Giuseppe Pellizzi Prize

CLUB OF BOLOGNA

CLUB OF BOLOGNA

FEDER UNACOMA

Italian Agricultural Machinery Manufacturers Federation

eima INTERNATIONAL TWENTYSIX

Research and implementation of robotic, digital and A.I. solutions for the management of agricultural and urban green spaces

Dissertation presented to University of Pisa, Pisa, Italy

Sofia Matilde Luglio

Department of Agriculture, Food and Environment, University of Pisa

✉: sofiamatilde.luglio@phd.unipi.it ☎: 0502218918

Dipartimento di Scienze Agrarie Alimentari e Agro-ambientali Università di Pisa 180 1840-2020

1 Introduction

European strategies are driving agriculture and green area management towards a **digital**, **sustainable**, and **biodiversity-oriented transition**.

Key challenges:

1. reduce chemical inputs
2. optimize resource consumption
3. preserve and enhance biodiversity
4. maintain productivity through innovative technologies

Digital and robotic opportunities

Robotics , digital imaging, artificial Intelligence (AI) can support more efficient, precise, and sustainable management operations.

Research objective

To develop and evaluate digital and robotic solutions for sustainable agroecosystem and green area management, with a focus on weed management and biodiversity assessment.

Research activities

The research was structured into three main areas

01 — Robot Benchmarking

Benchmarking and validation of agricultural robotic systems

02 — Robotic Performance

Evaluation of the management and operational performance of robotic platforms

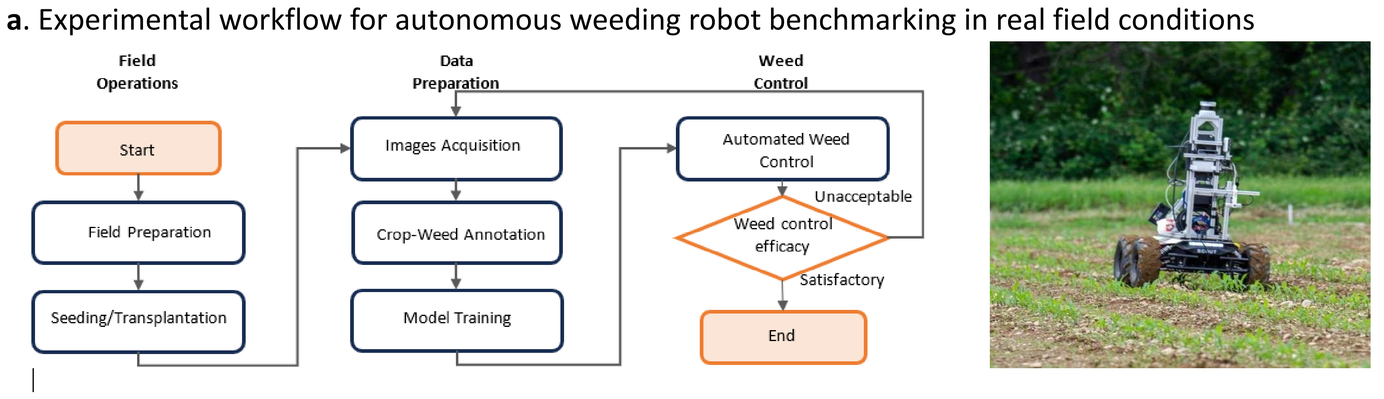
03 — Ecological Impact

Assessment of biodiversity and ecological impacts of robotic management

2 Benchmarking agricultural robots

2.1 Field campaign and experimental design for robot performance evaluation (ACRE 2023)

a. Experimental workflow for autonomous weeding robot benchmarking in real field conditions



b. The 2023 ACRE Competition Dataset was collected through a dedicated mobile rover and provided for a total of 2069 images, featuring corn and bean crops, alongside instances of three weed species.

2.2 Balancing accuracy and cost in precision agriculture: a few-shot learning approach for efficient weed - crop segmentation

To address the data-hungry problem, FSL HDMNet was evaluated for crop–weed segmentation on robot-acquired images and compared with a conventional YOLO-based approach.

Main results:

- Two comprehensive segmentation datasets for beans and corn cultivation: an expansive 'Early Dataset' (2069 images) and a meticulously annotated 'Refined Dataset' (102 images) with precise labels even for the smallest leaves.
- A quantification of the human labor involved in the dataset creation phases, providing a valuable benchmark for estimating the efforts required to curate new agricultural datasets.
- FSL HDMNet retained 73–80% of the accuracy compared with the data-hungry YOLOv5 and YOLOv8 models when detecting bean and corn plants, eliminating data annotation costs.

2.3 Tracking long-distance systematic trajectories of different robot mower patterns with enhanced custom-built software

Developed and validated custom-built software (v2.5.0.0) for RTK-GPS-based analysis of trajectories, enabling the evaluation of the Navigation Functionality Benchmark (FBM) for robotic platforms.

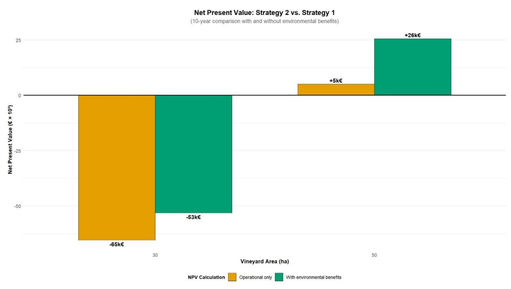
3 Evaluation of the management of different agricultural systems with robots

3.1 Comparison of two under-row weed control strategies in vineyards — autonomous robot vs. tractor-based management



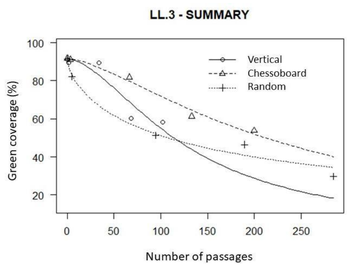


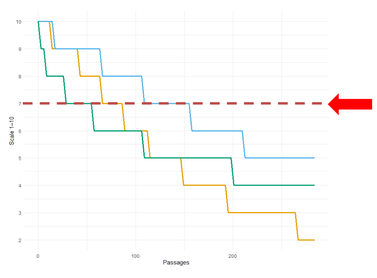
No significant differences in weed control efficacy, soil compaction, or weeding possibility zones.



Positive Net Present Value (NPV) for robotic solution adoption on areas > 50 ha, according to the Cost–Benefit Analysis (CBA).

3.2 Modelling the relationship between autonomous mower trampling activity and turfgrass green cover percentage



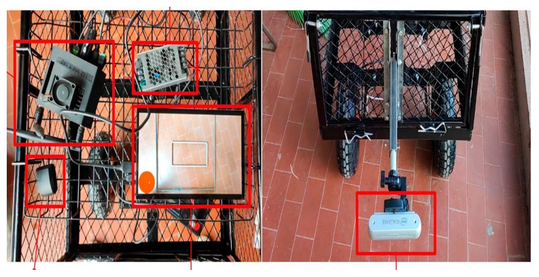


By estimating the average number of passages from the model, it emerges that the number of days required to reach 60% coverage varies depending on the pattern

4 Robotic agricultural management: effects on biodiversity

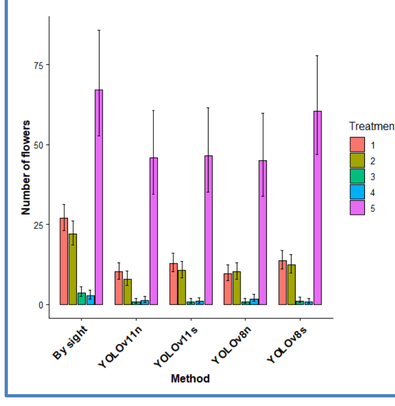
4.1 Analysis of football pitch performances based on different cutting systems: from visual evaluation to YOLOv8

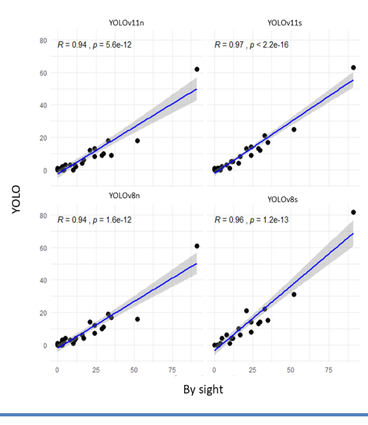


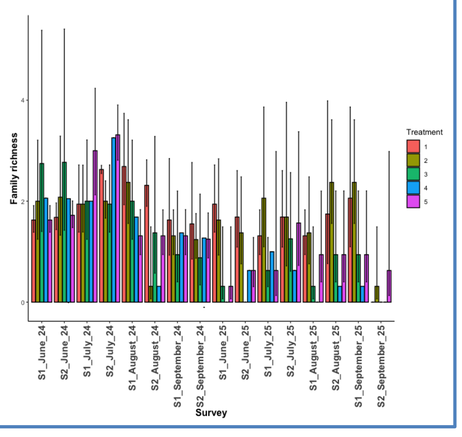


1. The autonomous systems ensured lower surface hardness in the central zone (10.15 G_{max} vs. 15.25 G_{max}) and a lower turfgrass height (2.61 cm).
2. The mean value of weed percentage in the function of type of management and position revealed how weed percentage increased much more in the corner zones managed by the robot mower (17,5%)
3. YOLOv8s achieved higher overall performance in detecting the investigated classes, highlighting its potential for floristic composition analysis and biodiversity quantification.

4.2 Assessment of autonomous mower effect on Phyla nodiflora and pollinator presence in urban lawns







5 Final Remarks

Overall, the results of this thesis confirm that robotic and AI-based technologies can effectively support sustainable agricultural and turf management by improving operational efficiency, reducing environmental impacts, and enabling biodiversity conservation. Future research should focus on extending these approaches to a wider range of species, environments, and management regimes, as well as on the integration of real-time sensing, predictive models, and decision-support systems to further enhance adaptive and site-specific management. The findings presented here contribute to the development of resilient, multifunctional agroecosystems and urban green spaces, positioning agricultural robotics as a key component of the ongoing digital and ecological transition.