Exploring YOLOv8 architecture applications for weed detection in crops

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Abstract. This work has a goal to test a deep-learning approach to the problem of aerial weed detection in crops. The issue of this type of detection lies in the nature of plants and their life cycles. Crops as well as weeds change their appearance and can be similar in physical appearance. The use of advanced models like the You Only Look Once v8 (YOLOv8) allows for fast and accurate predictions. In this work, five different sizes of the YOLOv8 are applied to the same dataset consisting of aerial images of plants. The results, metrics, and actual predictions are provided for every of the five models. The modernization of the agricultural domain has begun, and the use of artificial intelligence (AI) is paramount to stay ahead of the competition. The experimental outcomes indicate significant potential of YOLO networks in this domain, and further possibility to integrate these networks with precision agriculture.

Keywords: YOLOv8 · aerial imagery · weed detection · deep-learning.

1 Introduction

Weed control protocols are advancing from traditional mechanical and pesticide techniques. In some cases, more advanced systems based on robots are present in the current state of this domain. The application of AI has the potential to reduce the costs that come with the use of traditional techniques. Furthermore, the use of pesticides can be harmful and requires controlled use. The AI allows for the use of even more advanced use of robots with sensors that allow AI-enhanced detection of weeds in crop environments [55]. The reasons weed detection is

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problematic are that both weeds and crops change through cycles of their growth, obstructing leaves, and general similarity in their appearance.

Computer vision can be vital in weed control, as these algorithms are capable of analyzing the images from crop fields in order to identify presence of weed. Relying mostly on convolutional neural networks (CNNs), these methods can be trained on extensive datasets of labeled images to differentiate betwixt useful plants and weed, with respect to the visual properties such as color, size, shape of leaves etc. After identifying the weed plants, computer vision models can accurately locate them, allowing usage of targeted treatment, and reducing the application of herbicide.

Deep-learning has proven to have a significant role in computer vision and such potential is yet to be explored for the use cases related to crops. YOLOv8 model is particularly promising in the domain of real-time detection. The model has proven efficient while maintaining accuracy in various detection-based task environments. The use of YOLOv8 has the potential to increase the efficiency in the search for unwanted plants in yield, as well as to provide significant savings if used in combination with the right mechanization. Thus, it can be an integral part of the precision agriculture systems, that rely on a broad spectrum of technologies like GPS, wireless sensors, Internet of Things (IoT) devices and drones to monitor the crops' health, identify harmful plants, and perform adequate actions without necessitating the human presence.

Single and two-staged object detection solutions represent the current state of AI technologies used in this domain. The advantage of the simpler single-stage algorithms' mechanisms is the detection speed, while the slower two-staged solutions are capable of fine detection because of the higher precision that is a result of their region proposal mechanism. The proposed YOLOv8 method is of the single-staged type. The goal of this work is to explore the potential of lightweight architectures that can allow for the reduction of hardware requirements in real-time use cases.

The structure of the paper is provided in the following text. Section 2 is dedicated to the fundamentals of the technologies used in this research, Section 3 provides the experimental setup and the results of different model sizes of YOLOv8, and Section 4 concludes the paper.

2 Background

The main reason for the use of transfer learning is their ability to mitigate some of the challenges with crop prediction. The mechanisms that allow transfer learning can expedite model development which results in cost reductions. The reason for this is that such models can provide higher performance in training on large datasets which are required due to the plants' nature. The use of this principle can improve generalization performance and provide a solution for real-world use cases with limited labeled data.

Real-word use of AI is on the rise and thanks to metaheuristic optimization many solutions that were not feasible before are possible now. The role of metaheuristic optimizers in AI is to aid in hyperparameter optimization which provides significant performance improvements. Some of the use cases include computer security, phishing and intrusion detection [58, 2, 48, 28, 46, 14, 27, 11], plant classification[13, 66], credit card frauds identification [22, 38, 37],cloud computing problems [43, 8], medicine [32, 56, 31, 62, 25, 64, 61, 36], global optimization problems [16, 10], automotive traffic predictions [41, 18], environmental monitoring and pollutants tracking [34, 24, 7, 33, 17], economic problems [26, 30, 51, 20, 42, 40], wireless sensor networks optimization [57, 4], feature selection [63, 15, 23, 59, 6], predicting green energy production [50, 5, 29], spam emails [60, 44], enhancing the audit opinion [52], defect identification in software testing [67], marine vessel classification and trajectory prediction [39, 53], as well as general optimization in machine learning models [9, 49, 12, 35, 45, 65, 3, 19, 54].

2.1 YOLOv8 Models

You Only Look Once (YOLO) architecture represents a group of algorithms that are renowned for their high accuracy and speed. The images are only analyzed once for the reason of predicting bounding boxes with class probabilities [21]. The difference in these models from traditional two-stage detectors is that they work with raw pixels for predicting locations and categories of objects. Consequentially, the real-time application is realistic. Data augmentation, transfer learning, and fine-tuning are techniques employed in YOLO models that enhance the performance of generalization even with cases of high diversity.

YOLOv8 is the latest iteration of YOLO architecture. The upgrades include speed and accuracy improvements, as well as simplicity due to its novel availability as a pip package. The YOLOv8 supports all YOLO versions, making it a versatile tool [47].

YOLOv8 introduces feature pyramid and path aggregation neural networks along with a labeling tool for shortcuts, personalization of hotkeys, and automatization in labeling. The model is autonomous in detecting and categorizing objects, as well as regression tasks due to an anchor-free model with a decoupled head. The branches are executed independently with sigmoid and Softmax functions applied to for probability of an object falling into a bounding box and to a specific class, respectively. The use of bounding boxes results in superior accuracy with delicate tasks.

3 Results

3.1 Experimental setup

The dataset used in this research is publicly available [1] and consists of aerial imagery of the plants. This work tests the performance of different architecture sizes of YOLO models including nano, small, medium, large, and extremely large models. The results of each of the models are reported in the following text. The resolution of the images in the dataset is 640×640, and 100 epochs were applied for training.

3.2 YOLOv8 Nano Model

The Fig. 1 provides the results of the nano model structure. The Fig. 2 provides the PR curve of the model along the confusion matrix, while the predictions are provided in the Fig. 3. This is the smallest model of the five tested models, and it provides the highest detection speeds but lacks stability in comparison with more complex architecture.

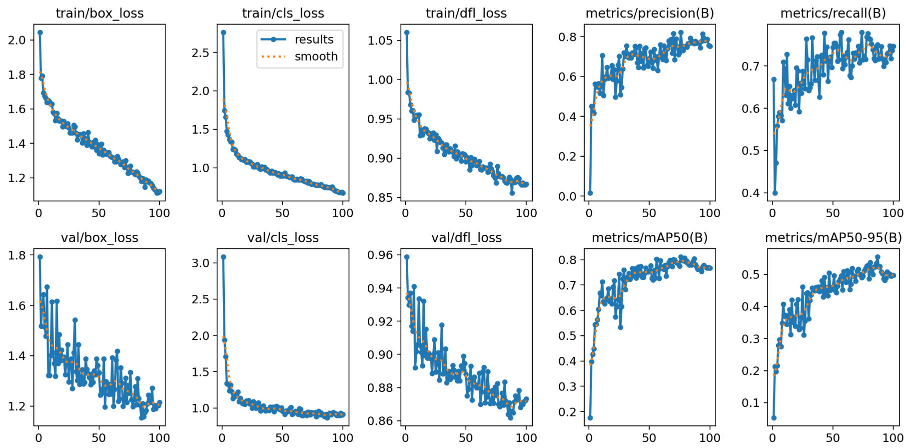

Fig. 1. Nano YOLOv8 model results

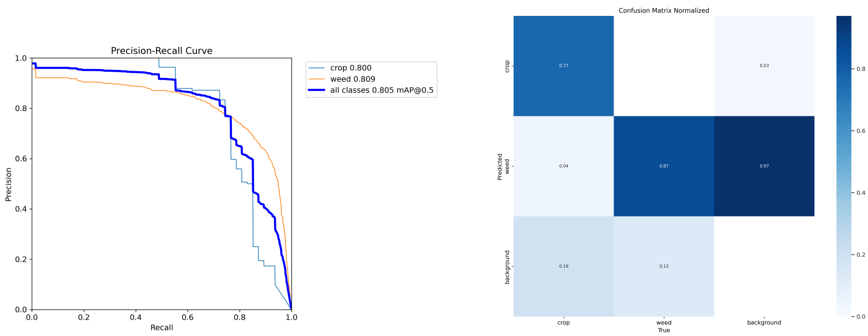

Fig. 2. Nano YOLOv8 model PR curve and confusion matrix

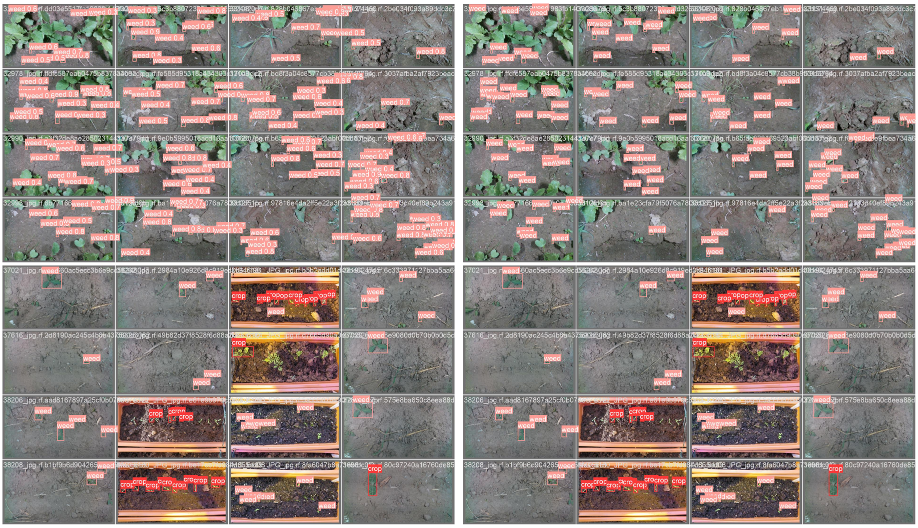

Fig. 3. Nano YOLOv8 predictions

3.3 YOLOv8 Small Model

Slightly bigger the small model begins to exhibit the trade-off between speed and accuracy as it is slightly slower and more accurate than the nano model. The results are provided in Fig. 4, while the PR curve and confusion matrix for the small model are given in Fig. 5. The predictions that the model made are provided in Fig. 6 for a better illustration of performance differences.

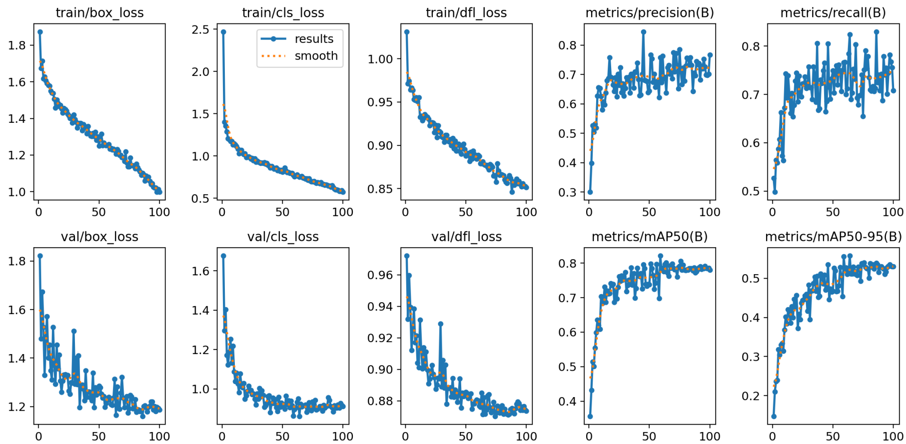

Fig. 4. Small YOLOv8 model results

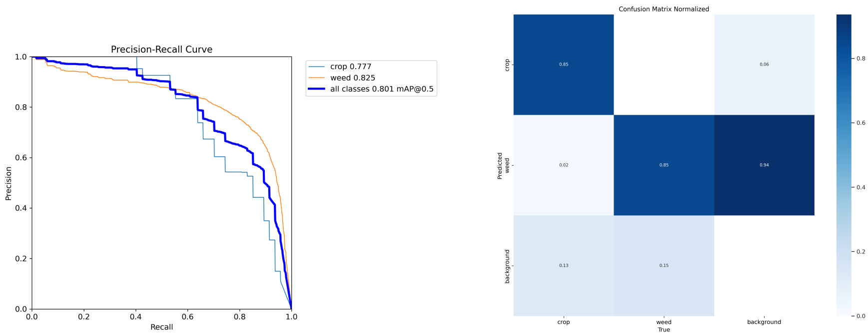

Fig. 5. Small YOLOv8 model results

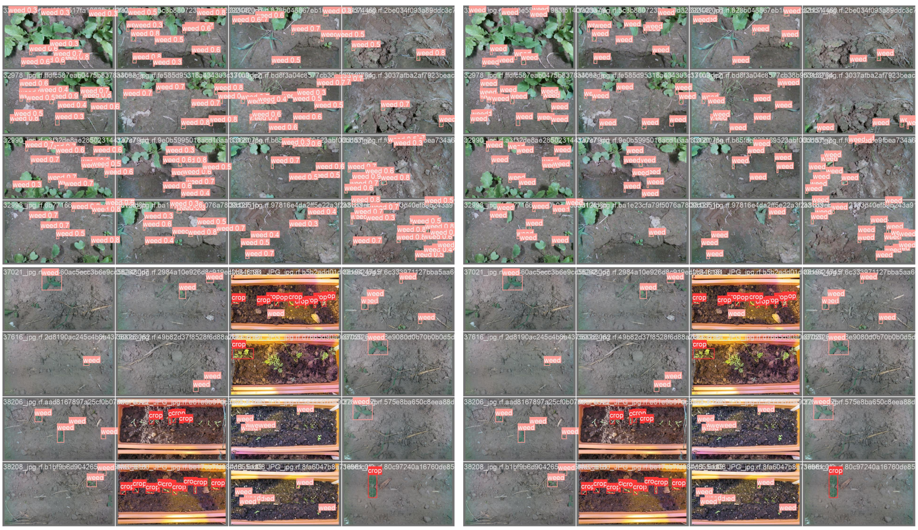

Fig. 6. Small YOLOv8 model results

3.4 YOLOv8 Medium Model

The medium model follows the incremental changes in the mentioned trade-off. The results are given in Fig. 7, the PR curve and the confusion matrix in Fig. 8, while the actual process of model-making predictions is given in Fig. 9.

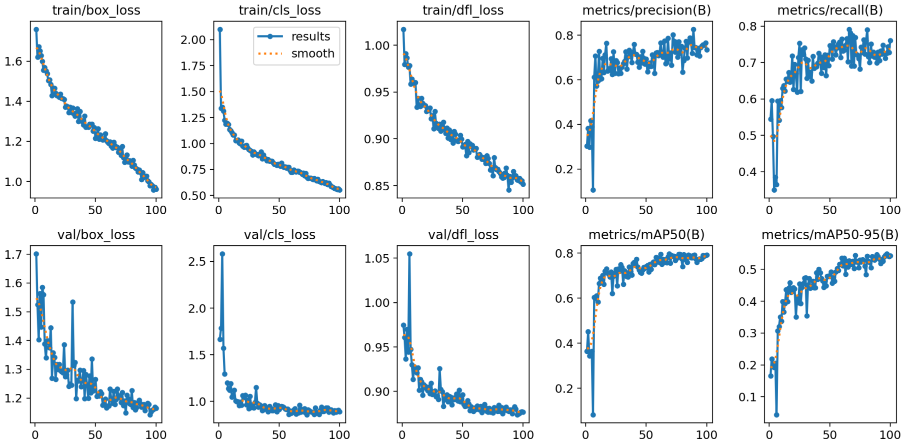

Fig. 7. Medium YOLOv8 model results

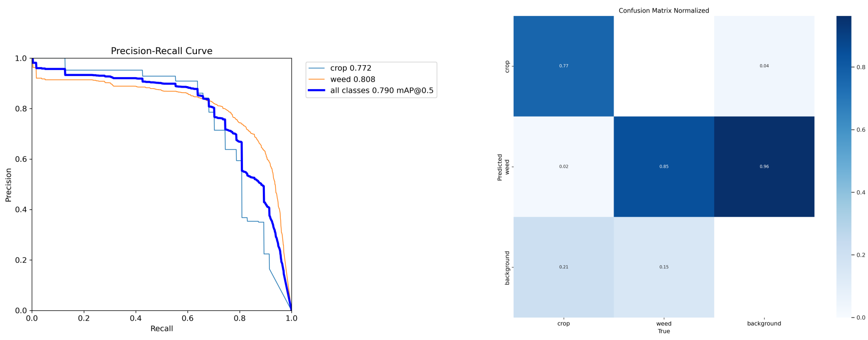

Fig. 8. Medium YOLOv8 model results

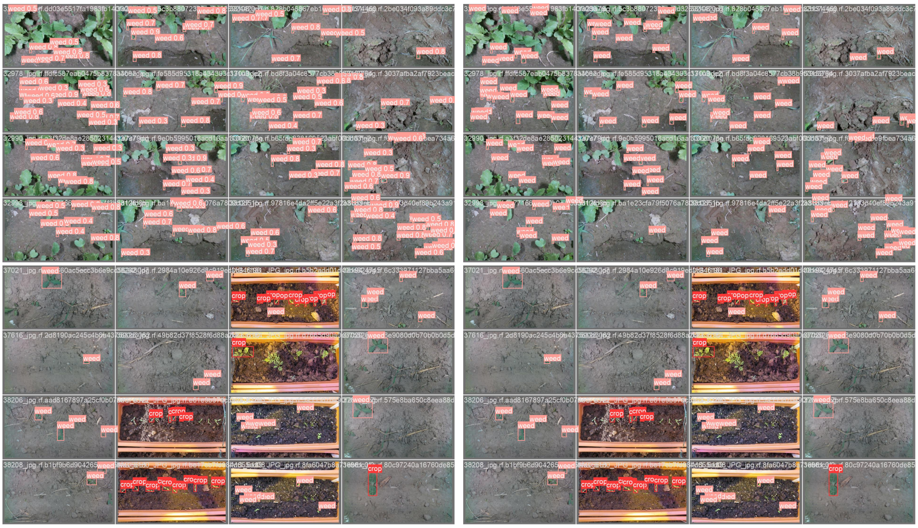

Fig. 9. Medium YOLOv8 model results

3.5 YOLOv8 Large Model

The highest stability and accuracy are exhibited in the large and extra-large models. Fig. 10 gives the results of this model, Fig. 11 provides the PR curve and the confusion matrix, and the actual predictions are provided in Fig. 12.

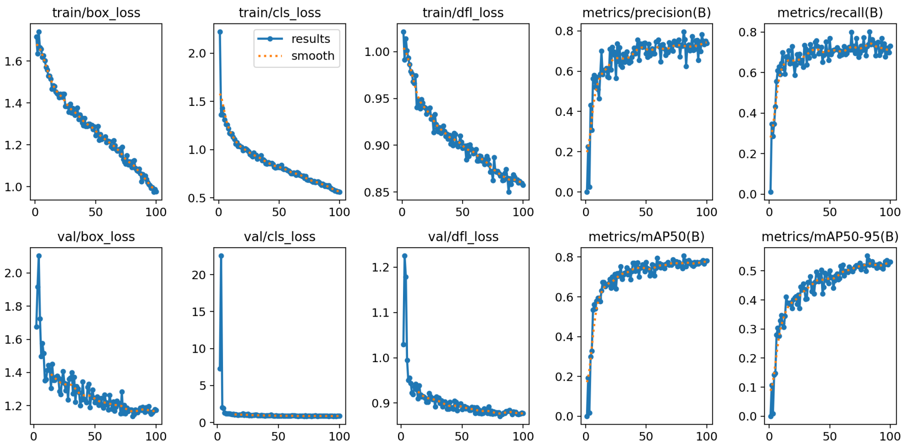

Fig. 10. Large YOLOv8 model results

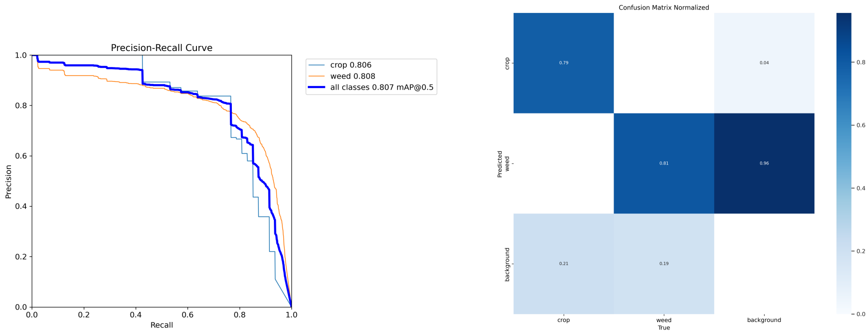

Fig. 11. Large YOLOv8 model results

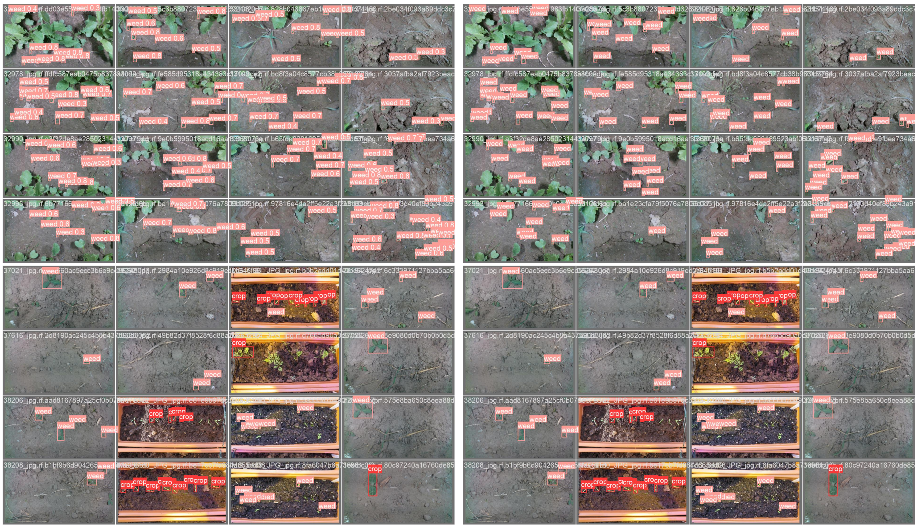

Fig. 12. Large YOLOv8 model results

3.6 YOLOv8 Extra-Large Model

The slowest model is of the extra-large architecture but it is the most stable as well. The increase in architecture can reduce false positives which further increases the accuracy of the model. The results of the extra-large model are provided in Fig. 13, the PR curve along the confusion matrix in Fig. 14, and the model's predictions in Fig. 15.

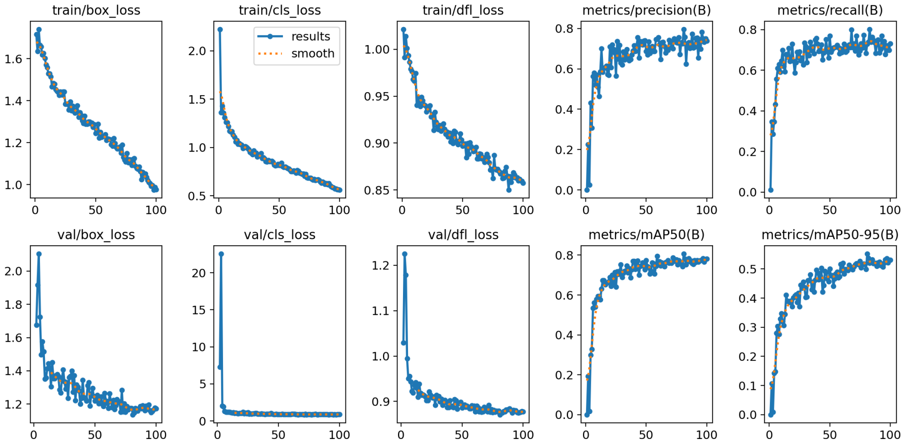

Fig. 13. Extra-Large YOLOv8 model results

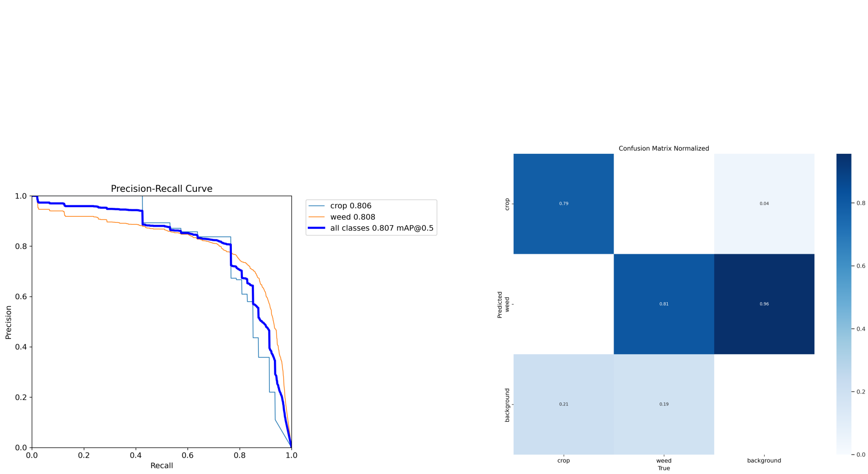

Fig. 14. Extra-Large YOLOv8 model results

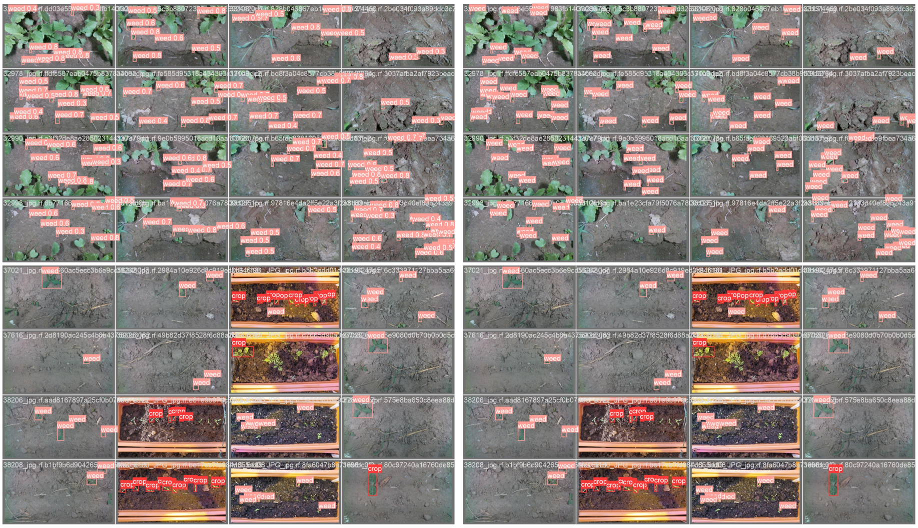

Fig. 15. Extra-Large YOLOv8 model results

4 Conclusion

This research tackles an important problem in agriculture. The detection of weeds between crops can be difficult due to their morphological similarities and hence the use of AI is justified. With the advancement of deep-learning, more powerful models have begun to emerge that are less computationally demanding. Such is the case with the YOLOv8 model chosen for this research. The data that was trained is publicly available and consists of aerial images of plants. The performance of the model was compared across its architecture. Models with five different sizes were tested and reported. The results indicate that the model can be even faster with lightweight architecture, but concern about its stability arises. Real-time use sacrifices stability so the predictions can be made with cheaper mechanization. However, in the cases where absolute precision is required and is not with a time factor, the larger models tend to excel. Future research in domains includes improvements to the framework for prediction including a potential optimizing algorithm, as well as to implement the YOLO network on other real-world problems.

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