



USE OF ARTIFICIAL INTELLIGENCE (AI) IN BIODIVERSITY OF SOIL ARTHROPODS

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Abstract

Soil arthropods constitute a significant portion of terrestrial biodiversity and play vital roles in ecosystem processes such as nutrient cycling, soil structure maintenance, and organic matter decomposition. Traditional methods of assessing soil arthropod biodiversity are labour-intensive, time-consuming, and require taxonomic expertise. Recent advances in Artificial Intelligence (AI) offer transformative potential for biodiversity assessment by enabling rapid, accurate, and scalable analysis of ecological data. This paper reviews current applications of AI techniques—including machine learning (ML), deep learning (DL), and computer vision—in studying soil arthropod biodiversity. We also propose a conceptual framework integrating AI in soil arthropod monitoring and discuss challenges and future research directions.

Keywords: Arthropods, Biodiversity AI (Artificial Intelligence)

INTRODUCTION

Arthropods are sensitive bioindicators of environmental change because of their rapid reproductive rates, short generation times and the fine grain at which they occupy space in the soil. Because of their small size and enormous diversity and abundance, soil arthropods are able to partition their habitat at very fine spatial scales. Since intensification of agricultural production was identified as one of the major factor of the soil destruction and loss of bio-diversity, International organization have called upon their members to contribute indicators which would be applicable to many countries and would be helpful to policy makers for low enforcement. With respect to indicators for agriculture soil biodiversity is generally linked to “SOIL FERTILITY” (F.A.O.2001). With respect to the impact of agricultural management on soils, attention has focused since the out on identifying possible indicators. Specially also micro biological bio-Indicators which are suitable for defining ‘soil quality ‘or ‘soil health’. Soil arthropods, including insects, mites, collembolans, and myriapods, are essential components of soil ecosystems. They influence nutrient cycling, soil aeration, plant health, and organic matter breakdown (Lavelle et al., 2006). Despite their ecological importance, global assessments of

soil arthropod biodiversity remain insufficient due to challenges in sampling, identification, and data processing. AI encompasses computational techniques capable of pattern recognition, prediction, and autonomous decision-making. In ecology, AI has been used for species distribution modeling (SDM), acoustic monitoring, and remote sensing, among other applications (Christin et al., 2019). Specifically, ML and DL methods applied to image data have shown promise in automating species identification.

OBJECTIVES:

1. Review current AI applications for soil arthropod biodiversity assessment.
2. Identify methodological challenges.
3. Propose an AI-integrated workflow for soil biodiversity monitoring.
4. Suggest future research pathways.

Soil Arthropod Biodiversity: Ecological Importance and Assessment Challenges

Soil arthropods contribute to: **Decomposition:** Breaking down plant material and recycling nutrients. **Bioturbation:** Mixing soil layers, affecting water infiltration. **Predation:** regulating soil nematode and pest populations.

METHODS:

Hand sorting Berlese-Tullgren, funnels Pitfall traps, Identification relies heavily on morphological expertise, limiting throughput and scaling.

Given the massive species diversity and cryptic taxonomy of soil arthropods, AI offers potential to: Automate image-based identification. Integrate multisensor ecological data. Detect biodiversity changes over space and time.

Artificial Intelligence Techniques for Biodiversity Assessment

ML uses algorithms such as Random Forests, Support Vector Machines, and k-Nearest Neighbours for classification and prediction tasks.

Applications include: Predicting species richness. Classifying taxa from image features.

DL, especially convolutional neural networks (CNNs), excel in image interpretation. Examples include: ResNet, Inception and YOLO

These models automatically extract image features, enabling high-accuracy classification of arthropod taxa.

Combining high-throughput sequencing with AI classifiers (e.g., neural networks) allows detection of cryptic biodiversity from soil eDNA datasets.

AI Applications in Soil Arthropod Research

Studies have demonstrated that deep learning models can classify arthropod images with accuracy comparable to expert taxonomists (Valan et al., 2019).

1. Collect arthropods using traps.
2. Capture standardized images under controlled lighting.
3. Train CNN model using labeled images.
4. Evaluate performance using precision, recall, F1-score.

Emerging methods use AI to detect species-specific acoustic signatures in soil environments. ML models integrate environmental variables (temperature, moisture, land use) to predict species richness and community structure. eDNA metabarcoding coupled with AI classifiers enables detection of species not visible via image-based methods.

Methodological Framework for AI-Assisted Soil Biodiversity Monitoring

Standardize trap design and deployment. Record metadata (GPS, soil properties). Images, environmental sensors, eDNA sequencing. Clean image data. Annotate using expert input. Normalize feature sets. Compare multiple AI algorithms. Use cross-validation. Implement explainability modules (e.g., feature importance). Mobile or cloud-based identification tools. Continuous model refinement.

Future Directions

- **Explainable AI (XAI):** Improve model transparency.
- **Multimodal Integration:** Combine images, eDNA, acoustic data.
- **Citizen Science Platforms:** Crowdsourcing image annotations.
- **Global Soil Biodiversity Monitoring Networks**

Conclusions

AI holds transformative potential for advancing soil arthropod biodiversity assessment. By automating taxonomic identification, modeling ecological patterns, and integrating various data streams, AI can support more accurate, scalable, and efficient biodiversity monitoring.

References

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