The Crop Plant Scheduling Problem

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AIRO ODS 2022 Conference, Florence, Italy

September 1st, 2022

Introduction

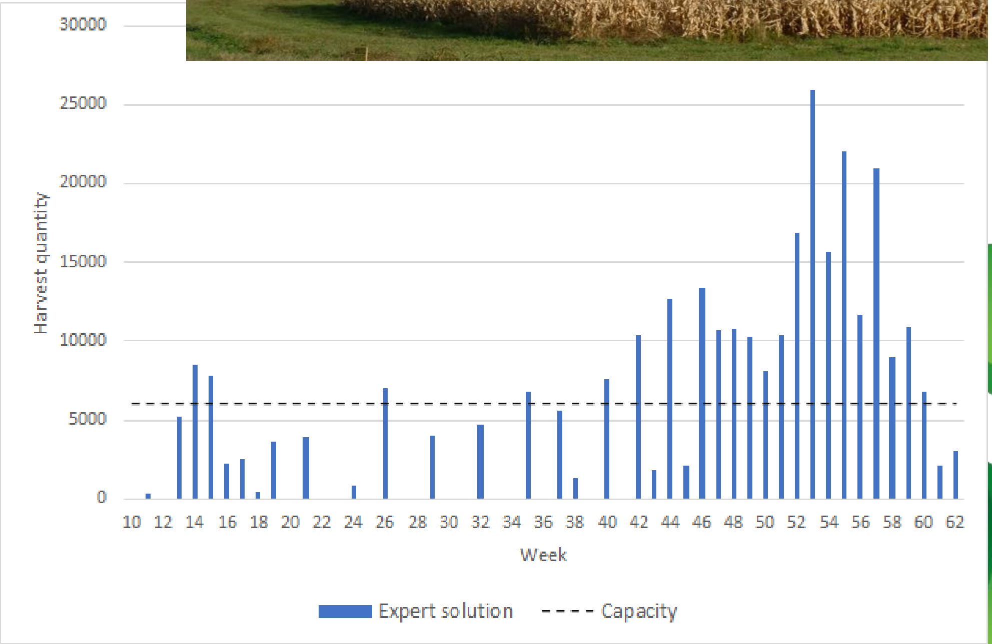
– Determine planting schedules for seed corn, to maximize the weekly production on the given field, while avoiding waste

  – Storage capacity should not be overflown by the weekly harvest

– The workforce should be cleverly engaged

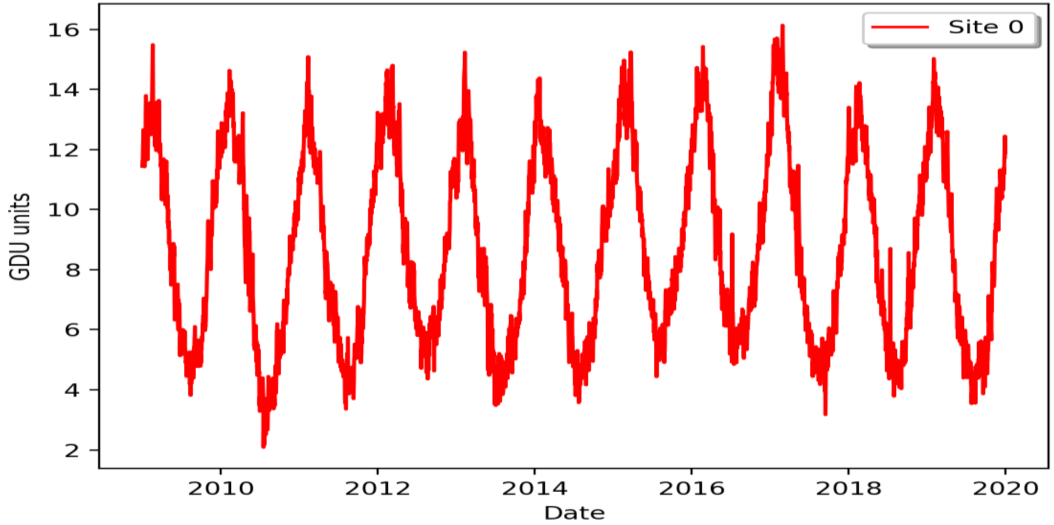
– Syngenta Crop Challenge in Analytics 2021

– Research funded by Ministry for Higher Education and Scientific Research of AP Vojvodina



Problem Data

- Set of crop populations to be cultivated on the given field
  - Crop population: Planting time window, the needed amount of accumulated GDUs, expected yield amount
- Storage capacity for each plantation
- Historical data about growing degree units (GDUs)



State of the art

- Quite few related works, e.g.:
  - Alberto Santini, Enrico Bartolini, Michael Schneider, Vinicius Greco de Lemos: The crop growth planning problem in vertical farming. European Journal of Operational Research, Volume 294, Issue 1, 2021, https://doi.org/10.1016/j.ejor.2021.01.034.
  - Moussa Waongo: Optimizing Planting Dates for Agricultural Decision-Making under Climate Change over Burkina Faso/West Africa, PhD thesis, Universität Augsburg, Germany, 2015.
- Grapes harvest optimization (Albornoz et al., 2021), forest harvest scheduling (Neto et al., 2020)
- However, the problem is gaining popularity, e.g.:
  - AIPLAN4EU Project: Agriculture use case “Campaign-Planning for Silage Maize Harvesting”

Solution Approach

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Forecast expected growing degree units (GDUs) for the planning horizon

To be used to determine the harvest week, for each potential planting date

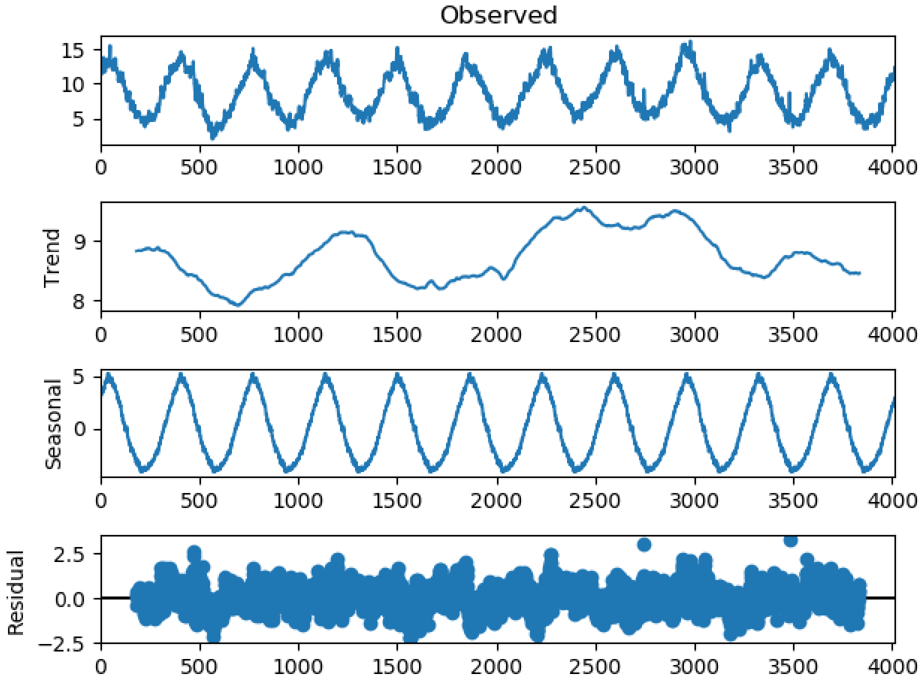
Determine optimal harvest schedules to meet the demand and avoid overproduction and waste

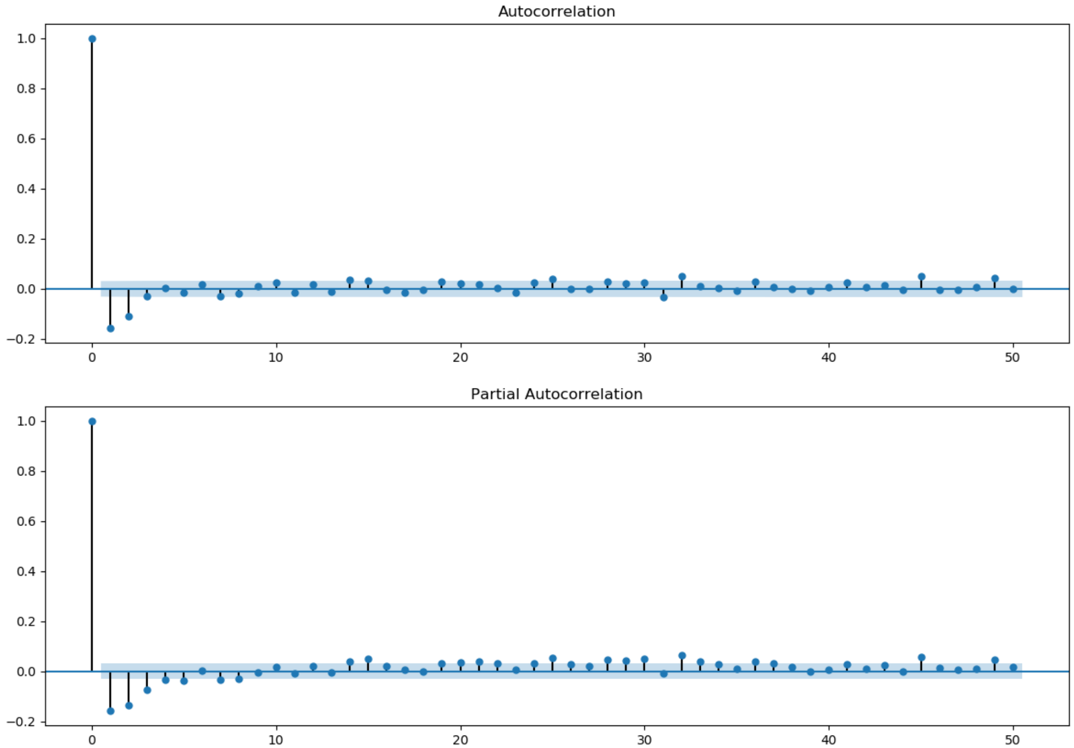
Avoid gaps in harvest weeks and keep their number as low as possible

Backtrack the possible planting dates for each population

GDU / Harvest Forecast

- ARIMA(p, d, q) model
  - Parameters determined with the Box-Jenkins method





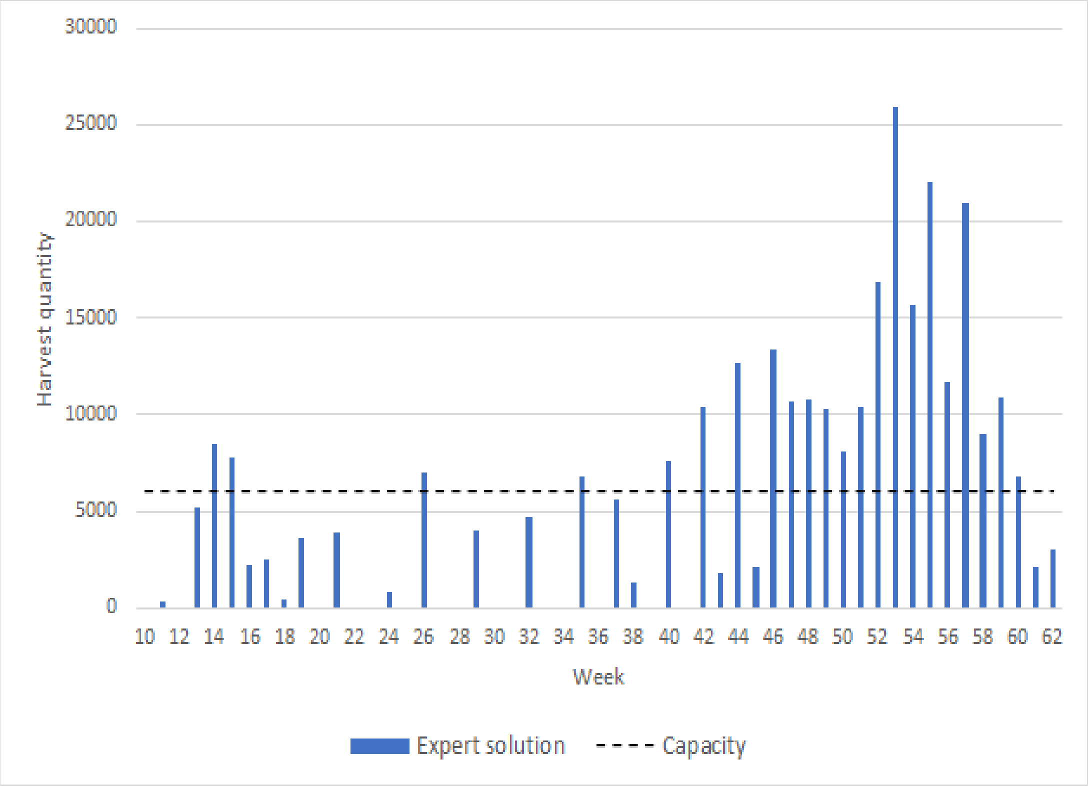
Harvest Schedule ILP 1/2

– Objectives

$$\min \quad f_1 = \sum_{w \in W} \left| \sum_{p \in P} h_{pw} Q_p - C \right| \qquad (1)$$

$$\min \quad f_2 = \sum_{w \in W} u_w \qquad (2)$$

$$\min \quad f_3 = \sum_{w \in \{1..|W|-1\}} |u_{w+1} - u_w| \qquad (3)$$



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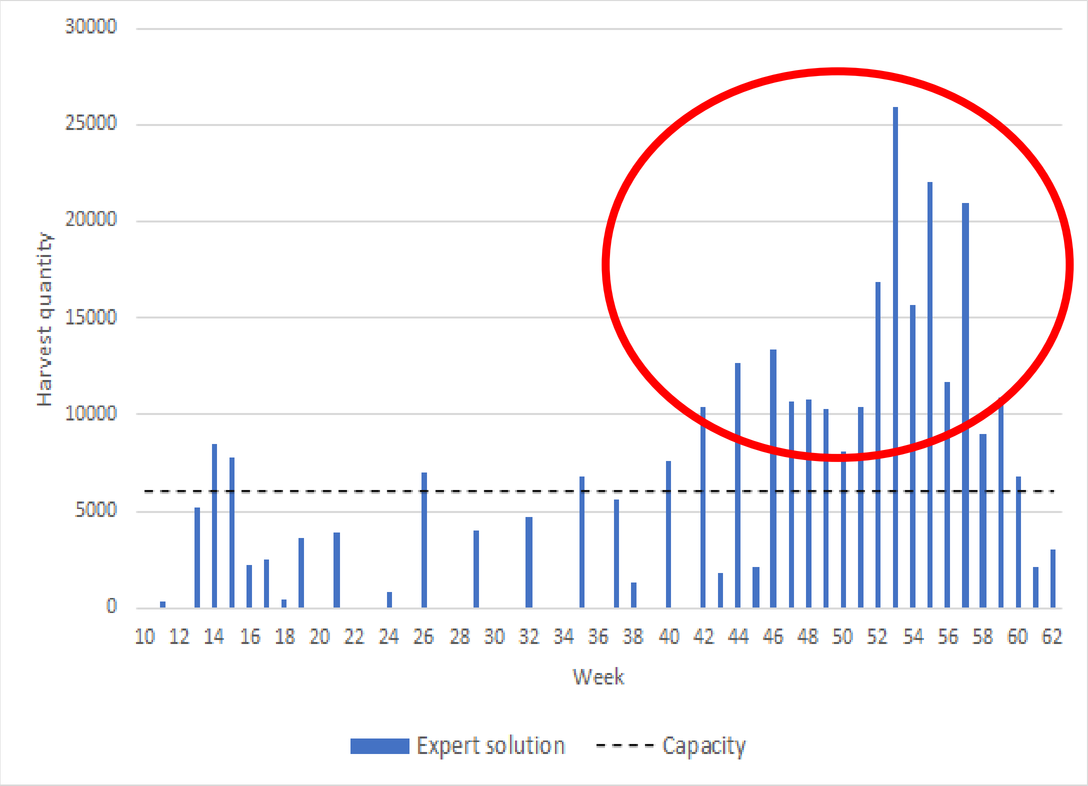

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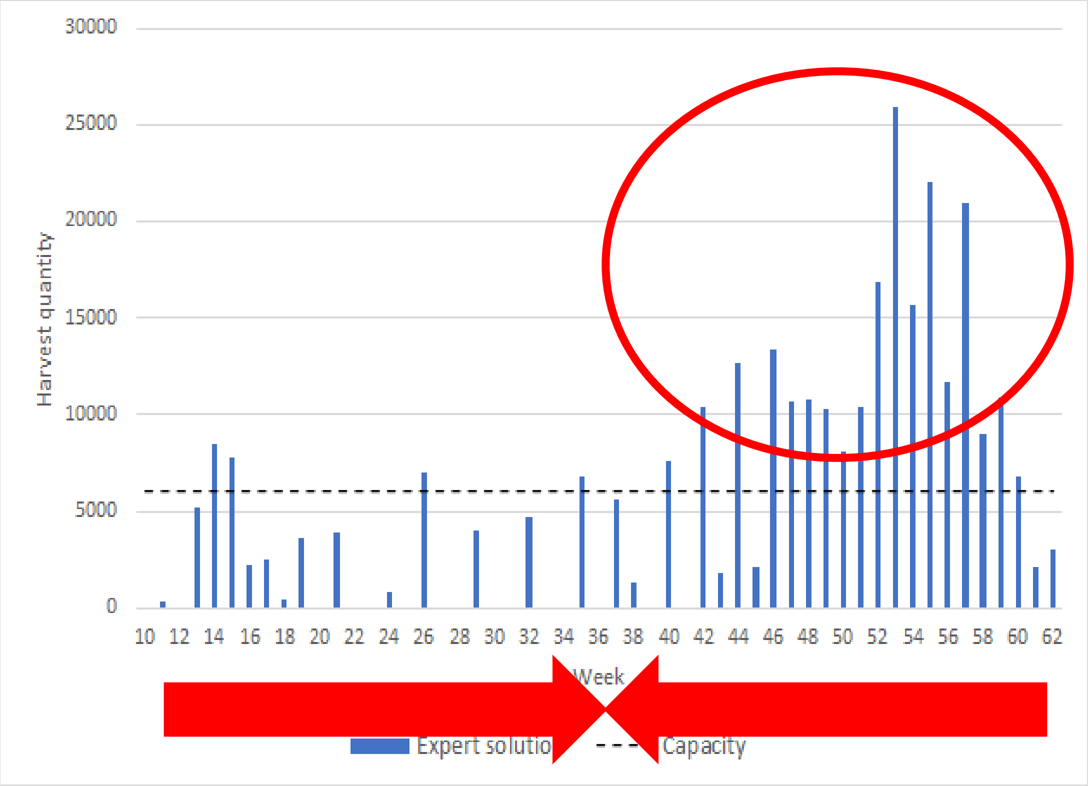

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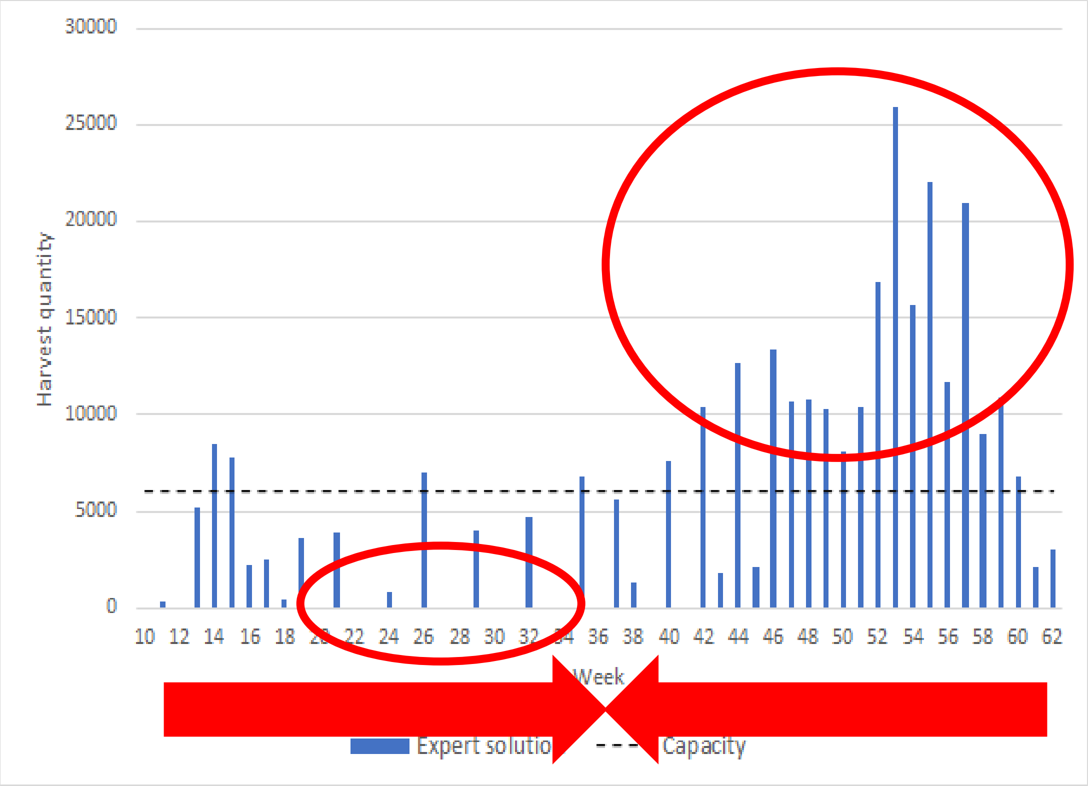

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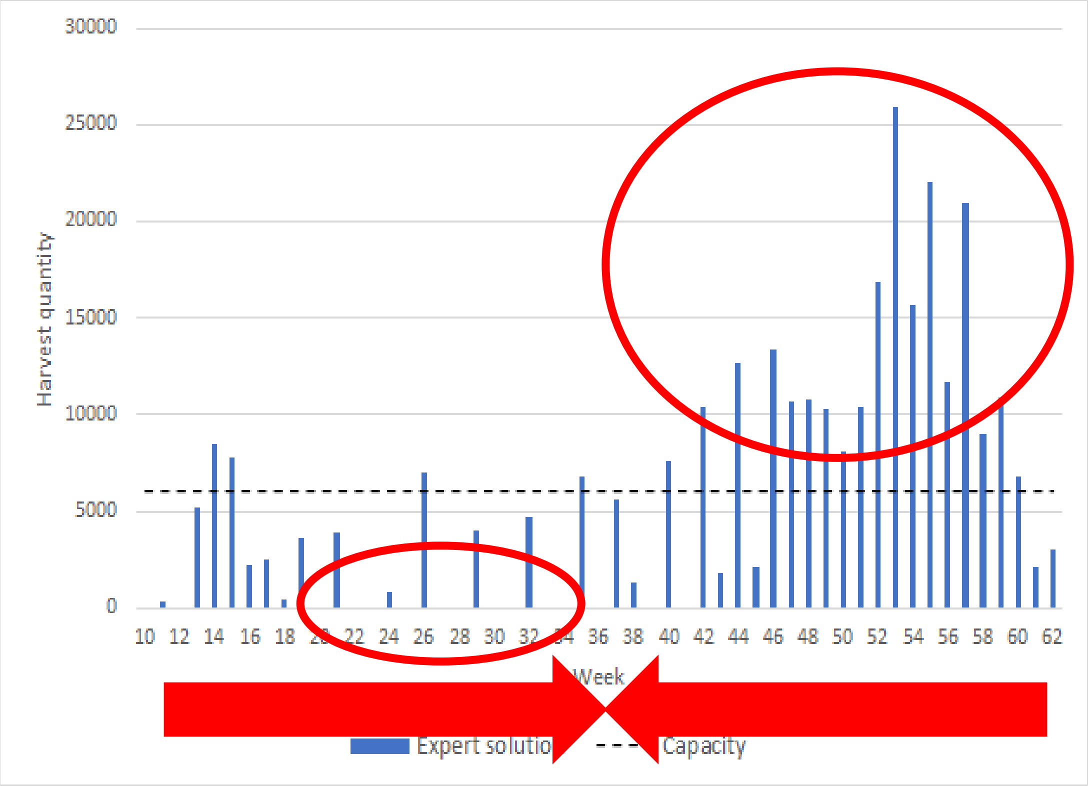
$$\min \quad z = f_1 + c \cdot f_2 + c \cdot f_3$$



Harvest Schedule ILP 2/2

– Constraints

$$\sum_{w:(p,w)\in F} h_{pw} = 1 \qquad \forall p \in P$$

$$\sum_{w\in W} h_{pw} = 1 \qquad \forall p \in P$$

$$\sum_{p:(p,w)\in F} h_{pw} \leq u_w \cdot M_1 \qquad \forall w \in W$$

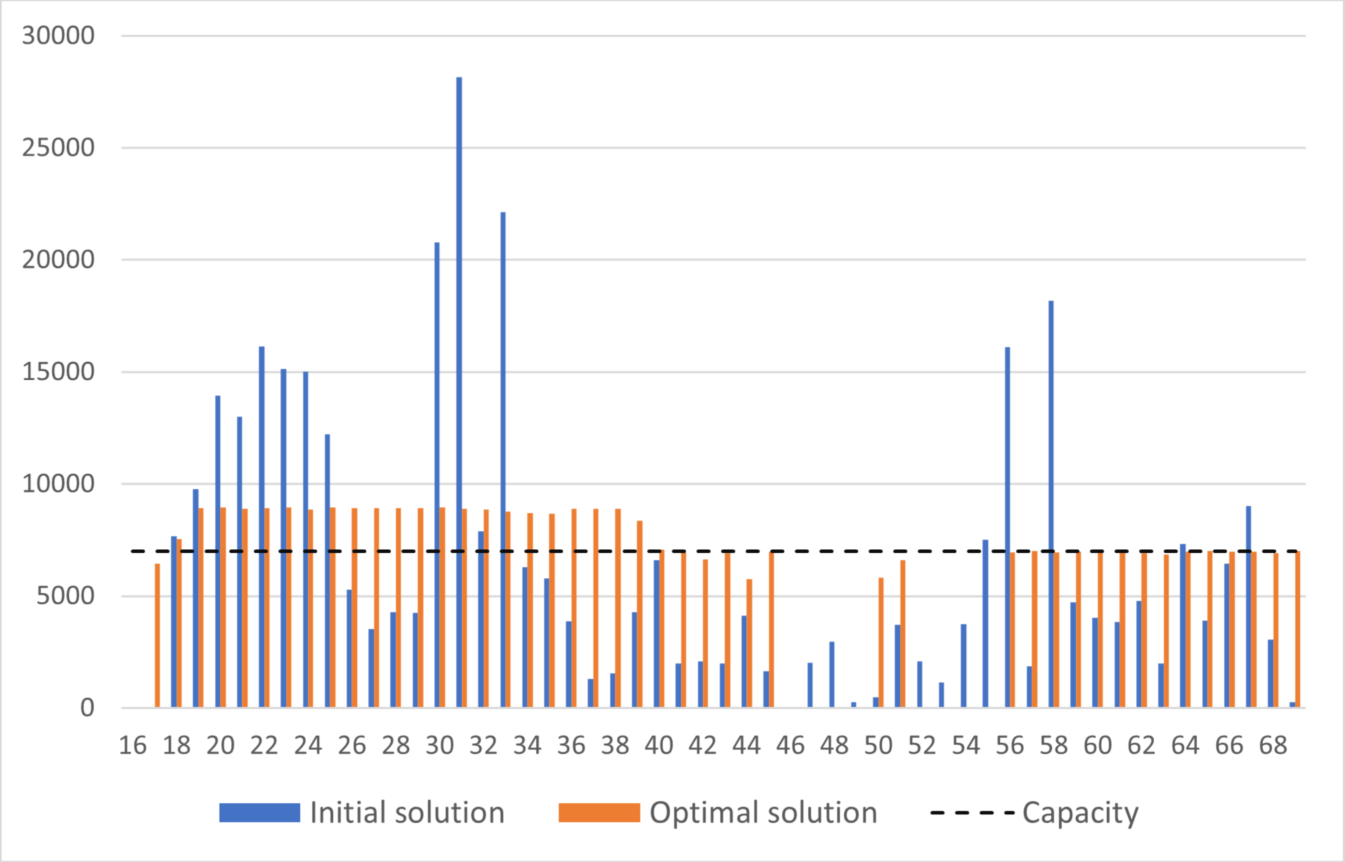
$$h_{pw} \in \{0, 1\} \qquad \forall p \in P, w \in W$$

$$u_w \in \{0, 1\} \qquad \forall w \in W$$

ILP Results – Site 1

– Instance 1 – 1375 corn populations, planning period of one year, storage capacity 7000 units.

– Solution time[1] 28.67 seconds

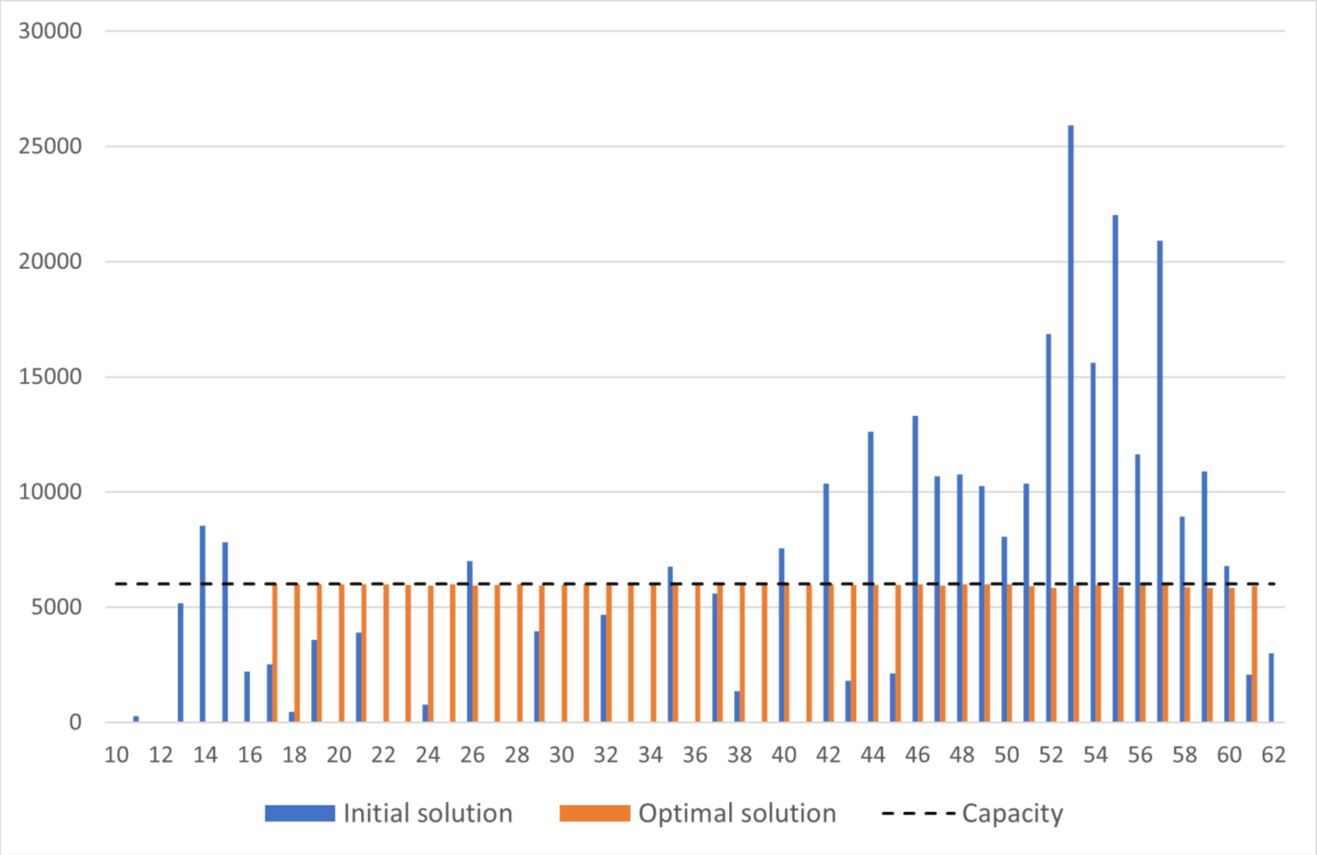


[1] IBM ILOG CPLEX ver. 12.9 on Intel(R) Core(TM) i5-9400 processor at 2.90GHz, with 16GB RAM

ILP Results – Site 2

– Instance 2 – 1194 corn populations, planning period of one year, storage capacity 6000 units.

– Solution time[1] 324.28 seconds



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Heuristic Solution Approach

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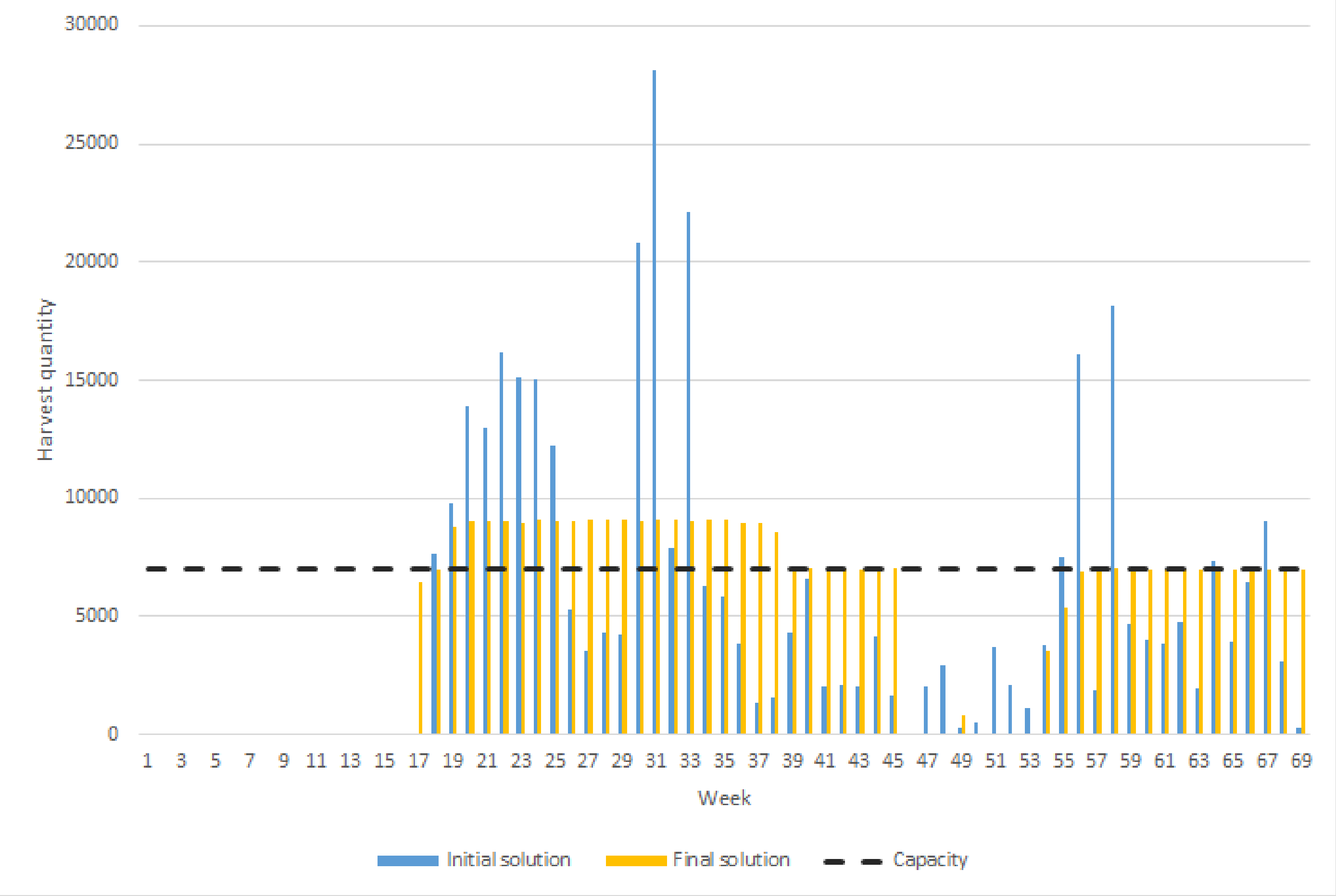
- ALNS-based heuristic
- Operators:
  - Rebalancing operators which change the harvest week of some populations from high-quantity harvest weeks to low-quantity harvest weeks
  - Stability operator which aims at equalizing the amount of harvest collected in consecutive weeks
  - Emptying operators which aim at removing all populations from a given week in order to completely avoid harvesting in that week
  - Capacity operator which aims at setting the harvest quantity of a given week as close as possible to capacity

ALNS Results – Site 1

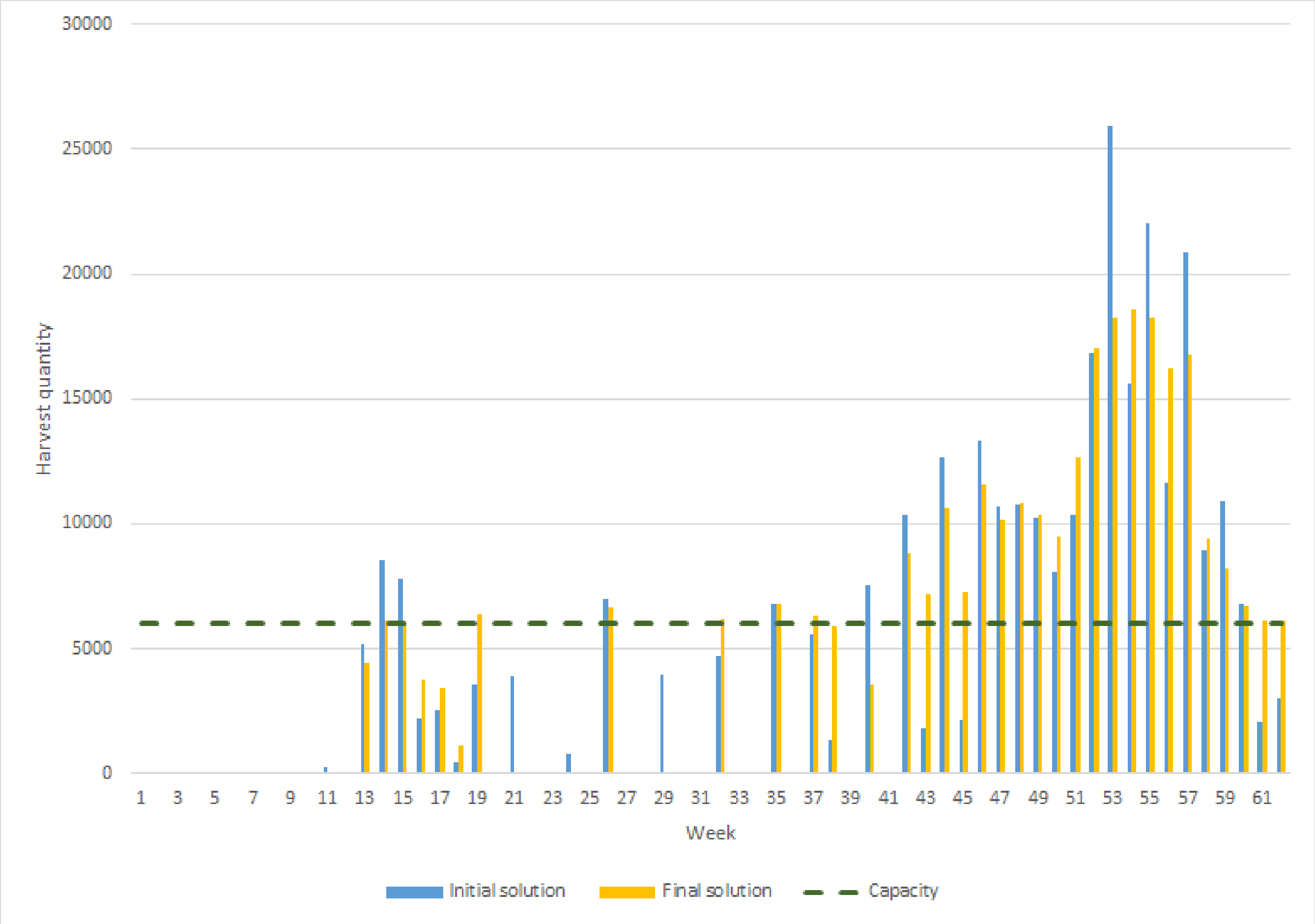
- Instance 1 – 1375 corn populations, planning period of one year, storage capacity 7000 units.
- Approx. 34 min.



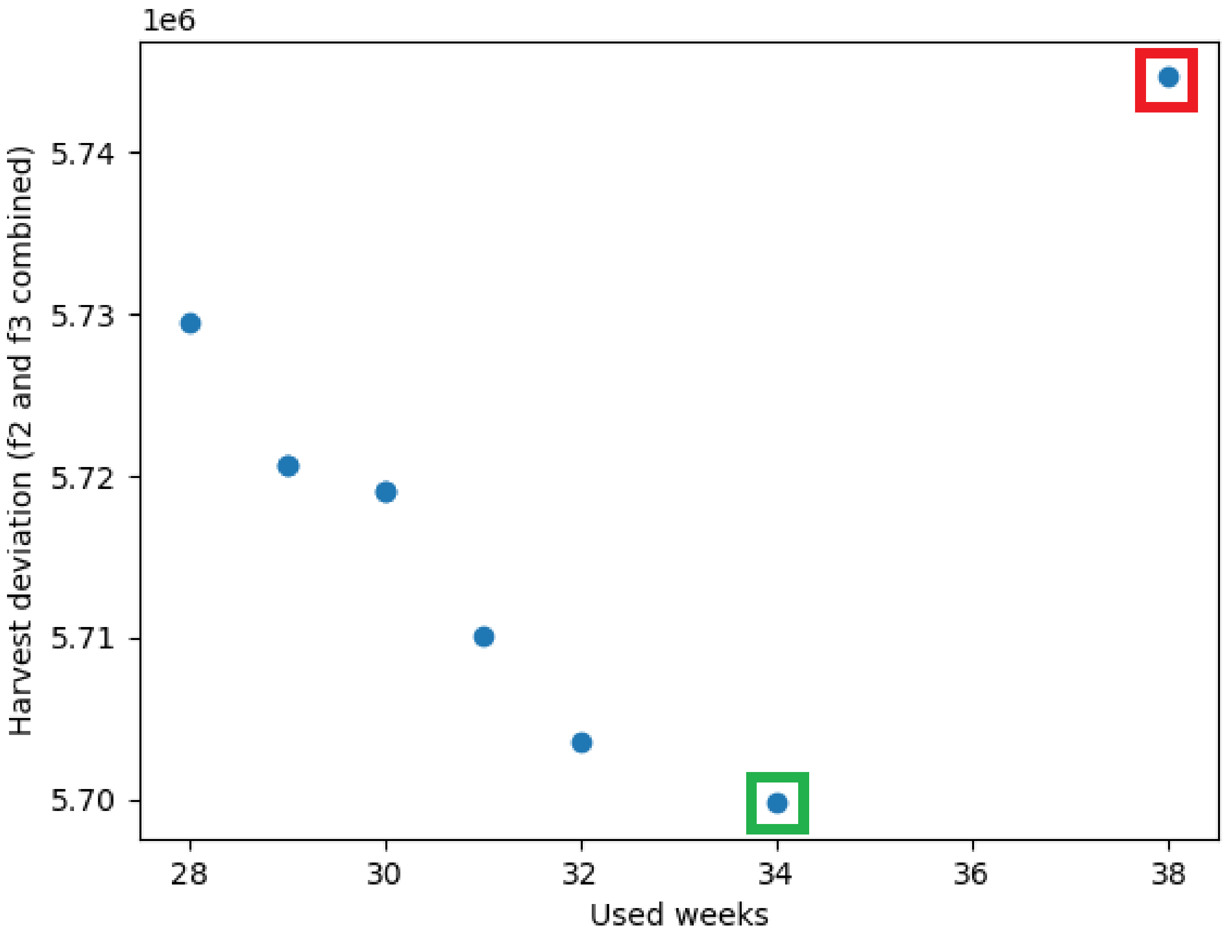
ALNS Results – Site 2

– Instance 2 – 1194 corn populations, planning period of one year, storage capacity 6000 units.

– Approx. 31 min.



ALNS Results – Pareto Analysis



Future / ongoing work

- Enrichment of the problem / model, e.g.:
  - Choice of field and accounting for its capacity
  - Expected yield as a function of the accumulated GDUs amount
  - Robust or stochastic modelling to account for GDU forecast imprecision
- Development of synthetic and real (larger) case studies
- Development of the GA-based algorithm
  - Comparison with the previously developed ALNS heuristic (S metric)
- More detailed forecast of GDUs

$$GDD = \frac{T_{\text{max}} + T_{\text{min}}}{2} - T_{\text{base}}$$

Conclusions

- We have defined the Crop Plant Scheduling Problem
  - Solvable with the MP solver
- Practical importance and potential
  - Further work on enriching the problem with real aspects
  - Development of solution approach for the enhanced problem version

Q & A

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