

A Distributed System for Yield Prediction and Order Allocation in the Short-Food Supply Chain

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SMALLDERS
Empowering the Small Holders

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01

Context and Motivation

Context and Motivation: Why smallholders?



Smallholders are small-scale agriculture models that usually support the life of a single family



They are producing about one-third of the population's food supply



With the increase in population, food production should increase to go with this demand

Context and Motivation: Why smallholders?



Smallholders face challenges at different fronts of the supply chain



Other than production, there are difficulties in planning, delivery, and increase in raw material prices



Unfortunately, many of these problems are difficult to overcome

Context and Motivation: The SMALLDERS Project

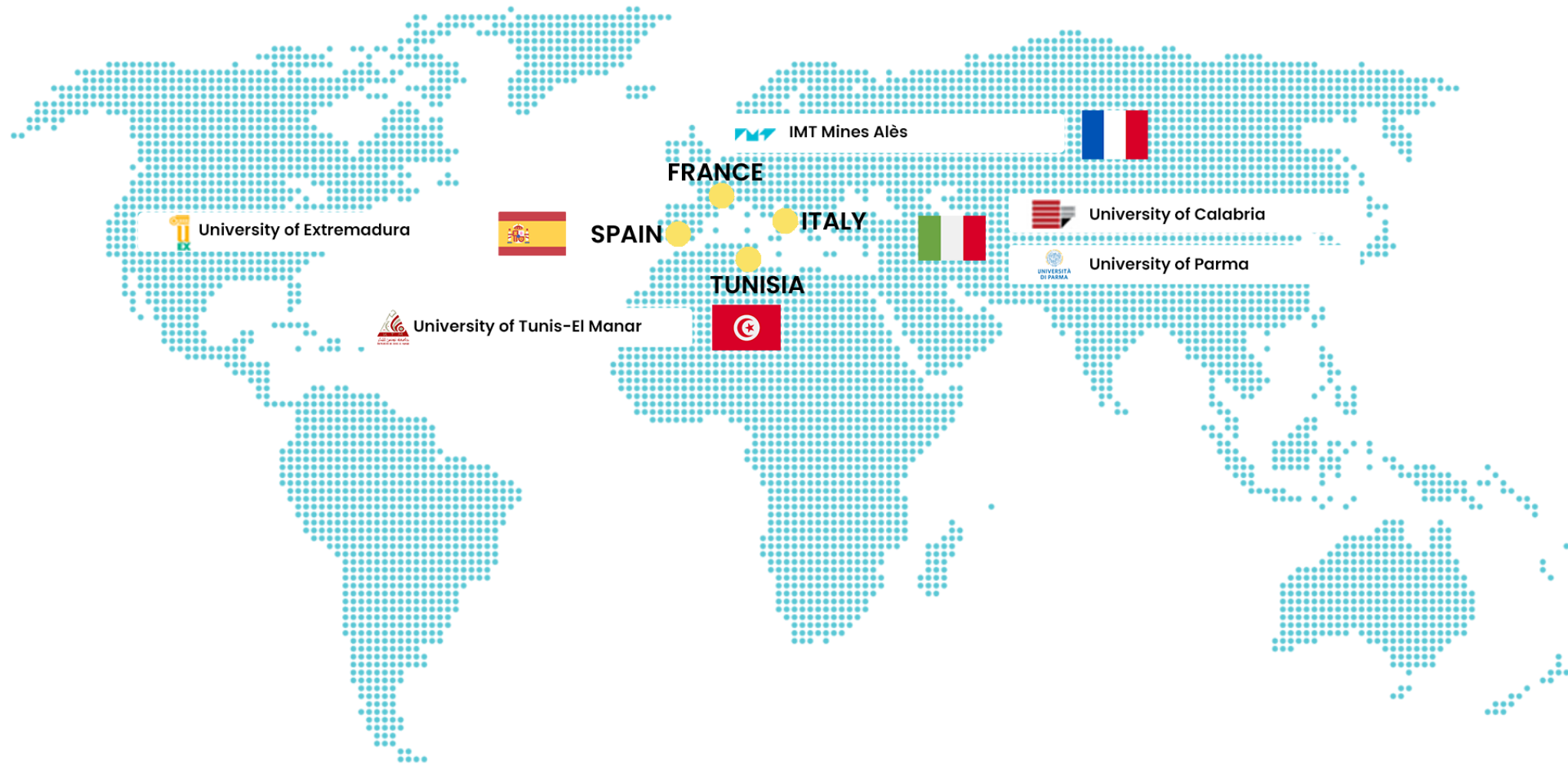
- Smart
- Models for
- Agrifood
- Local
- vaLue chain based on
- Digital technologies for
- Enabling covid-19
- Resilience and
- Sustainability



SMALLDERS

Empowering the Small Holders

Context and Motivation: The SMALLDERS Project



Context and Motivation: The SMALLDERS Project

Increase Salability



Coping with shortage of workforce



Increase farm production efficiency

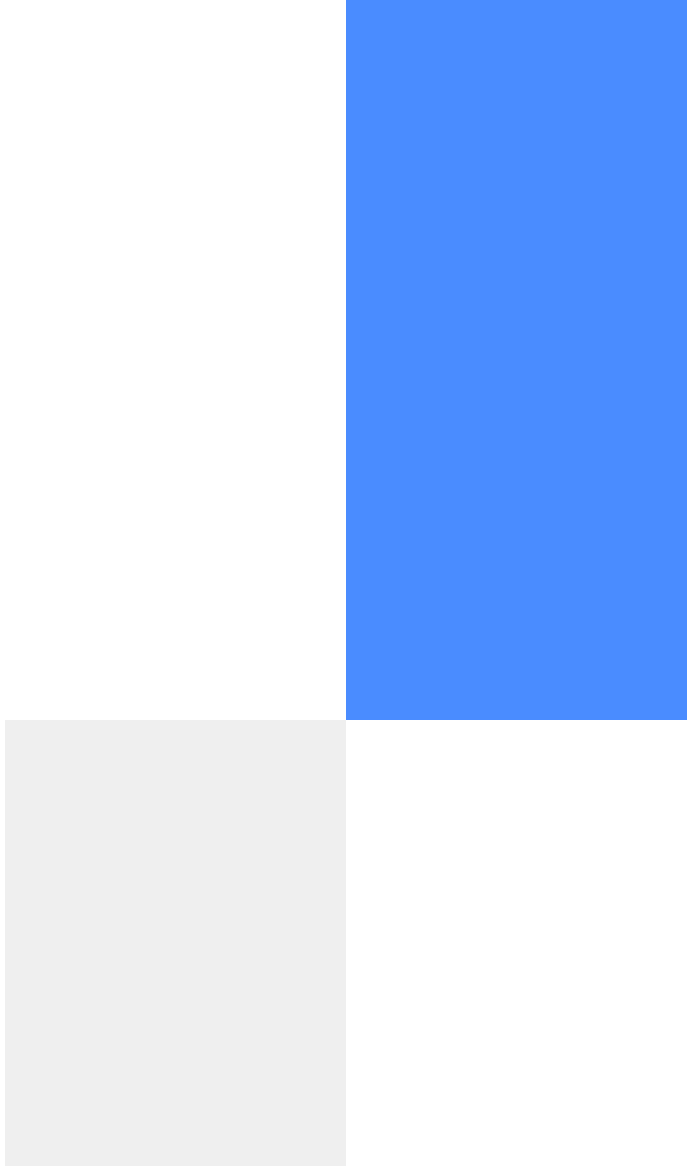


Increase multi-capital sustainability



Context and Motivation: What is our goal

- The partners of the SMALLDERS project will work hand in hand to complete the objectives of the project
- The main task of our work is to offer decision-making support to the smallholders



02

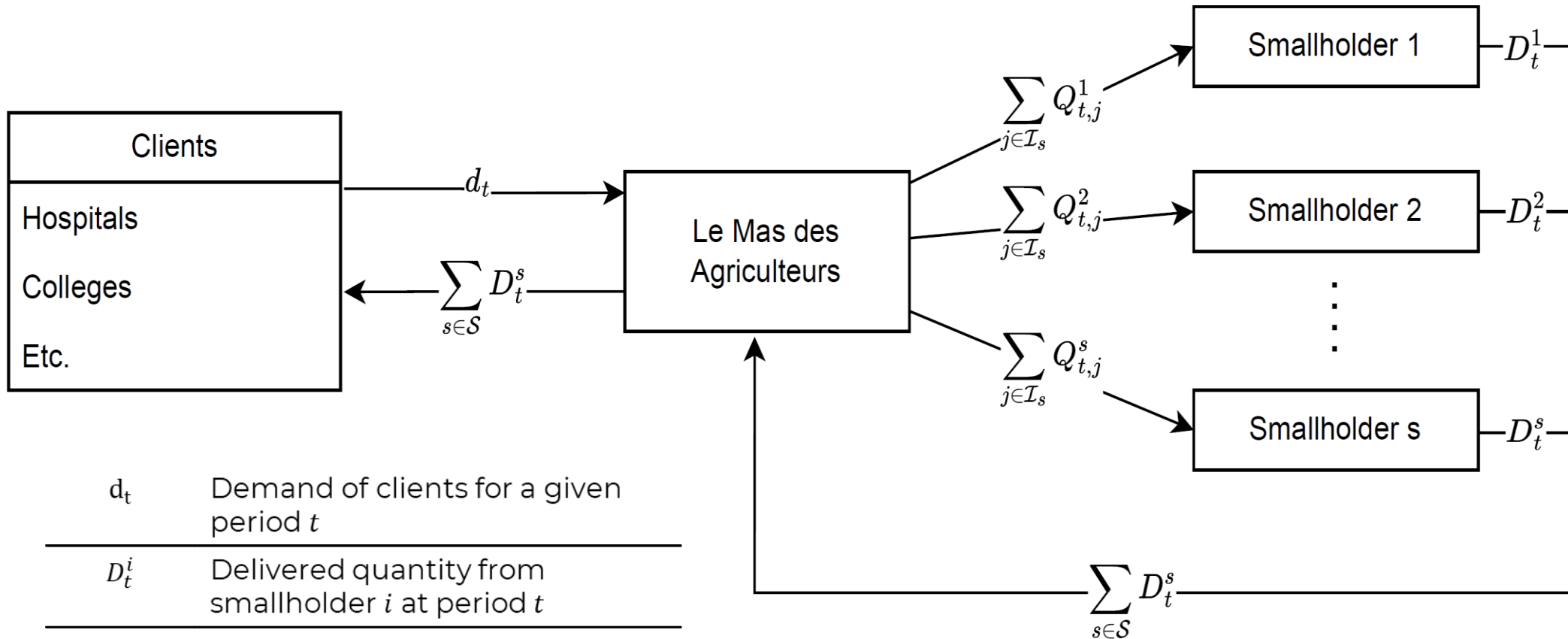
Our work so far

Our work so far: Supplier Selection

- To get a better understanding of the market, we contacted “Le Mas des Agriculteurs”
- It is an association that acts as a retailer between the smallholders of the Gard and clients
- The biggest challenges for Le Mas des Agriculteurs:
 - predicting demand
 - choosing which producers to buy from
 - optimizing production planning



Our work so far: Supplier Selection



d_t Demand of clients for a given period t

D_t^i Delivered quantity from smallholder i at period t

$\sum_{s \in \mathcal{S}} D_t^s$ Delivered quantity from all smallholders for a given period t

$\sum_{j \in \mathcal{I}_s} Q_{t,j}^i$ Ordered quantity from smallholder i at time t

Our work so far: Supplier Selection

- We developed a [Linear Programming](#) model that aims to minimize the cost of purchasing and storage for “Le Mas des Agriculteurs”
- The model takes as input the expected demand for the upcoming months and plans the orders accordingly
- The model takes into consideration:
 - Dynamic demand
 - Dynamic production capacity
 - Dynamic inventory
 - Quantity dependent pricing

Our work so far: Supplier Selection

- This linear program is able to offer a purchasing plan for “Le Mas des Agriculteurs”
- However, it does not account for possible disruptions in the delivered quantities by the smallholders



03

Proposed Approach

Proposed approach: A distributed system

- We need to predict possible shortages of yield to manage them as early as possible
- To do so, we need to track the expected yield of every smallholder
- This can be achieved by getting the updates directly from the smallholder and by placing sensors (humidity, temperature, etc.) in the fields.

Proposed approach: A distributed system

- Once a change in yield is predicted, we need to account for it from the side of “Le Mas des Agricultures”
- The previously proposed linear programming model can be adjusted for this task
- We propose using [High Level Architecture](#) (HLA) to organize the flow of information between these components

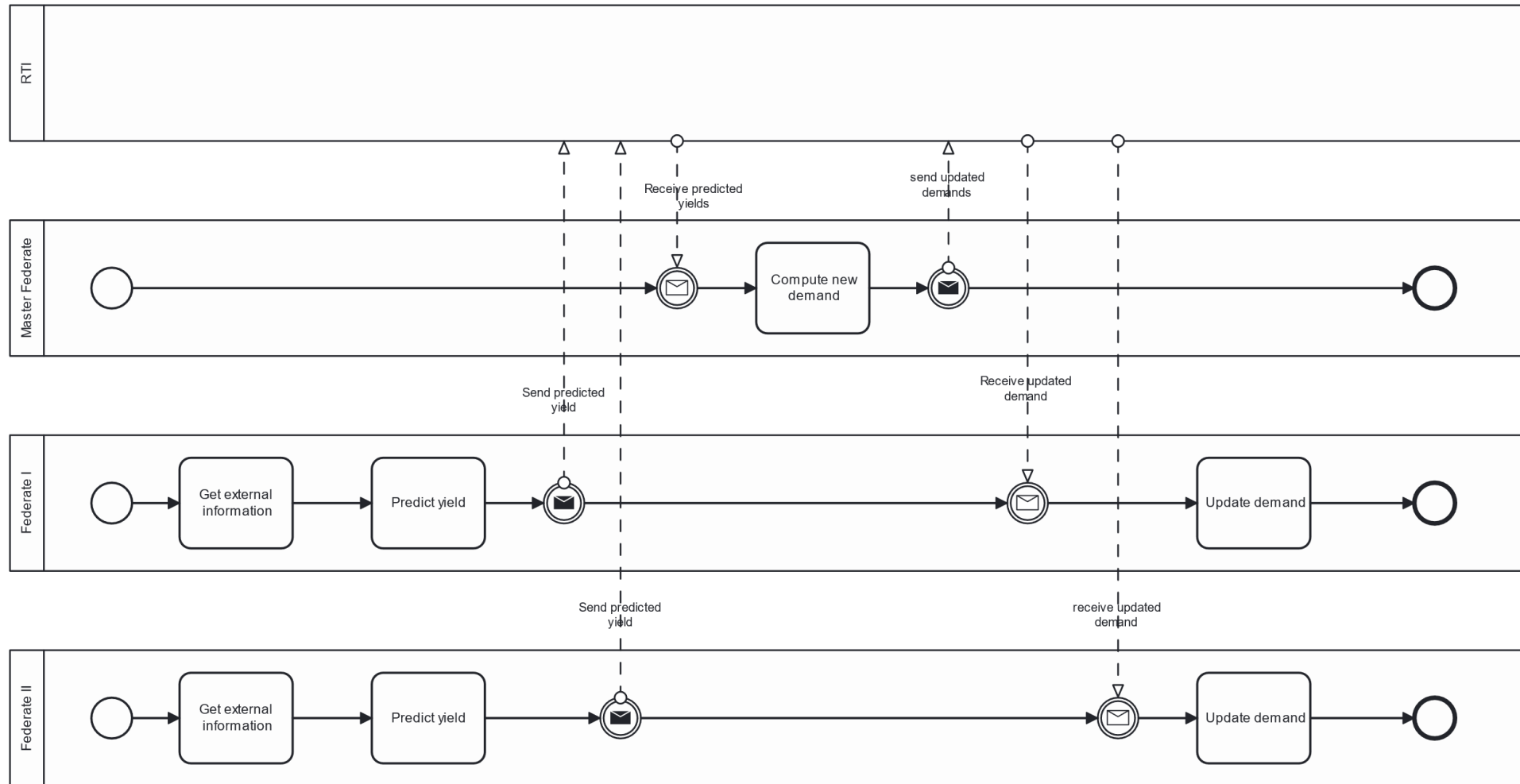
Proposed approach: A distributed system

- HLA is a framework and a set of standards used for developing and integrating complex distributed simulation systems
- HLA allows multiple systems to exchange information
- In HLA, we have a set of federates that communicate with each other using the publish/subscribe model
- All of the operations are overseen by a RunTime Infrastructure (RTI)

Proposed approach: A distributed system

- In our proposal there are two types of federates:
 - Master federate:
 - Reserved for “Le Mas des Agriculteurs”
 - Subscribes to the yield predictions of the smallholders
 - Adjusts and publishes the demand according to the predictions
 - Regular federate:
 - Reserved for the smallholders
 - Receives information from sensors and the smallholder
 - Predicts and publishes changes in yield
 - Subscribes to the updates in demand

Proposed approach: A distributed system





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Discussion and Future Direction

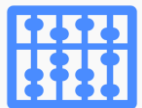
Discussion and Future Direction



We aim to help retailers adjust to possible disruptions in production in the agricultural field



We propose an HLA system that allows the farms and retailer to communicate



Any change in the expected yield will be sent to the retailer which will allow them to account for it

Discussion and Future Direction



A review of the literature is needed to decide on which sensors to use



Multiple prediction methods should be tested to select the best model



The security risks should be addressed and the privacy of the information should be ensured

Thank You

Do you have any questions?

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Appendix A: Linear programming model

$$\text{TC: min } \sum_{t \in \mathcal{T}} \sum_{s \in \mathcal{S}} \left(h_t^s I_t^s + \sum_{j \in \mathcal{P}_s} c_j^s Q_{t,j}^s \right) \quad (1)$$

Subject to constraints:

$$I_t^s \geq \sum_{\tau=1}^t \sum_{j \in \mathcal{I}_s} Q_{\tau,j}^s - \sum_{\tau=1}^t D_{\tau}^s \quad \forall s \in \mathcal{S}, \forall t \in \mathcal{T} \quad (2)$$

$$\sum_{s \in \mathcal{S}} D_t^s \geq d_t \quad \forall t \in \mathcal{T} \quad (3)$$

$$I_t^s \leq i_t^s \quad \forall s \in \mathcal{S}, \forall t \in \mathcal{T} \quad (4)$$

$$\sum_{j \in \mathcal{I}_s} Q_{t,j}^s \leq c_t^s \quad \forall s \in \mathcal{S}, \forall t \in \mathcal{T} \quad (5)$$

$$l_{sj} Y_{t,j}^s - Q_{t,j}^s \leq 0 \quad \forall s \in \mathcal{S}, \forall t \in \mathcal{T}, \forall j \in \mathcal{P}_s \quad (6)$$

$$Q_{t,j}^s - u_{sj} Y_{t,j}^s \leq 0 \quad \forall s \in \mathcal{S}, \forall t \in \mathcal{T}, \forall j \in \mathcal{P}_s \quad (7)$$

$$I_t^s \geq 0 \quad \forall s \in \mathcal{S} \setminus \{|S|\}, \forall t \in \mathcal{T} \quad (8)$$

$$I_t^{|S|} = 0 \quad \forall t \in \mathcal{T} \quad (9)$$

$$\sum_{j \in \mathcal{P}_s} Y_{t,j}^s \leq 1 \quad \forall s \in \mathcal{S}, \forall t \in \mathcal{T} \quad (10)$$

$$Y_{t,j}^s \in \{0, 1\} \quad \forall s \in \mathcal{S}, \forall j \in \mathcal{P}_s, \forall t \in \mathcal{T} \quad (11)$$

$$Q_{t,j}^s, D_t^s \geq 0 \quad \forall s \in \mathcal{S}, \forall t \in \mathcal{T} \quad (12)$$

TABLE I
NOTATION OF THE PROPOSED MODEL

Parameters

\mathcal{S}	set of smallholders
\mathcal{T}	number of time buckets
s	index of smallholders, $s \in \mathcal{S}$
t	index of the period
\mathcal{P}_s	ordered set of indices of quantity intervals defining supplier's pricing policy
$[l_{si}, u_{si}]$	lower and upper limits of the i -th quantity interval of smallholder s pricing policy
c_i^s	unit selling price of the i -th quantity interval of smallholder s pricing policy
c_t^s	capacity limit of smallholder s at period t
d_t	monthly certain demand
h_t^s	unit inventory holding cost of smallholder s at period t
i_t^s	capacity in the inventory of smallholder s at period t

Variables

D_t^s	integer decision variable that gives the delivered quantity from supplier s at the end of period t
I_t^s	inventory level of supplier s at the end of period t
$Q_{t,j}^s$	integer decision variable that gives the total quantity to order from smallholder s within the i -th interval of its pricing policy at period t
$Y_{t,j}^s$	binary decision variable indicating if the total ordered quantity from smallholder s at period t is within the i -th interval of its pricing policy