Rabat Business School

2024 SUPPLY CHAIN RESEARCH SUMMIT
Africa's Supply Chain Resilience for Economic Transformation

Developing an Industry 4.0 Ecosystem for Sustainable Supply Chain Practices in the VUCA World: An Exploration in the Emerging Economies

CARISCA's 2024 Supply Chain Research Summit

PhD Dissertation Award Competition

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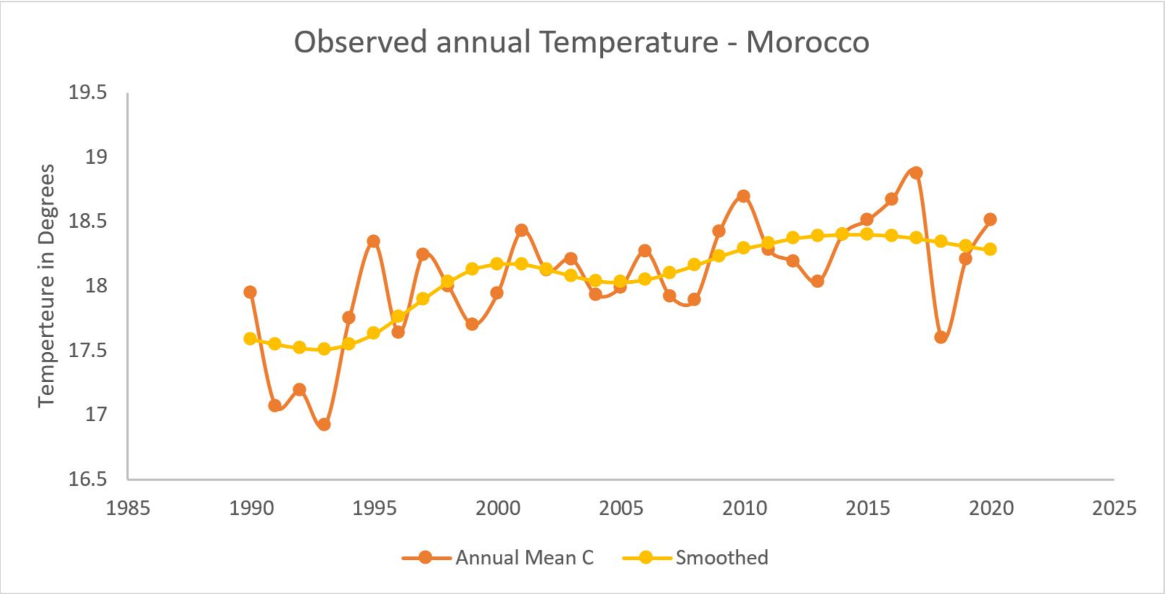
Introduction

- The world has become more volatile and impulsive due to market volatility, manufacturing uncertainty, data complexity, and decision-making ambiguity, shaping the VUCA world **(Bennett and Lemoine, 2014; Mack et al., 2015)**. Most supply chain activities have different stakeholders, changes in process, and lack of clarity creating ambiguity in decision making. So, VUCA influences the supply chain and logistics activities at different levels leading to volatile processes, uncertain demands, complex information sharing, and ambiguous decisions **(El Hathat et al., 2023)**.
- The carbon footprint in supply chain operations has been an issue in the VUCA world. A significant contribution comes from the manufacturing and process industry, and more specifically, the food supply chain is a critical domain. Overall, the industry represents 26 percent of the global greenhouse gas (GHG) emissions, around 13.7 billion tonnes **(Poore and Nemecek, 2018)**.
- The agricultural industry is one such domain that offers a significant challenge to offset the carbon due to its volatile demand and complexities in decoding the carbon dioxide equivalents (CO2eq) usage by land, CO2eq generated from food waste, transportation, and inventory energy usage **(Aikins and Ramanathan, 2020)**.

Introduction

Morocco's annual temperature has risen significantly in the past five years due to global warming due to GHG emissions. Therefore, studying the GHG emissions considering Morocco's environmental and economic impacts is essential and can aid better decision-making. Monitoring the carbon emission at the different stages is imperative for its contribution to the sustainability domain.



Literature and Method

- Within the operations management (OM) scientific community, many studies addressed minimizing carbon footprints and GHG emissions. However, there is a need for indigenous studies from developing countries in the supply chain context, as the production conditions are different in those economies **(Bailis et al., 2015, PAS 2050)**.
- Leading international environ mental efforts (e.g., the United Nations Sustainable Development Goals) are dedicated to the urgent task of reducing carbon emissions and mitigating the effects of climate change. The United Nations has delineated Sustainable Development Goal (SDG) 2 to "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture" (**Gupta et al. 2023**).
- According **Gupta et al. (2023)**, increased digital interconnection and emerging technologies can create data-intensive environments, enabling and improving future OM research on agricultural operations. Also, emerging technologies may dynamically improve stakeholder interactions in the agriculture industry. In this vein, machine learning and blockchain are widely used to manage significant challenges in agriculture practices.

Research objectives

Study 1: Strategizing a Logistics Framework for Organizational Transformation: A Technological Perspective

» How to leverage emerging technologies for competitive advantage in the VUCA world?

Study 2: Modelling and analyzing the GHG emissions in the VUCA world: Evidence from tomato production in Morocco

» How do we integrate machine learning prediction models for assessing the carbon footprint in agricultural production to achieve carbon neutrality?

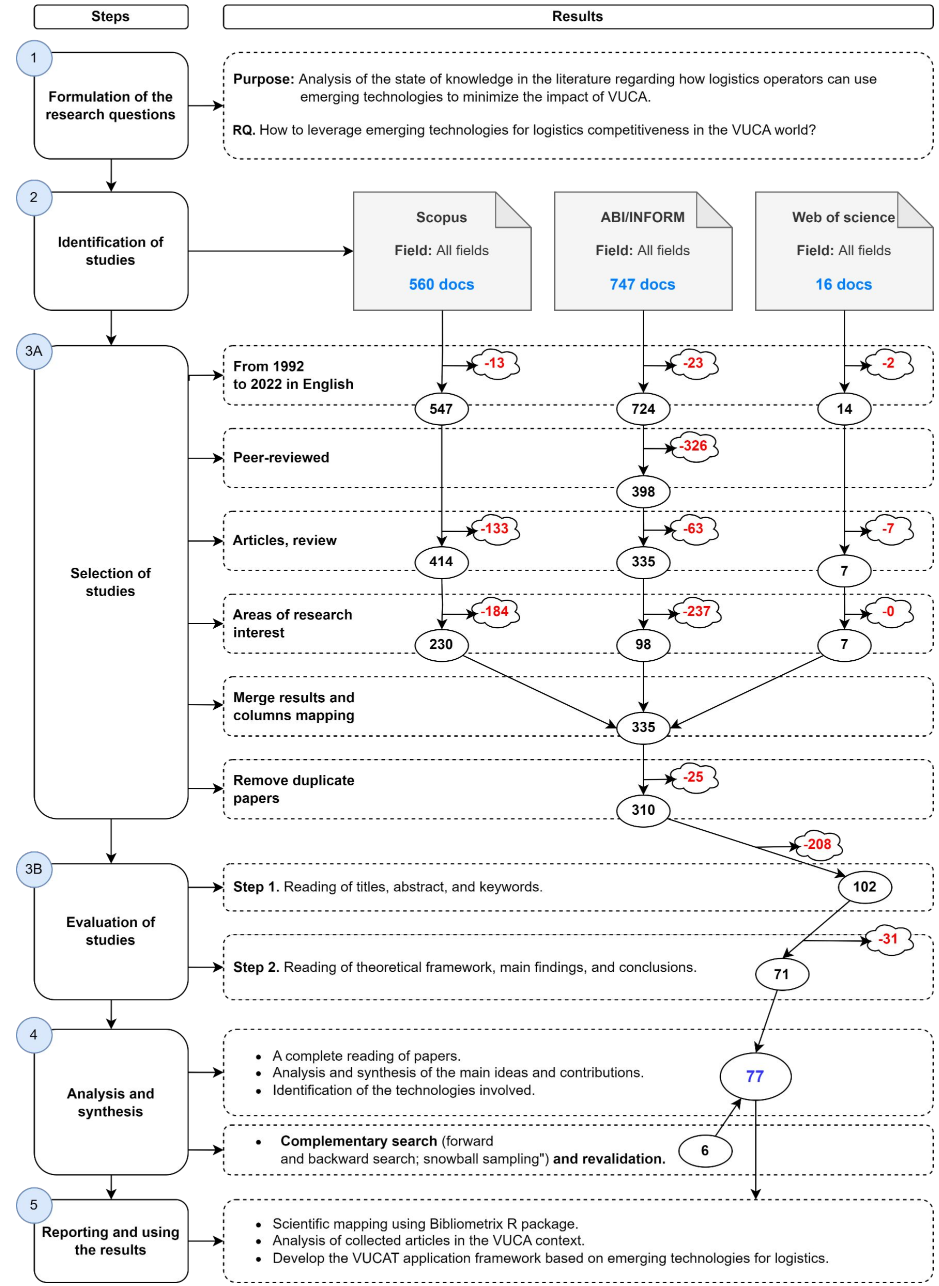
Study 3: Leveraging greenhouse gas emissions traceability in the groundnut supply chain: Blockchain-enabled off-chain machine learning as a driver of sustainability

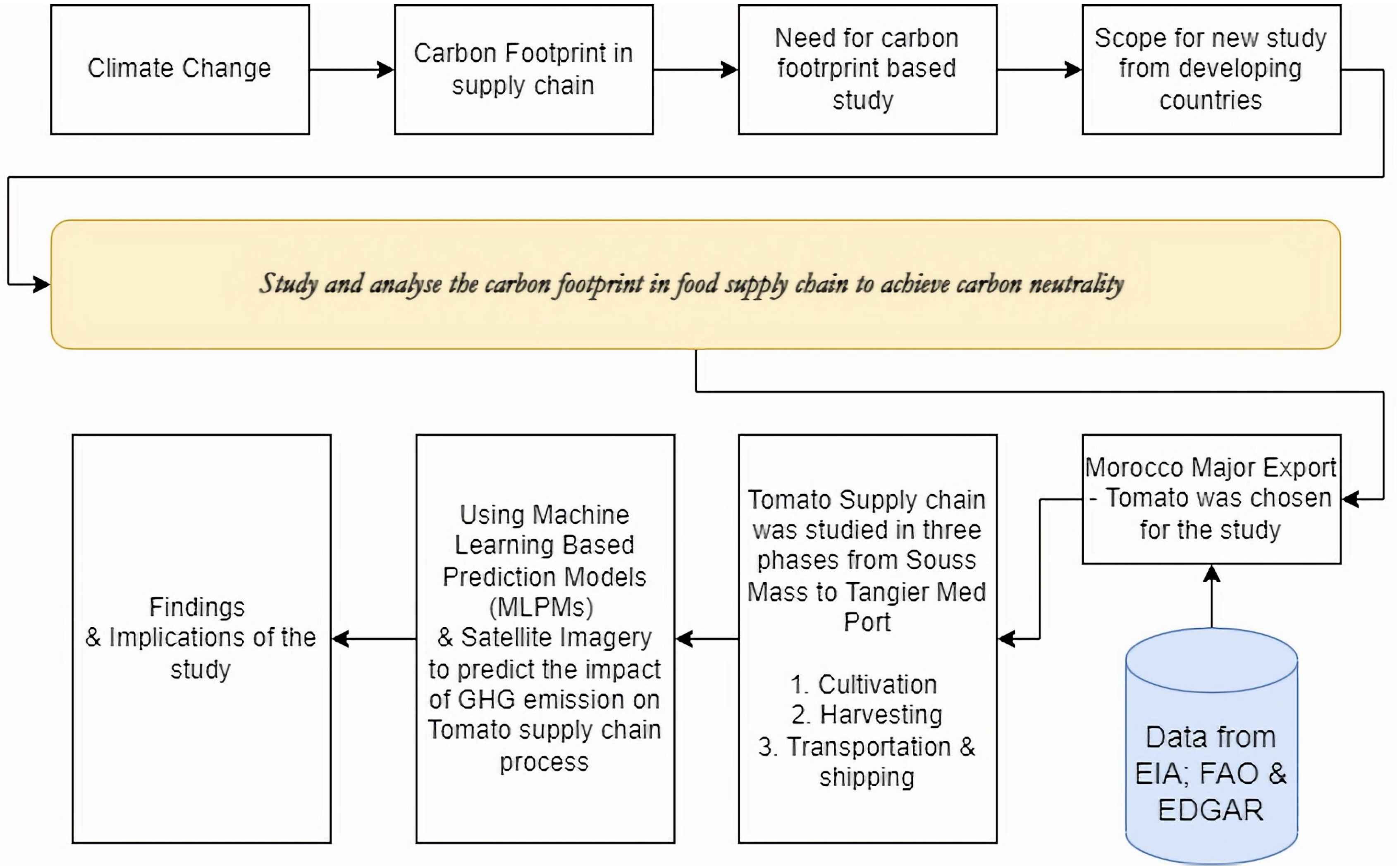
» What impact does integrating blockchain with machine learning have on GHG trans parency in the groundnut supply chain?

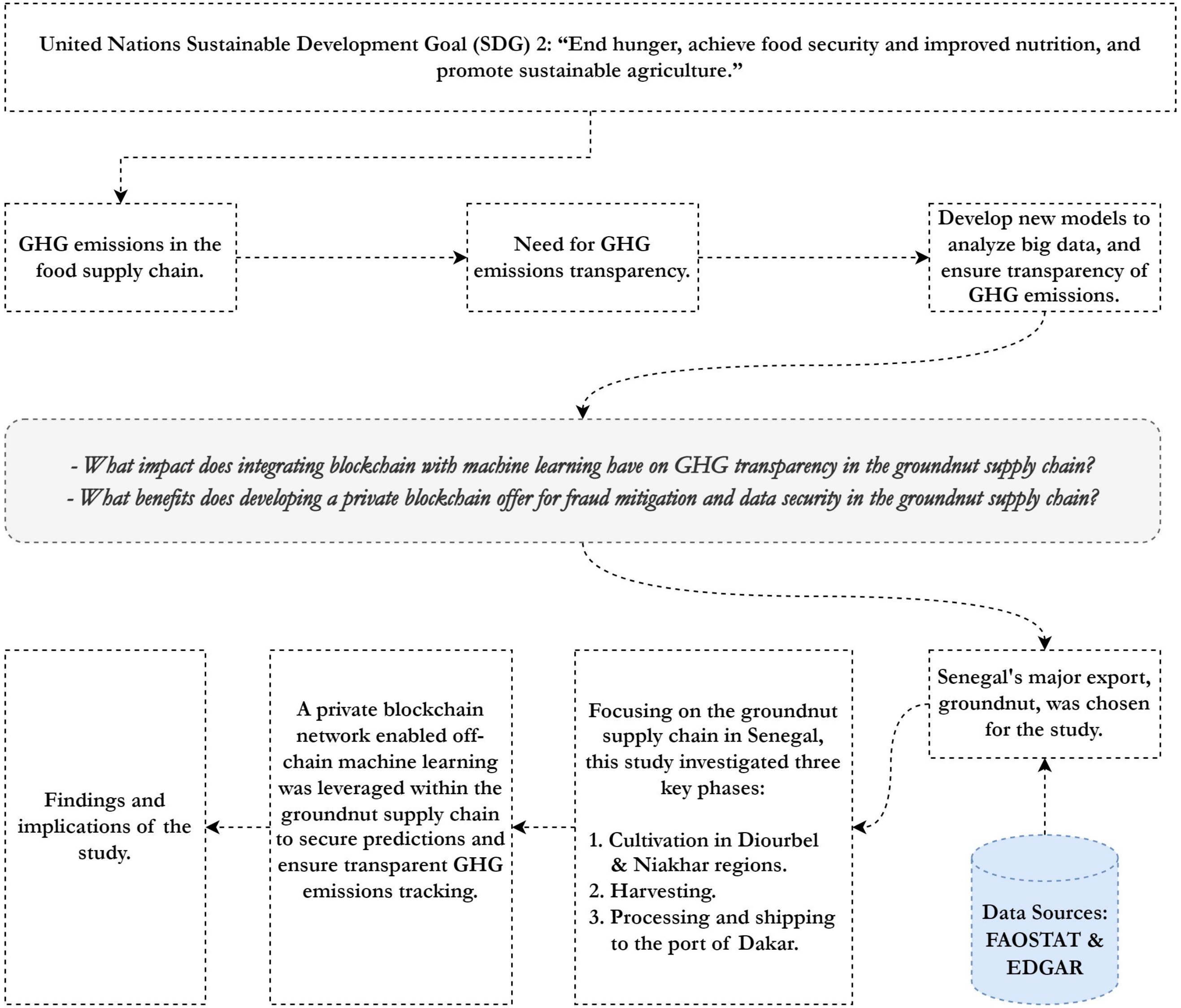
» What benefits does developing a private blockchain offer for fraud mitigation and data security in the groundnut supply chain?

Study 4: Ensuring transparency in the olive oil supply chain: A blockchain study **(In progress)**

» What factors influence the implementation of the Industry 4.0 ecosystem, leveraging blockchain smart contracts and ML, at different stages of the olive oil supply chain?


Steps
Results
1
Formulation of the research questions
Purpose: Analysis of the state of knowledge in the literature regarding how logistics operators can use emerging technologies to minimize the impact of VUCA.
RQ. How to leverage emerging technologies for logistics competitiveness in the VUCA world?
2
Identification of studies
Scopus
Field: All fields
560 docs
ABI/INFORM
Field: All fields
747 docs
Web of science
Field: All fields
16 docs
3A
Selection of studies
From 1992 to 2022 in English
-13
-23
-2
547
724
14
Peer-reviewed
-326
398
Articles, review
-133
-63
-7
414
335
7
Areas of research interest
-184
-237
-0
230
98
7
Merge results and columns mapping
335
Remove duplicate papers
-25
310
-208
3B
Evaluation of studies
Step 1. Reading of titles, abstract, and keywords.
102
-31
Step 2. Reading of theoretical framework, main findings, and conclusions.
71
4
Analysis and synthesis
A complete reading of papers.
Analysis and synthesis of the main ideas and contributions.
Identification of the technologies involved.
77
Complementary search (forward and backward search; snowball sampling") and revalidation.
6
5
Reporting and using the results
Scientific mapping using Bibliometrix R package.
Analysis of collected articles in the VUCA context.
Develop the VUCAT application framework based on emerging technologies for logistics.


Climate Change
Carbon Footprint in supply chain
Need for carbon footrprint based study
Scope for new study from developing countries
Study and analyse the carbon footprint in food supply chain to achieve carbon neutrality
Morocco Major Export - Tomato was chosen for the study
Data from EIA; FAO & EDGAR
Tomato Supply chain was studied in three phases from Souss Mass to Tangier Med Port
1. Cultivation
2. Harvesting
3. Transportation & shipping
Using Machine Learning Based Prediction Models (MLPMs) & Satellite Imagery to predict the impact of GHG emission on Tomato supply chain process
Findings & Implications of the study


United Nations Sustainable Development Goal (SDG) 2: “End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.”
GHG emissions in the food supply chain.
Need for GHG emissions transparency.
Develop new models to analyze big data, and ensure transparency of GHG emissions.
- What impact does integrating blockchain with machine learning have on GHG transparency in the groundnut supply chain?
- What benefits does developing a private blockchain offer for fraud mitigation and data security in the groundnut supply chain?
Senegal's major export, groundnut, was chosen for the study.
Data Sources: FAOSTAT & EDGAR
Focusing on the groundnut supply chain in Senegal, this study investigated three key phases:
1. Cultivation in Diourbel & Niakhar regions.
2. Harvesting.
3. Processing and shipping to the port of Dakar.
A private blockchain network enabled off-chain machine learning was leveraged within the groundnut supply chain to secure predictions and ensure transparent GHG emissions tracking.
Findings and implications of the study.

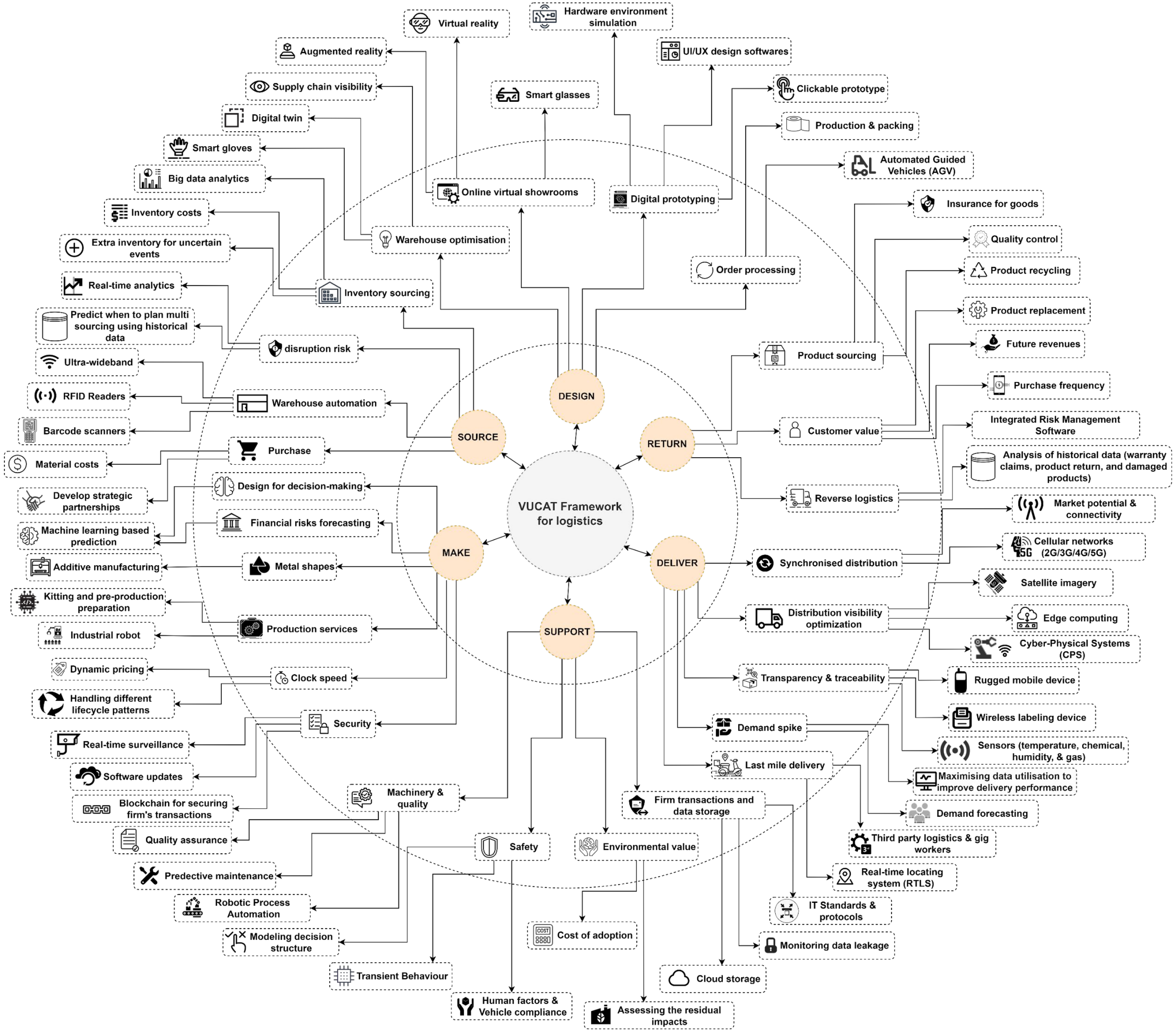
Morocco has traditionally dominated the olive oil industry, contributing significantly to global production **(Donner et al., 2022)**. Olive oil has significant trading potential, and companies need to understand the different phases at the operational level, including in the GHG context, to understand the carbon emissions and identify the stakeholders in the supply chain to track and trace the value flow in olive oil production.

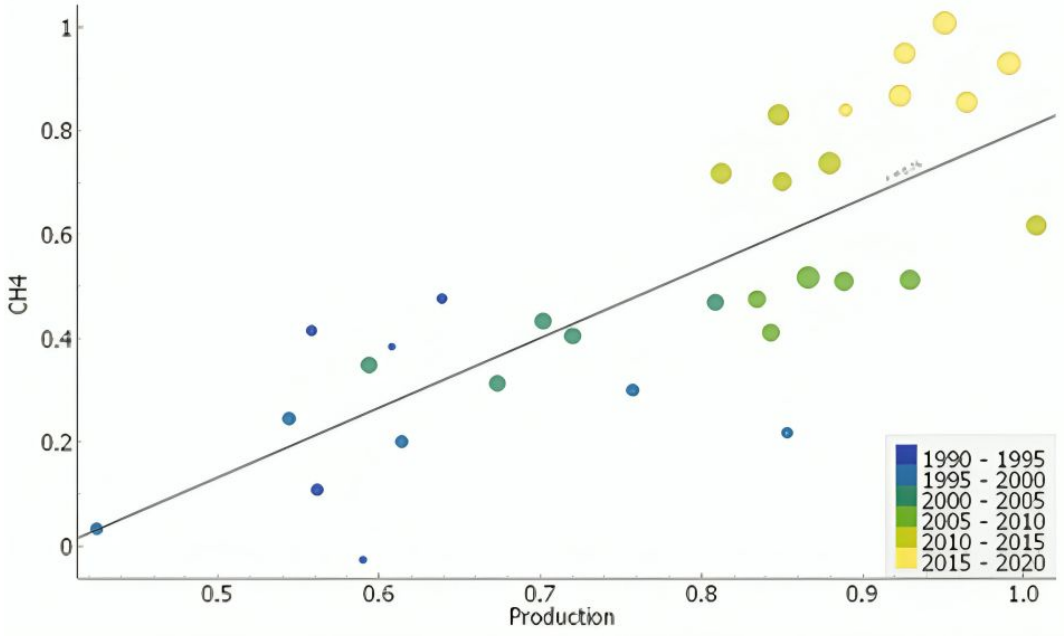
Results and Discussion

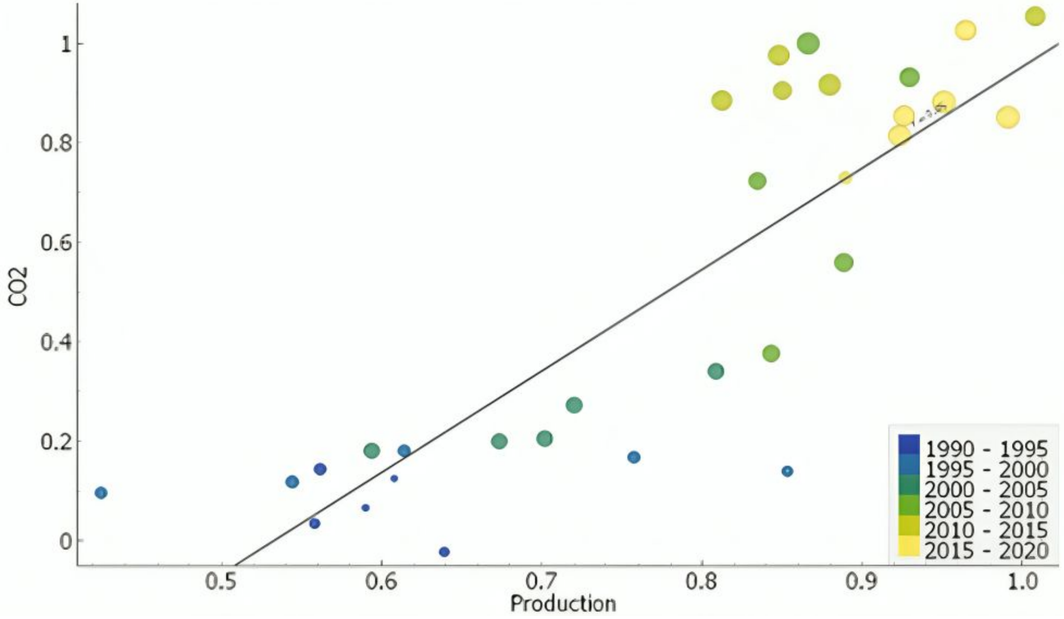
» The first study proposed a novel VUCAT framework-based technology for supply chain and logistics challenges to assess the efficiency of its operations and make better decisions.

» The second study designed a unique and robust mapping of GHG emissions in the Moroccan tomato production system. The study fulfills the objective, using secondary data combined with MLPMs to discover the impact of GHG emissions in the tomato supply chain. Furthermore, the study focused on analyzing factors, such as CO2, CH4, and N2O in the different phases: cultivation, harvesting, transportation, and shipping.

» The third study studied and analyzed the groundnut supply chain in Senegal. By using UN SDG 2 as a motivation, the study analyzed GHG emissions in the groundnut supply chain in three phases: groundnut farming, cultivation, processing and shipping. By innovatively integrating blockchain-enabled off-chain machine learning with smart contracts, this work addresses key challenges in GHG emissions tracking, offering a more transparent, secure, and efficient approach.


VUCAT Framework
for logistics
DESIGN
SOURCE
RETURN
MAKE
DELIVER
SUPPORT
Virtual reality
Hardware environment
simulation
UI/UX design softwares
Augmented reality
Smart glasses
Clickable prototype
Supply chain visibility
Production & packing
Digital twin
Automated Guided
Vehicles (AGV)
Smart gloves
Online virtual showrooms
Digital prototyping
Big data analytics
Insurance for goods
Inventory costs
Warehouse optimisation
Quality control
Extra inventory for uncertain
events
Order processing
Product recycling
Real-time analytics
Inventory sourcing
Product replacement
Predict when to plan multi
sourcing using historical
data
disruption risk
Future revenues
Product sourcing
Ultra-wideband
Purchase frequency
RFID Readers
Warehouse automation
Integrated Risk Management
Software
Barcode scanners
Customer value
Purchase
Analysis of historical data (warranty
claims, product return, and damaged
products)
Material costs
Design for decision-making
Develop strategic
partnerships
Reverse logistics
Market potential &
connectivity
Financial risks forecasting
Machine learning based
prediction
Cellular networks
(2G/3G/4G/5G)
Additive manufacturing
Metal shapes
Synchronised distribution
Satellite imagery
Kitting and pre-production
preparation
Distribution visibility
optimization
Edge computing
Production services
Industrial robot
Cyber-Physical Systems
(CPS)
Dynamic pricing
Clock speed
Transparency & traceability
Rugged mobile device
Handling different
lifecycle patterns
Security
Wireless labeling device
Demand spike
Real-time surveillance
Sensors (temperature, chemical,
humidity, & gas)
Last mile delivery
Software updates
Maximising data utilisation to
improve delivery performance
Machinery &
quality
Blockchain for securing
firm's transactions
Firm transactions and
data storage
Demand forecasting
Quality assurance
Safety
Environmental value
Third party logistics & gig
workers
Predective maintenance
Real-time locating
system (RTLS)
Robotic Process
Automation
IT Standards &
protocols
Modeling decision
structure
Cost of adoption
Monitoring data leakage
Transient Behaviour
Cloud storage
Human factors &
Vehicle compliance
Assessing the residual
impacts


CH4
1
0.8
0.6
0.4
0.2
0
0.5
0.6
0.7
0.8
0.9
1.0
Production
1990 - 1995
1995 - 2000
2000 - 2005
2005 - 2010
2010 - 2015
2015 - 2020


CO2
1
0.8
0.6
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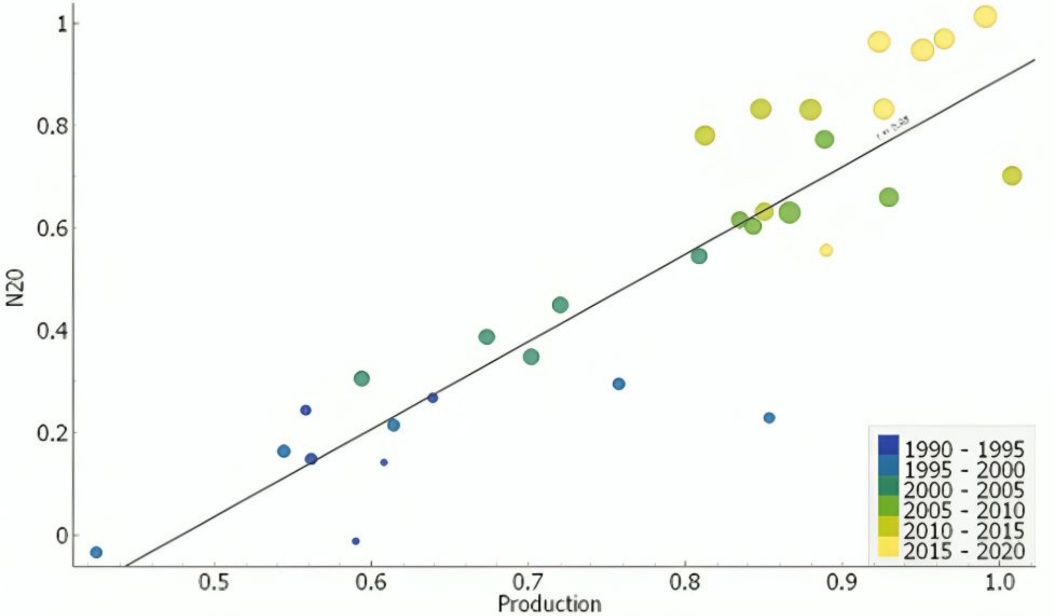
1.0
Production
1990 - 1995
1995 - 2000
2000 - 2005
2005 - 2010
2010 - 2015
2015 - 2020


N20
1
0.8
0.6
0.4
0.2
0
0.5
0.6
0.7
0.8
0.9
1.0
Production
1990 - 1995
1995 - 2000
2000 - 2005
2005 - 2010
2010 - 2015
2015 - 2020

Home Contact

Moroccan Tomatoes Carbon Footprint Monitoring Dashboard

Home / Carbon footprint dashboard

Cultivation

Yield of tomato by 2020: 906456 hg/ha
N2O>CH4>CO2
5.9 kg/CO2 produced by every 100kg of tomatoes

More info

Harvesting

(CO2eq) (AR5): 1718981.26 kt in the last 10 years
(CO2eq) (AR5) >(CO2eq) from N2O (AR5) > (CO2eq) from CH4 (AR5) > (CO2) > (CH4) > (N2O)

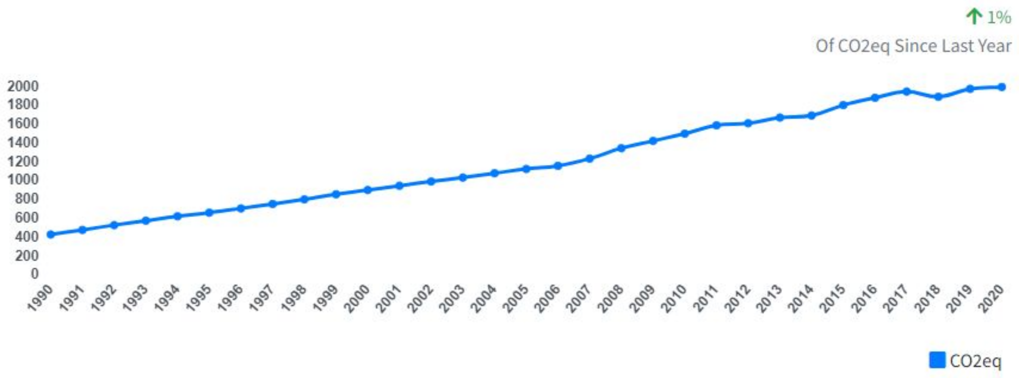
More info

Transportation

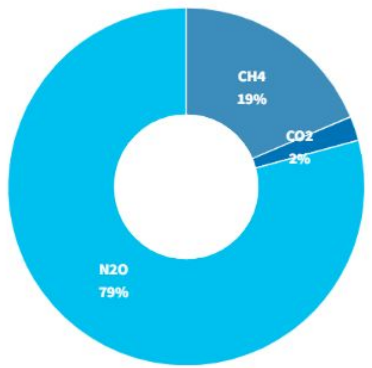
Diesel (CH4 -8.6%, CO2 - 82.91%, N2O - 8.39%)
Motor (CH4 -18.6%, CO2 – 2.2%, N2O – 79.1%)
Electricity (CH4 -0.16%, CO2 – 99.84%)

More info

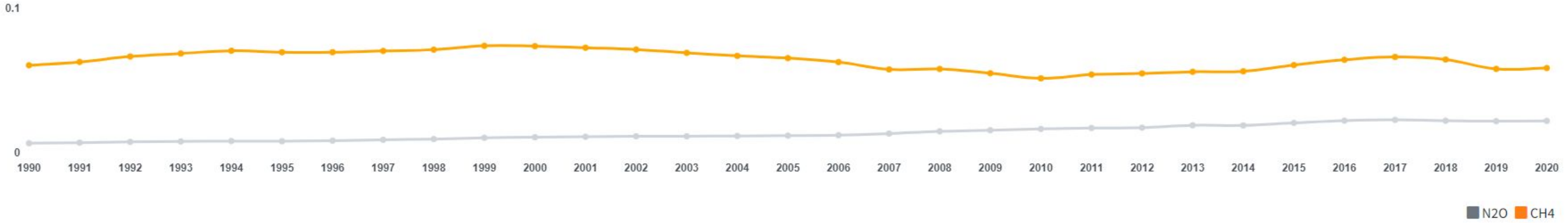
CO2eq evolution over time

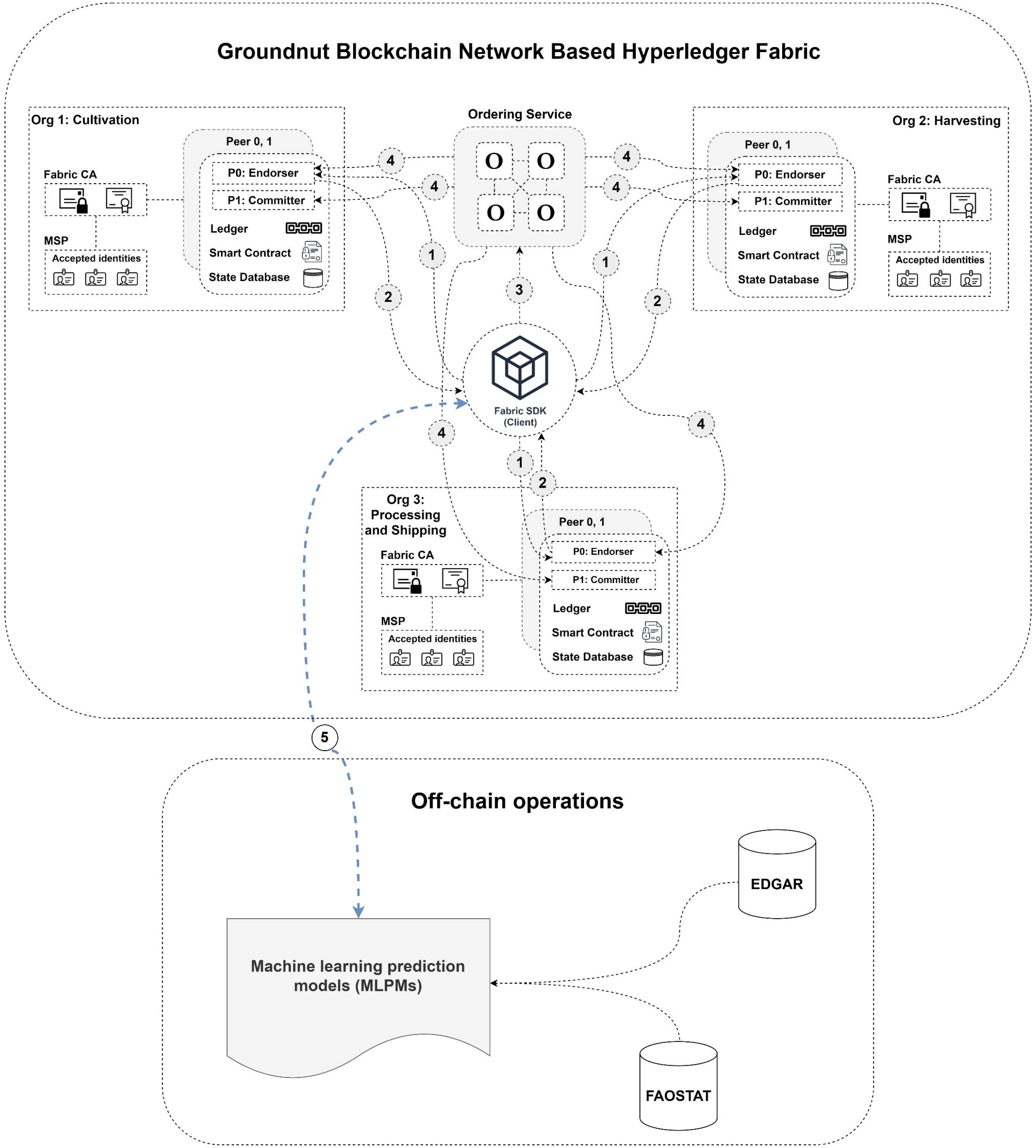


Transportation GHG emissions produced by Motor-Gasoline



CH4 & N2O evolution over time




Groundnut Blockchain Network Based Hyperledger Fabric
Org 1: Cultivation
Fabric CA
MSP
Accepted identities
Peer 0, 1
P0: Endorser
P1: Committer
Ledger
Smart Contract
State Database
Ordering Service
Org 2: Harvesting
Fabric CA
MSP
Accepted identities
Peer 0, 1
P0: Endorser
P1: Committer
Ledger
Smart Contract
State Database
Fabric SDK
(Client)
Org 3:
Processing
and Shipping
Fabric CA
MSP
Accepted identities
Peer 0, 1
P0: Endorser
P1: Committer
Ledger
Smart Contract
State Database
1
2
3
4
5
Off-chain operations
EDGAR
Machine learning prediction
models (MLPMs)
FAOSTAT

Algorithm : Data Collection and Transmission

Smart Contract: Collect and Send Data to Off-Chain Machine Learning Models

Input: Blockchain Historical Data

Output: Data Transmission Confirmation

```
function CollectData(data)
    validate data format and completeness;
    if (data is valid) then
        SendDataToMLModel(data);
    else
        return error “Invalid data”;
end function

function SendDataToMLModel(data)
    prepare data for machine learning model processing;
    transmit data to designated off-chain machine learning model API;
    if (transmission successful) then
        return confirmation “Data sent to machine learning model”;
    else
        return error “Data transmission failed”;
end function
```

Contributions and Outlook

This dissertation contributes to the achievement of sustainable development goals within the African context as follows:

Refereed Journal Publications

- **El Hathat, Z.,** Zouadi, T., Sreedharan, V. R., & Sunder M, V. (2023). Strategizing a Logistics Framework for Organizational Transformation: A technological Perspective. **IEEE Transactions on Engineering Management**.
- **El Hathat, Z.**, Sreedharan, V. R., Venkatesh, V. G., Zouadi, T., Arunmozhi, M., & Shi, Y. (2023). Modelling and analyzing the GHG emissions in the VUCA world: Evidence from tomato production in Morocco. **Journal of Cleaner Production.**

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» R. Bailis, R. Drigo, A. Ghilardi, and O. Masera, "The carbon footprint of traditional woodfuels," Nature Climate Change, vol. 5, no. 3, pp. 266–272, Jan. 2015. DOI: 10.1038/ nclimate2491