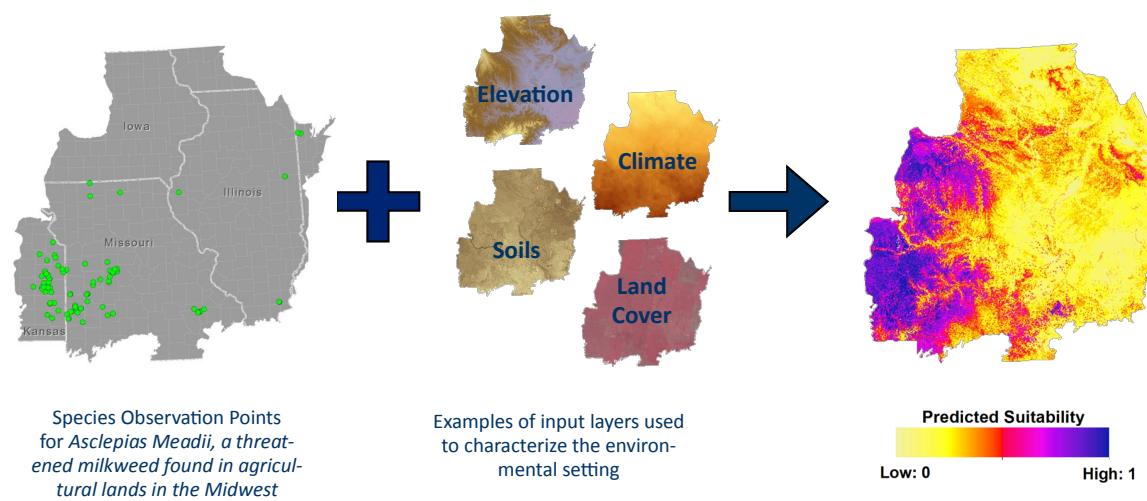


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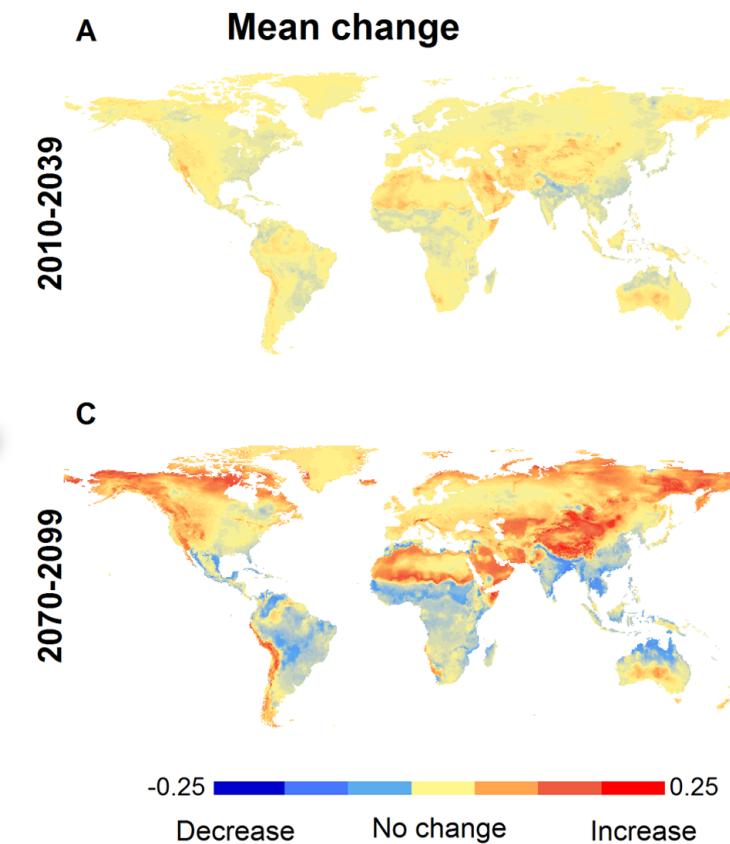
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Fire susceptibility mapping with Maximum Entropy (27 papers)



<https://www.natureserve.org/conservation-tools/species-distribution-modeling>

eg. Used in species distribution modelling,
statistical mechanics (physics)



Moritz et al, (2012). Climate change and disruptions to global fire activity. *Ecosphere*, 3(6)

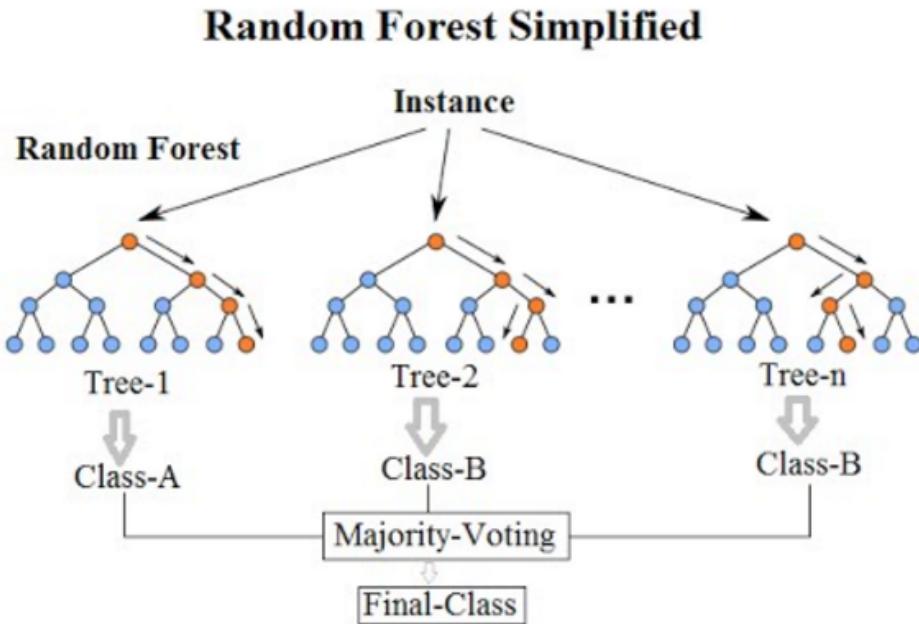


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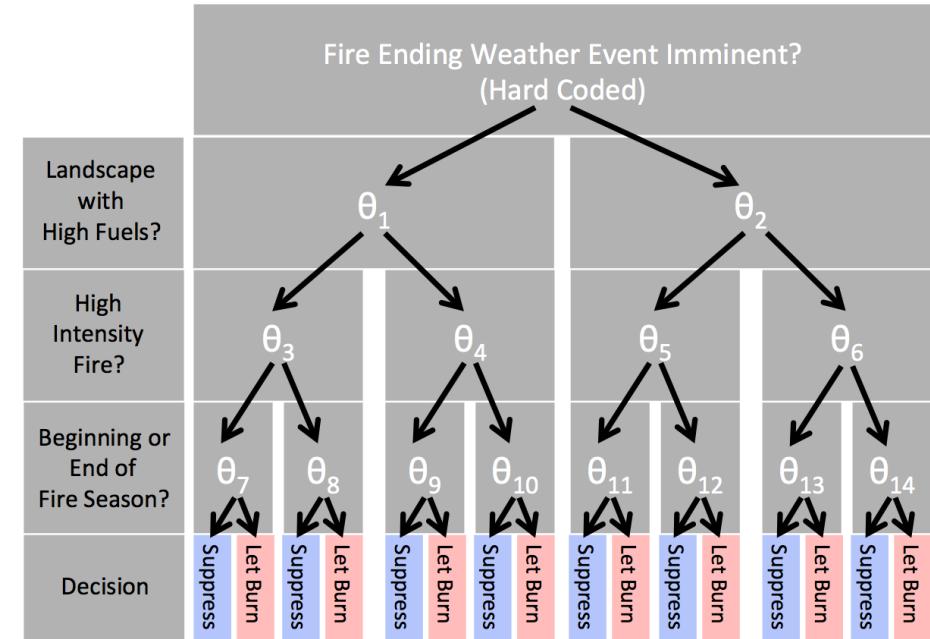
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Fire Management with Random Forests (2 papers)



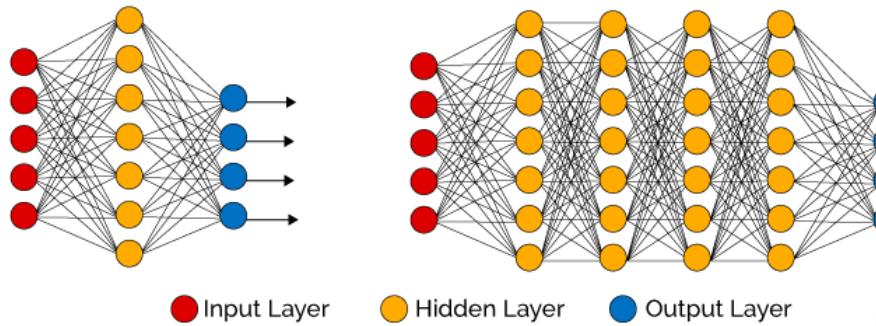
eg. Fraud detection, drug development,
recommender systems



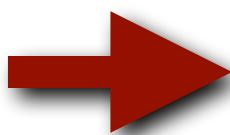
McGregor et al. (2017). Fast Optimization of Wildfire Suppression Policies with SMAC. <http://arxiv.org/abs/1703.09391>

Fire spread with Deep Learning (2 papers)

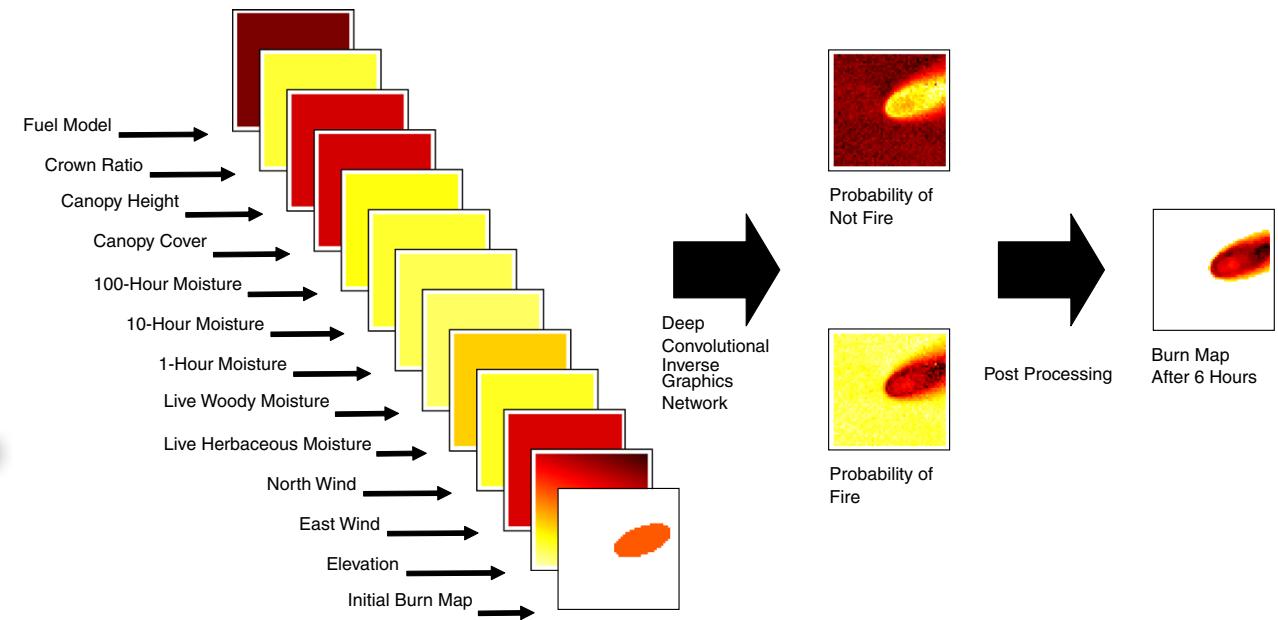
Simple Neural Network



Deep Learning Neural Network



eg. Object detection and classification,
Super-frame and super-resolution video



Hodges & Lattimer. (2019). Wildland Fire Spread Modeling Using Convolutional Neural Networks. *Fire Technology*, 55, 2115–2142



Take-aways

- **When comparisons have been made**, ML methods generally outperform other statistical methods
- Many opportunities exist, particularly:
Predictive - Fire Occurrence Prediction, Fire Behaviour Prediction
Prescriptive - Fire Management
- **Proliferation of available data** at higher temporal and spatial resolution: eg. remote sensing, modelled weather/climate
- **Deep Learning** is effective tool for dealing with large spatio-temporal datasets



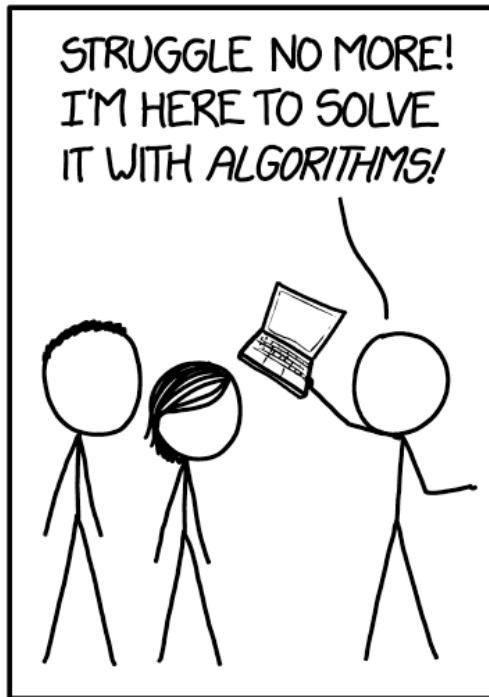
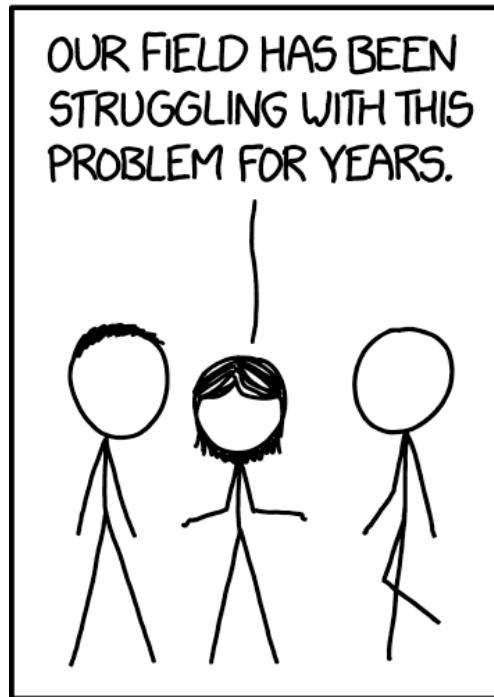
Machine Learning is just another tool

<https://xkcd.com/1838/>

- **G-I-G-O** (Garbage in garbage out)
- **Overfitting** can be a problem
- **Validation and comparison** to traditional methods
- **Extrapolation** may be a problem
 - implications for predicting extremes and climate change impacts
- **Interpretation?**
 - Advancing science by seeing inside the “black box”



Domain expertise is still needed!



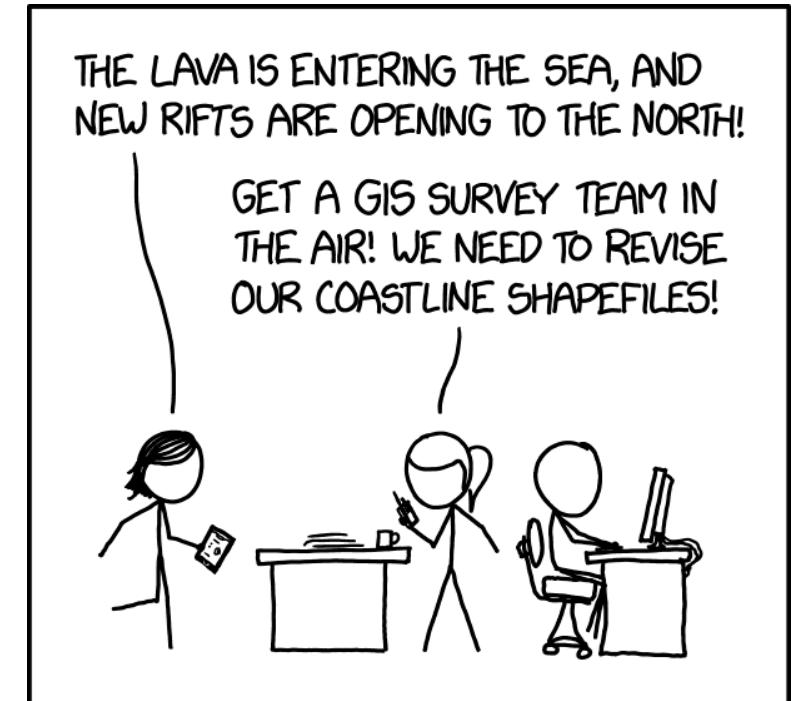
<https://xkcd.com/1831/>

Asking the **right questions**, providing the **right data**, interpreting results

Challenges for fire management

- Better understand where and how ML can be applied
- Moving from Descriptive/Diagnostic analytics to Predictive/Prescriptive analytics.
- Knowledge transfer to operations - supplement or replace existing systems?
- Provide high quality datasets - open data?

<https://xkcd.com/2029/>



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