How AI can be used in land management?

Ron DALUMPINES, Trent LARSON, Justin HOWARD, and Josh HANKS, United States

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SUMMARY
Land management is the process of managing the use and development of land resources. For most countries, land management has remained the same and fails to address new realities. Despite rapid technological advancements, land management has not changed for decades, if not centuries, especially in the developing and transition economies. However, pressures continue to grow against efficient and effective land management: rapid urbanization, conversion of forested areas to agricultural lands, increasing occurrence of natural hazards such as wildfires and flash floods, and so on.

This decade is marked by the meteoric popularity of AI technologies that brought excitement and fear. In all this AI "hype" as others used to call it, is there something positive that AI can bring into the field of land management? What needs to be true for such positive contributions to happen? Is there any evidence of AI implementations to date?

This paper aims to explore the potential of AI in land management by finding answers to the questions posed earlier. We hope that this exploration will shed some light on potential issues that AI may help with land management, along with identification of the challenges and solutions. We understand that addressing the technical challenges of land management is just one piece of the puzzle. We hope that this exploration will shore up debates that may inform legal and institutional frameworks related to land management.

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1. INTRODUCTION

Land management is the process of managing the use and development of land resources. For most countries, land management has remained the same and fails to address new realities. Pressures continue to grow against efficient and effective land management: rapid urbanization, conversion of forested areas to agricultural lands, increasing occurrence of natural hazards such as wildfires and flash floods, and so on.

Land management activities can be categorized into three components: *land policies*, *land information infrastructures*, and *land administration infrastructures* (Enemark et al., 2005). In general, it is the implementation of land policies in an effective and efficient manner to achieve sustainable development. For most countries, land use planning and related controls fail to institutionalize mechanisms to manage land values and land transactions in sustainable ways. Such disconnect between land use and land tenure encourages exploitation of lands, with those with limited access rights and unsecure tenure are further marginalized.

1.1 Why AI will be a gamechanger in land management?

AI involves the use of computers and algorithms to automate tasks or make predictions better than traditional approaches. In general, AI has several subfields: machine learning (ML), computer vision (CV), natural language processing (NLP), knowledge-based systems, optimisation, robotics, and automated planning and scheduling (Rich & Knight, 1991). ML and its subfield, deep learning (DL), are the most popular AI techniques. Machine learning is a way to use standard algorithms to derive predictive insights from data and make repeated decisions.

Now, the question is how AI can be used to support effective land management?

AI is naturally suited to land management because of:

- many manual and repetitive tasks
- expensive and time-consuming tasks
- village to national/cross-national geographical scopes
- involves numerous vertical and horizontal organizational hierarchies

Key benefits from adopting AI:

- save time and money from speeding up manual/repetitive tasks
- encourage digitalization and therefore force the improvement/streamlining of current processes
- capture of non-traditional data that will enrich existing datasets

- gain more insights that could lead to operational efficiencies or new revenue streams
- lead to more innovation such as creation of new services not thought possible before

2. AI ADOPTION IN LAND MANAGEMENT

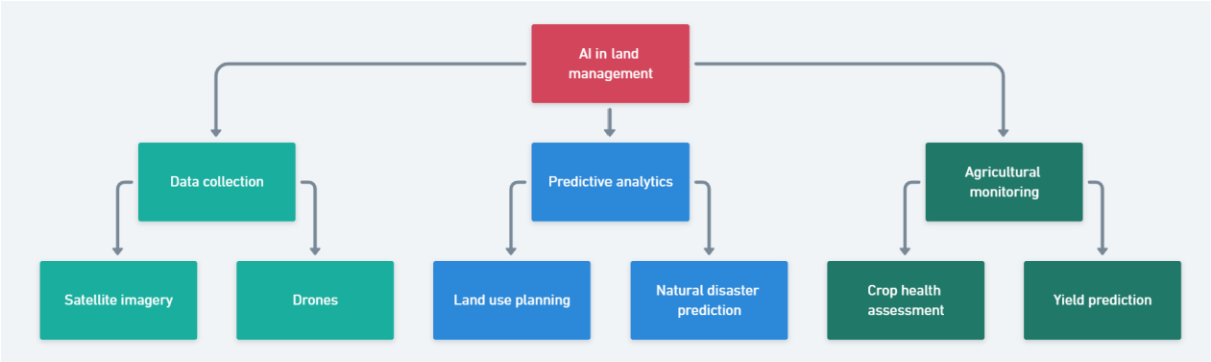

Figure 1. AI-generated categorization of AI applications in land management

2.1 Data collection

It is common to categorize remote sensing (RS) data into satellite imagery (traditional RS data) and those captured by drones, which is becoming increasingly popular in land management applications (Figure 1).

In land management, the *land administration* aspect can be the natural target for AI adoption. According to Enemark et al. (2005), land administration consists of:

- Land tenure: allocation and security of land rights, legal surveys of parcel boundaries, etc.
- Land value: assessment of the value of land and properties, tax collection, management of disputes arising from valuation/taxation
- Land use: control of land use thru policies and regulations, enforcement of regulations, and management of land use conflicts
- Land development: building constructions, implementation of construction planning and management of planning and building permits

Janga et al. (2023) identified the current practical applications of AI in remote sensing:

- land cover mapping: AI techniques have been widely used to assign labels to individual image pixels (e.g., convolutional neural networks (CNNs))
- object detection: identify objects and their movements over time to correlate with economic activities (e.g., deep neural networks (DNNs))
- 3D and invisible object extraction: LiDAR data allows generation of 3D objects while hyperspectral RS data allows detection of objects often invisible to naked eye, AI techniques such as CNNs allow automated generation of 3D objects and detection of invisible objects

2.2 Predictive analytics

AI is used mainly in land use planning, particularly in predicting land use land cover change (Girma et al., 2022). With the revolution in computing and felt impacts of climate change, research has been burgeoning in the use of AI in natural disaster prediction (Janga et al., 2023), with research applications in wildfire detection and management is on the rise.

2.3 Agricultural monitoring

The Agricultural Research Service (ARS) within the United States Department of Agriculture has identified the following agricultural research areas where AI techniques are applied (Liu, 2020):

- agricultural production management: AI techniques are used to provide guidance on crop rotation, planting times, water, and nutrient management, etc.
- crop monitoring: AI together with Internet-of-Things (IoT) sensors provide an efficient way of monitoring plant health issues (Talaviya et al., 2020) or nutrient deficiencies in the soil
- yield prediction: using remote sensing data or those collected by drones and AI techniques such as ML algorithms increase the accuracy and speed of predicting crop yields

Patel et al. (2023) found the following AI techniques to be most common in land and water management research:

- artificial neural networks (ANN)
- adaptive neuro-fuzzy inference systems (ANFIS)
- support vector regression (SVR)
- random forest (RF)
- multilayer perceptron-ANN (MLP-ANN)

2.4 Challenges in AI adoption

Janga et al. (2023) identified the key challenges with AI in remote sensing, which we believe also applies to land management:

- data availability: AI techniques depend on lots of data, for cash-strapped government agencies, this is a major challenge to overcome; however, there are some AI techniques that use reinforcement learning to build from limited data and increase the accuracy of AI models as more data gets collected over time
- model interpretability: it is a challenge to explain AI models that will be the basis for land policies and regulations as AI models are often seen as ‘blackbox’

3. CONCLUSION

There is no question that AI has a lot of existing and potential applications in land management. However, there is lack of generally accepted categorization of AI applications in the field due to the wide scope of research areas in the field.

AI adoption may exacerbate power imbalances between powerful and vulnerable sectors of society. With the lack of control mechanisms and transparency, AI tools may end up being a powerful tool for those in power to increase their foothold, if not increase, their ownership of lands at the behest of vulnerable groups. Hence, we should not stop at the AI benefits and challenges but consider further how those benefits and challenges will be distributed to various groups. Particular emphasis should be given to those who are already vulnerable, that AI may put them more at a disadvantage than before.

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