Development of image classification models for the identification of earthworms exposed to glyphosate-based herbicide: a pilot study

Diovana Gelati de Batista[1]*, Juliana Furlanetto Pinheiro[1], Isadora Sulzbacher Ourique[1], Vítor Basto Fernandes[2], Rafael Z. Frantz[1], Nuno Costa[3], Thiago Gomes Heck[1]

[1] Regional University of Northwestern Rio Grande do Sul, Rua do Comércio 3000, Ijuí, RS, Brazil, CEP 98700-000
[2] Instituto Universitário de Lisboa (ISCTE-IUL), Centro de Investigação em Ciências da Informação, Tecnologias e Arquitetura, Lisboa, Portugal
[3] Computer Science and Communication Research Center, School of Technology and Management, Polytechnic University of Leiria, Campus 2, Morro do Lena, Alto do Vieiro, 2411-901, Leiria, Portugal
*diovana.g.debatista@gmail.com

Background

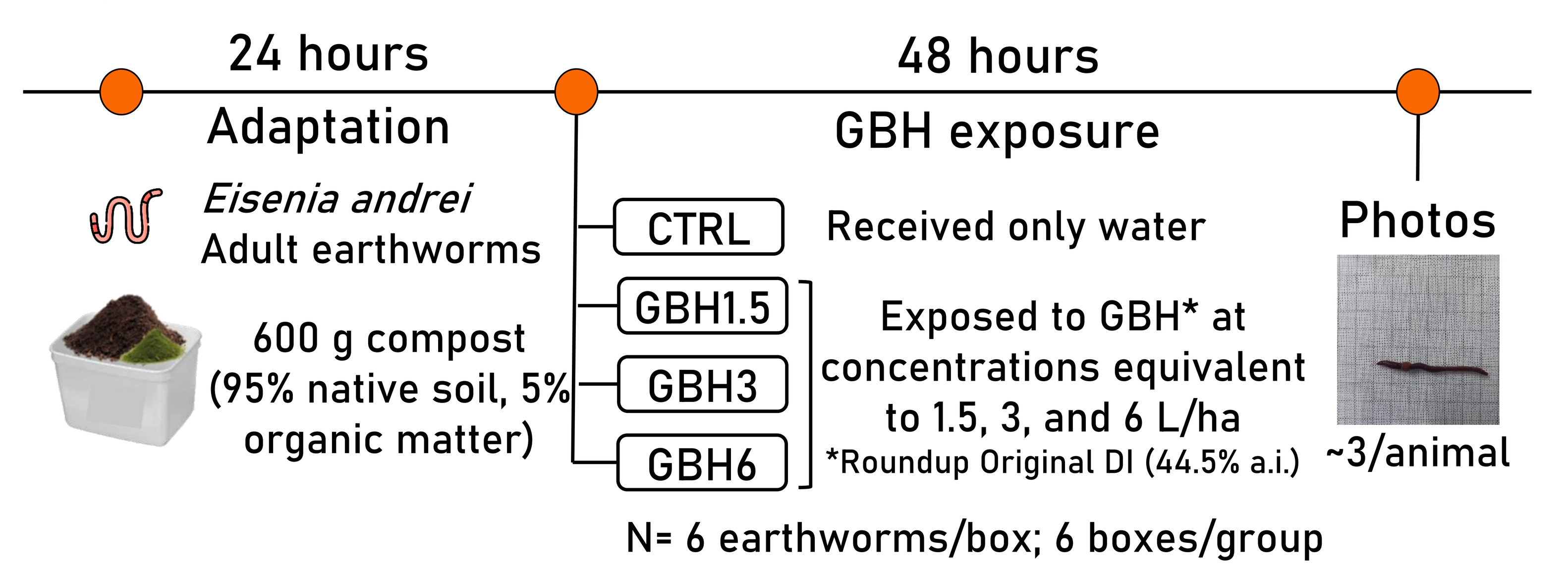
- Glyphosate-based herbicides (GBH) are widely used pesticides around the world. Its wide application, however, may threaten ecosystems and human health [1].
- Among contaminated environments, soil is the first site of deposition from which GBH molecules are carried to other natural resources. In this environment, earthworms are bioindicators of GBH contamination [2].
- However, environmental monitoring of GBH is still scarce in many countries due to the cost and equipment involved in its detection [3].
- To address this issue, developing machine learning models can be an effective and cost-efficient alternative for identifying contaminated environments and organisms.

Objective

We tested if machine learning models of earthworm image classification can be used to identify GBH-exposed environments.

Methods

1) Laboratory experiments to collect images of earthworms exposed to GBH



2) Image augmentation and models definition

- We generated 20 artificial images (AI) variations of each original image (OI) using data augmentation techniques of *imgaug* library [4].
- Then, using OI and AI, we created four models:

Original-images models
- OI-4G: Model with OI from all groups (CTRL, GBH1.5, GBH3, and GBH6).
- OI-2G: Model with OI from CTRL and GBH6 groups.

Artificial-images models
- AI-4G: Model with OI plus AI from all groups (CTRL, GBH1.5, GBH3, and GBH6).
- AI-2G: Model with OI plus AI from CTRL and GBH6 groups.

- Randomly, images were distributed to train (85%) and test (15%) the models.

3) Machine learning experiments

- The models were trained six times each in Google's Teachable Machine with 50, 20, and 10 epochs (learning rate=0.001; batch size=16).
- The accuracy was compared using two-way ANOVA, followed by Tukey's multiple comparisons test.
- The models were tested using Python with test images.

Results

In the training stage, the OI-2G model showed better accuracy when trained with 50 epochs (P=0.02), but the AI-2G model presented the best accuracy in all epochs tested (P<0.002). In contrast, the OI-4G model presented the worst performance compared to the others (P<0.0001) (Figure 1).

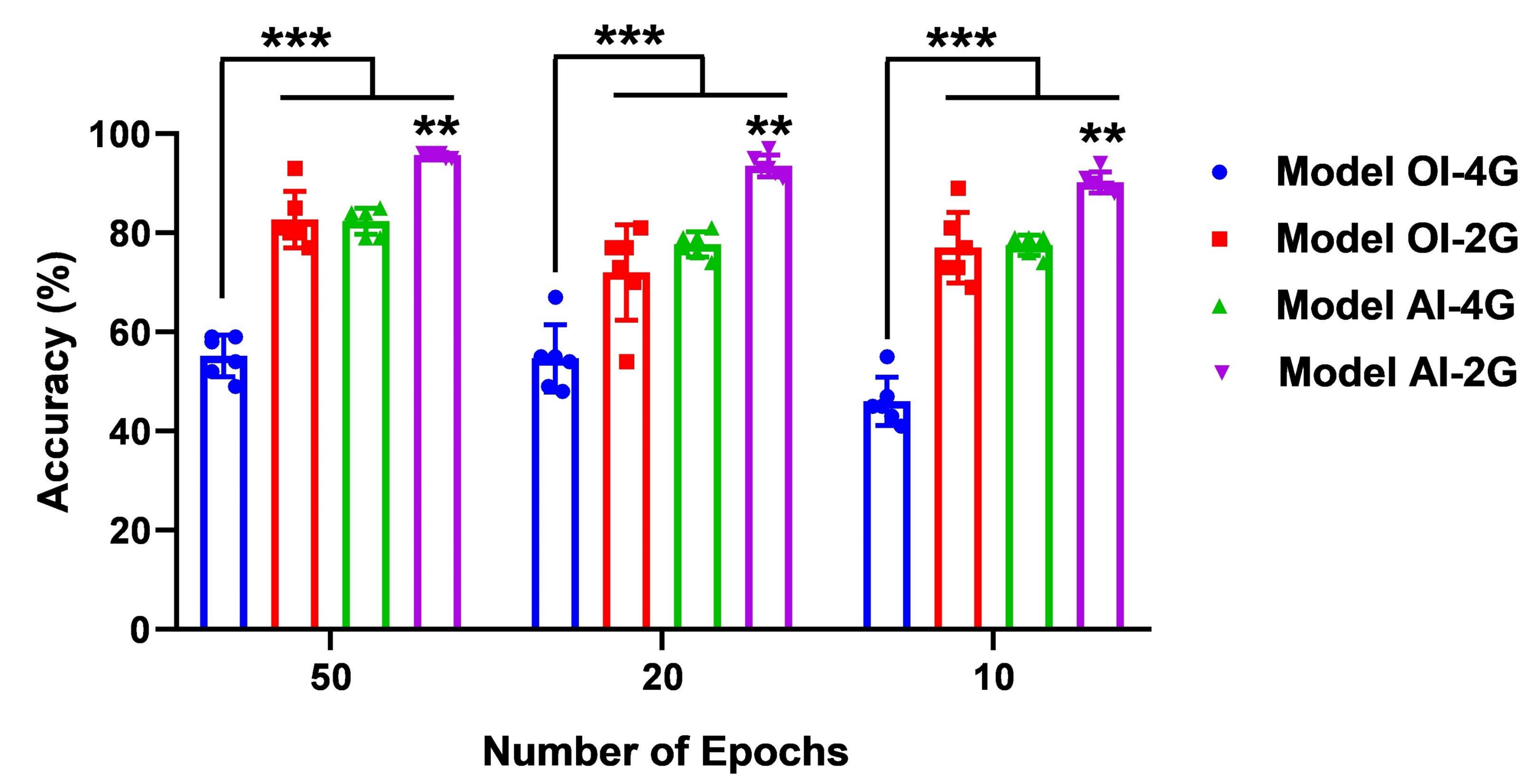


Figure 1. Models' accuracy (%) in the training stage. Two-way ANOVA, followed by Tukey's multiple comparisons test. **p<0.002 in model AI-2G vs. the others. ***p<0.0001 in models OI-2G, AI-4G, and AI-2G vs. OI-4G.

When tested, however, AI models had lower accuracy compared to OI models (Table 1).

Table 1. Models' accuracy (%) in the test stage.

Model	OI-4G	OI-2G	AI-4G	AI-2G
Test accuracy	47%	86%	38%	65%

The best performance of OI-2G can also be seen in the confusion matrix (Figure 2):

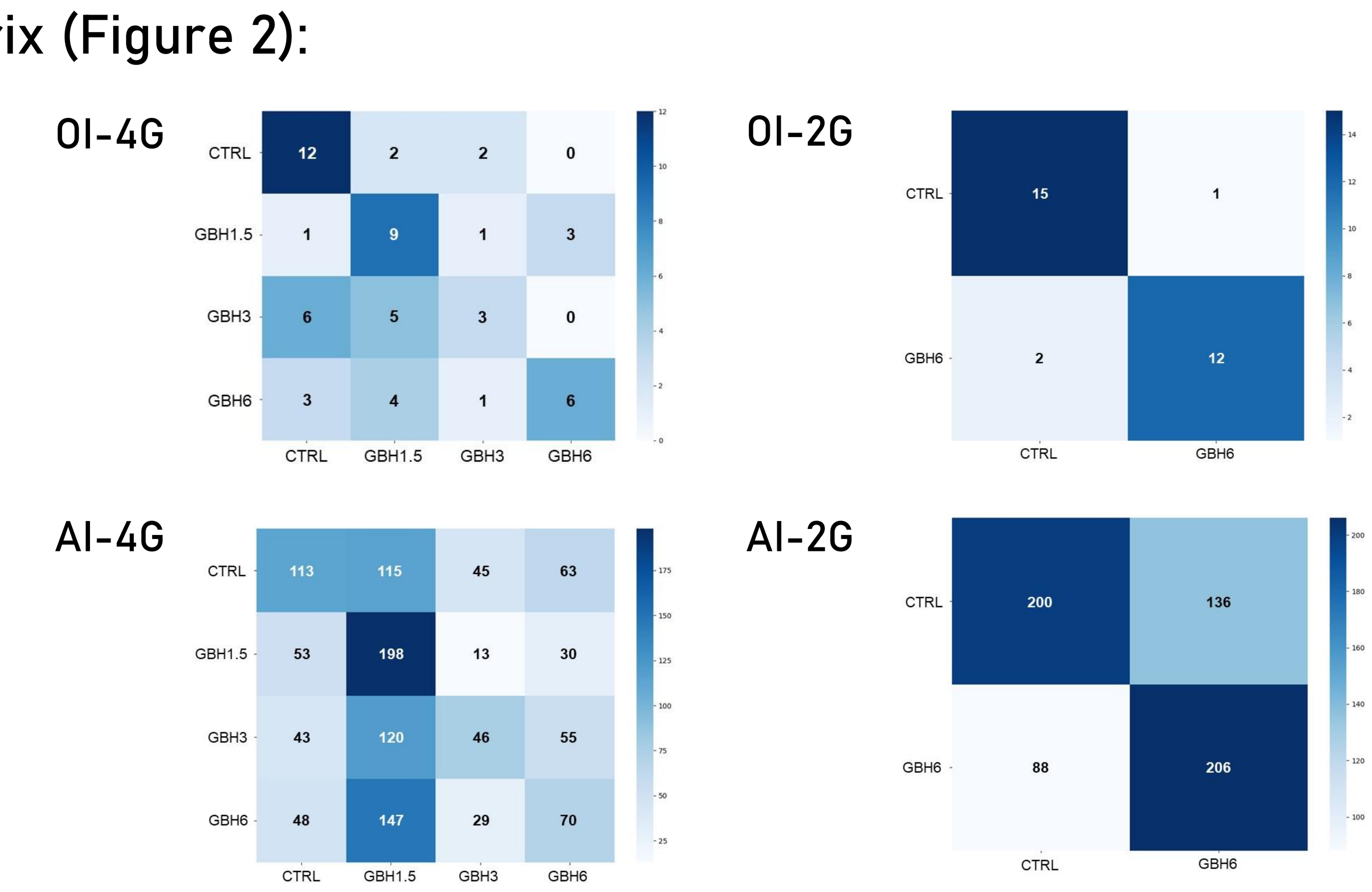


Figure 2. Models' confusion matrix of the test stage.

Conclusions

It is possible to detect the presence of GBH in the soil by evaluating earthworm images using machine learning models, even with small sample sizes (photos) and without images created artificially. Models need to be improved to detect the concentration of GBH.

References

1. Van Bruggen, A.H.C. et al. Environmental and health effects of the herbicide glyphosate. *Sci Total Environ* 2018, 616-617, p. 255-268.
2. Zaller, J.G. et al. Effects of glyphosate-based herbicides and their active ingredients on earthworms, water infiltration and glyphosate leaching are influenced by soil properties. *Environ Sci Eur* 2021, *33*, p. 51.
3. Valle, A.L. et al. Glyphosate detection: methods, needs and challenges. *Environ Chem Lett* 2019, *17*, p. 291-317.
4. imgaug library documentation: https://imgaug.readthedocs.io/en/latest/

iscte INSTITUTO UNIVERSITÁRIO DE LISBOA
UNIJUÍ UNIVERSIDADE REGIONAL
TOXRUN ONE HEALTH TOXICOLOGY RESEARCH UNIT
CESPU INSTITUTO UNIVERSITÁRIO DE CIÊNCIAS DA SAÚDE
IPL instituto politécnico de leiria