AI in Forestry—Raster Tools Integrates Machine Learning and Geospatial Analysis at Scale

By John Hogland

Today, we hear a great deal about Artificial Intelligence (AI) and how it is changing society. Every time we search for something on our computers, buy something over the internet, take a picture on our phone, ask Google where to eat, get mapping directions, or search for a phone number, we are knowingly, and often unknowingly, using AI. But what exactly is AI and how is it being used within forestry?

While the term "artificial intelligence" conjures the notion of a sentient race of machines, thinking and performing tasks for their benefit, the AI we are discussing refers to a branch of computer science dedicated to creating systems capable of mimicking complex tasks that typically require human intelligence. AI is composed of multiple subdisciplines that include Machine Learning (ML), Neural Networks (NN), and Deep Learning (DL).

Recent advancements in this field revolve around deep learning techniques that create models of optimized, "learned" coefficients derived from extremely large sets of training data. These models are then used to perform clustering, classification, and regression, which serve as "reasoning" features used to automate descriptive and generative tasks such as labeling, estimating, writing, creating sounds, speaking, and making images and videos, as well as other more general tasks such as turning a motor on and off, sending a signal to another device, opening a door, storing and retrieving data, and robotic movement.

AI in forestry

Forestry has used AI, specifically ML, for decades. ML has been, and continues to be, used for a wide variety of tasks ranging from optimized and automated sawlog extraction and timber processing to estimating and quantifying various aspects of our forests, climate change, and forest and rangeland disturbances. Part of the success of AI within forestry is its ability to quickly ingest and reliably process substantial amounts of often disparate data. Unique to forestry and natural resources, especially with regards to planning, is the role of geography.

Geography plays a crucial role in describing the underlying relationships among forests, vegetation, soil, landscapes, and the processes that occur in those systems. This is the primary reason so many natural resource managers use geographic information systems (GISs) to store data, perform spatial analyses, and plan management actions. To combine the power of geospatial data and analyses with AI, the University of

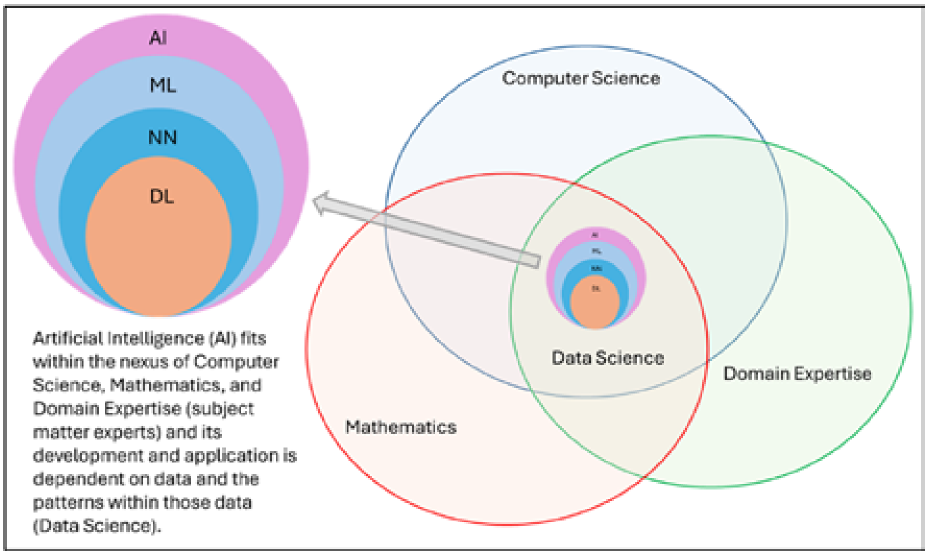

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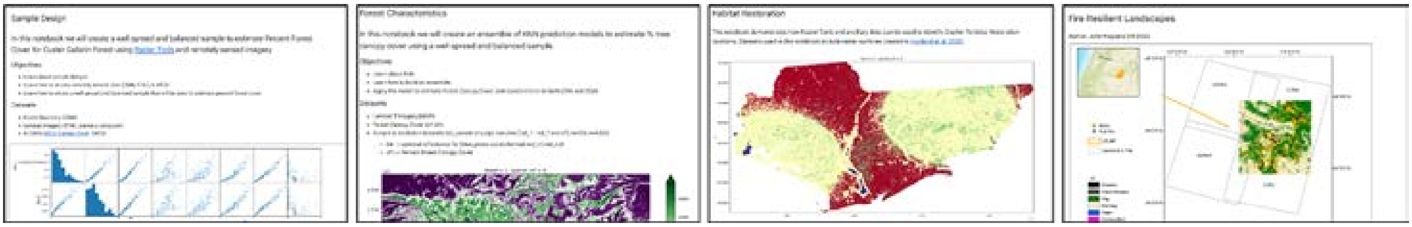
Diagram of the overlap among different fields that link the branch of computer science referred to as Artificial Intelligence (AI) and its subdisciplines; ML (Machine Learning), NN (Neural Networks), DL (Deep Learning).



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Landing pages for each Colab use case.

Montana and the US Forest Service's Rocky Mountain Research Station have developed Raster Tools [1]. Raster Tools is an open-source Python package that facilitates a wide range of geospatial, statistical, and ML analyses using delayed and automated parallel processing of raster and vector datasets.

Raster tools

At its core, Raster Tools facilitate larger than memory processing through Dask [2] scheduling and data parallelization. This enables users to execute geospatial and machine learning workflows that were once too time consuming and computationally expensive to perform.

Additionally, Raster Tools is built on top of Python's coding ecosystem making it extremely easy to integrate any processing workflow into Raster Tools' parallel processing framework.

For example, AI machine learning is linked to Raster Tools through the Model Predict API, making it simple to:

- cluster raster and vector datasets [3]
- perform regression and classification type analyses [4]
- generate well spread and balanced sample designs [5]
- estimate various forest characteristics given field and remotely sensed data [6]
- estimate the cost to deliver woody biomass [7]
- identify and quantify the location and impacts of habitat restoration [8], and
- plan treatment locations, quantify potential revenues, and estimate costs associated with returning national forests to fire resilient landscapes [9].

Use cases

To highlight the utility of Raster Tools, we present four use cases that readers can freely deploy and process in real time: 1) *Sample Design*, 2) *Forest Characteristics*, 3) *Habitat Restoration*, and 4) *Fire Resilient Landscapes*. Use cases are described below and presented as Jupyter notebooks that can be evaluated and processed within Google's Colab [10]. All that is required to run each notebook is a personal Google account and an internet connection. To launch each notebook within Colab, click on the embedded link for each use case and then click on "Open in Colab" link at the top of each notebook.

1) *Sample design*

This notebook demonstrates how to create a well-spread and balanced sample of field locations using remotely sensed data, space filling curves, and systematic sampling. Notebook objectives include:

- Learn about sample designs
- Learn how to access remotely sensed data
- Learn how to create a well-spread and balanced sample based on ancillary data

https://github.com/jshogland/SpatialModelingTutorials/blob/main/Notebooks/knn_sample_design.ipynb

2) *Forest characteristics*

This notebook demonstrates how to create a well-spread and balanced sample of locations, extract remotely sensed data for those locations, preprocess data, use ML techniques for regression, evaluate models, and create surfaces using remotely sensed data and calibrated ML models. Notebook objectives include:

- Learn how to acquire remotely sensed data
- Learn how to build an ensemble of ML models
- Apply ML models back to remotely sensed data
- Bring satellite images to a common radiometric scale
- Summarize and estimate forest characteristics for various spatial domains and subdomains

https://github.com/jshogland/SpatialModelingTutorials/blob/main/Notebooks/knn_create_model.ipynb

3) *Habitat restoration*

This notebook demonstrates how Raster Tools and ancillary data derived from remotely sensed imagery can be used to identify and prioritize gopher tortoise restoration sites. Notebook objectives include:

- Download data
- Identify potential gopher tortoise restoration sites
- Transform spatial data into various metrics for prioritization
- Visualize and store results

https://github.com/jshogland/SpatialModelingTutorials/blob/main/Notebooks/GopherTortoise.ipynb

4) *Fire resilient landscapes*

This notebook explores how potential operational delineations (PODs) can be used to plan, budget and monitor treatments designed to create fire resilient landscapes. Notebook objectives include:

- Learn how to define desired future conditions
- Learn about the Delivered Cost Modeling process
- Learn how to define potential operation units
- Summarize, visualize, and store results

https://github.com/jshogland/SpatialModelingTutorials/blob/main/Notebooks/PODs_Integration.ipynb

Raster Tools Agent-LLM

For those unfamiliar with coding, Raster Tools can be linked to large language models (LLM) to facilitate code generation, notebook modification, and universal task completion. Each linked notebook can be prompted within Colab using Google's Gemini LLM to update markdown and code cells, create new types of analyses, explore additional questions, and summarize existing functionality and results. Linking Gemini to Colab, our notebooks, and Raster Tools lower the entry barrier for managers and practitioners to perform complex spatial and machine learning tasks and to generate summarized results and reports.

While intuitive and easy to use, caution should be practiced when relying on LLM prompting to aid in reporting, creating content, performing spatial operations, and running ML tasks. All modeled outputs, including those generated by an LLM, should be verified, interpreted, and evaluated by domain experts. Remember, AI is a field within computer science, it is not intelligence. AI simply uses optimization and mathematical relationships to mimic patterns within data. While quick to filter and generate content and easy to automate actions, AI may generate patterns that may not be appropriate and may not fully address the question at hand. Regarding AI in forestry, experts in ecology, natural resource management, engineering, silviculture, botany, procurement, wildlife, economics, and wildfire are needed to evaluate and interpret the outputs of all models, including those that mimic how we communicate.

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