Environmental impacts of agricultural robots and possible improvements: example of weeding robots used in vineyards

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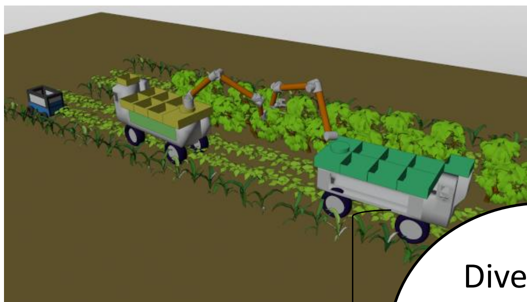
Moving toward the agroecological transition in a climate change context

A need to change traditional agricultural models for agroecological models

The agroecological transition = new challenges for agricultural robotics !



Adaptability of agricultural robots in newly design agroecological systems

Diversity in agricultural production systems

Redesigning agricultural production systems

Preserving natural resources (water...)

Reducing chemical products

Closing biogeochemical cycles

Using DoD technologies or mechanical weeding robots

Using precision agriculture for the right application rate at the right moment

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But a lack of data regarding the environmental impacts of agricultural robots

Robotics and digital equipment can reduce GHG emissions by improving agroecological practices such as optimizing the use of mineral fertilizers (N_2O ➘) or reducing fuel consumption (CO_2 ➘)

BUT…

- ❑ No study of environmental impacts of agricultural robots up to now
- ❑ A need to
  - Assess the environmental impacts in a context of conventional equipment substitution by robots
  - Assess which life cycle step is the most impacting in order to ecodesign agricultural robots
  - Provide data on the environmental and energetic efficiency of agricultural robots to final users

Objective of our study

➔ Assess the environmental impact of weeding agricultural robots used in vineyards for inter-row and intra-row weeding on its whole life cycle using LCA method

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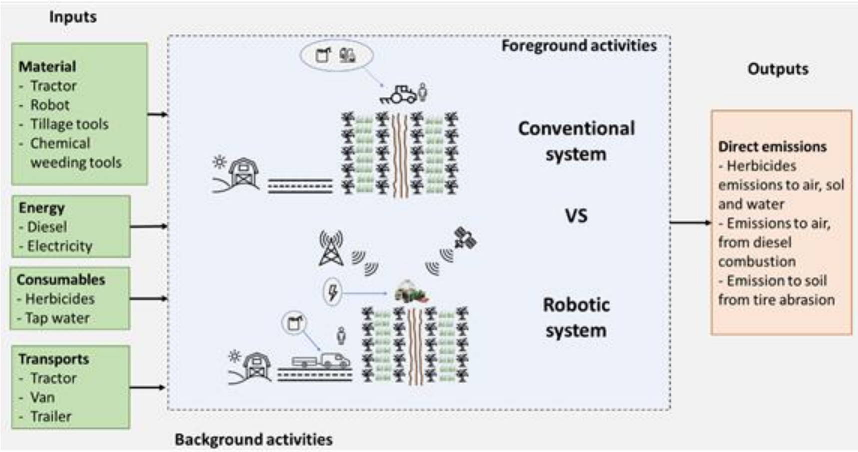
LCA study in a nutshell

System boundaries



Functional Unit :

Optimal weeding control of the intra-row and inter-row of 1 hectare of vines for 1 year

Life Cycle Inventory :

Background data => Ecoinvent v3.7 data/reports

Foreground data => AgriBalyse and technical institutes data, Naïo Technologies data, OLCAPest model

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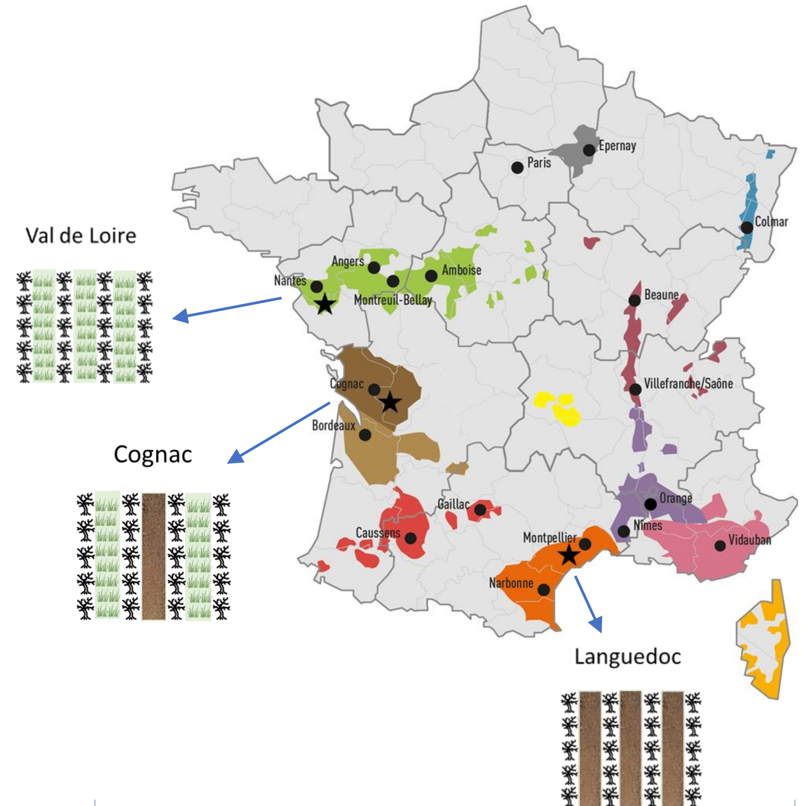
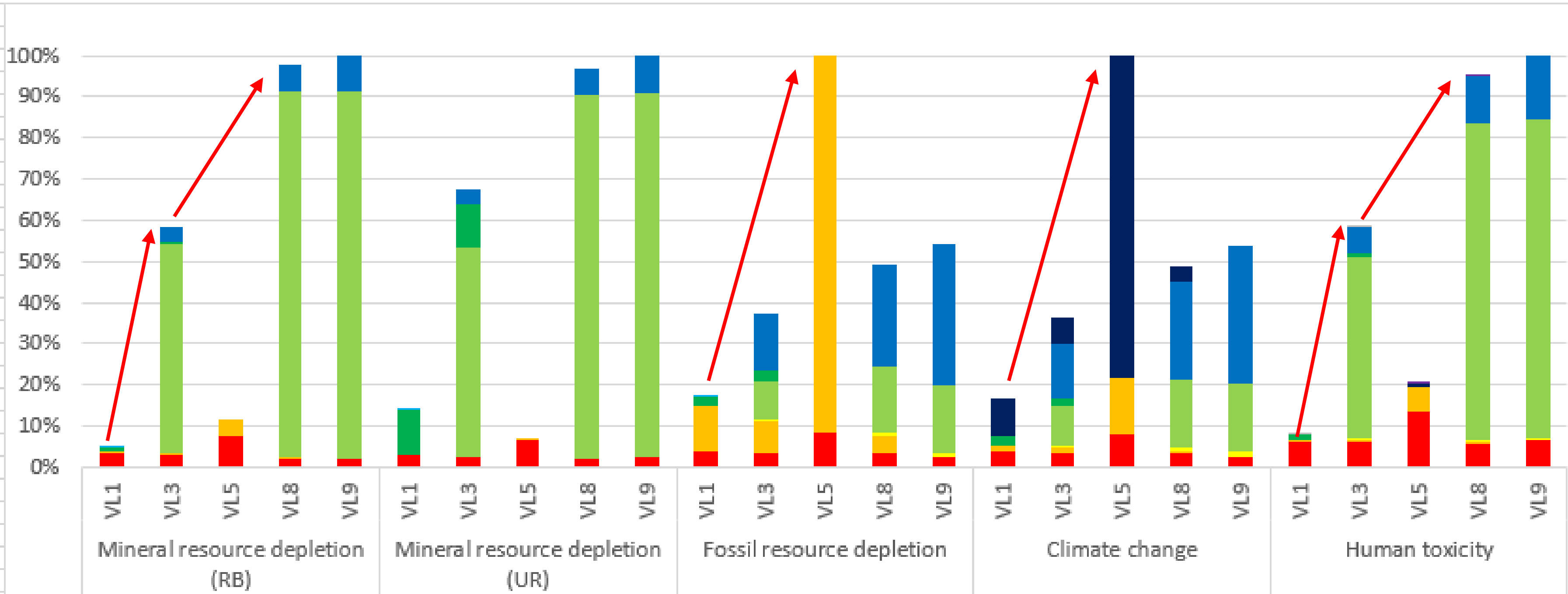
27 comparative scenarios



Mechanical weeding | Chemical weeding

TED Robot | Tractor | Tractor

Comparative LCA results for Val de Loire vineyard (CML-IA)



<u>Intra row / inter row management :</u>

VL1 : Chemical weeding (T: 2) / Mowing (T: 2)

VL3 : Chemical weeding (T: 1) + mechanical weeding (R: 4) / Mowing (T: 2)

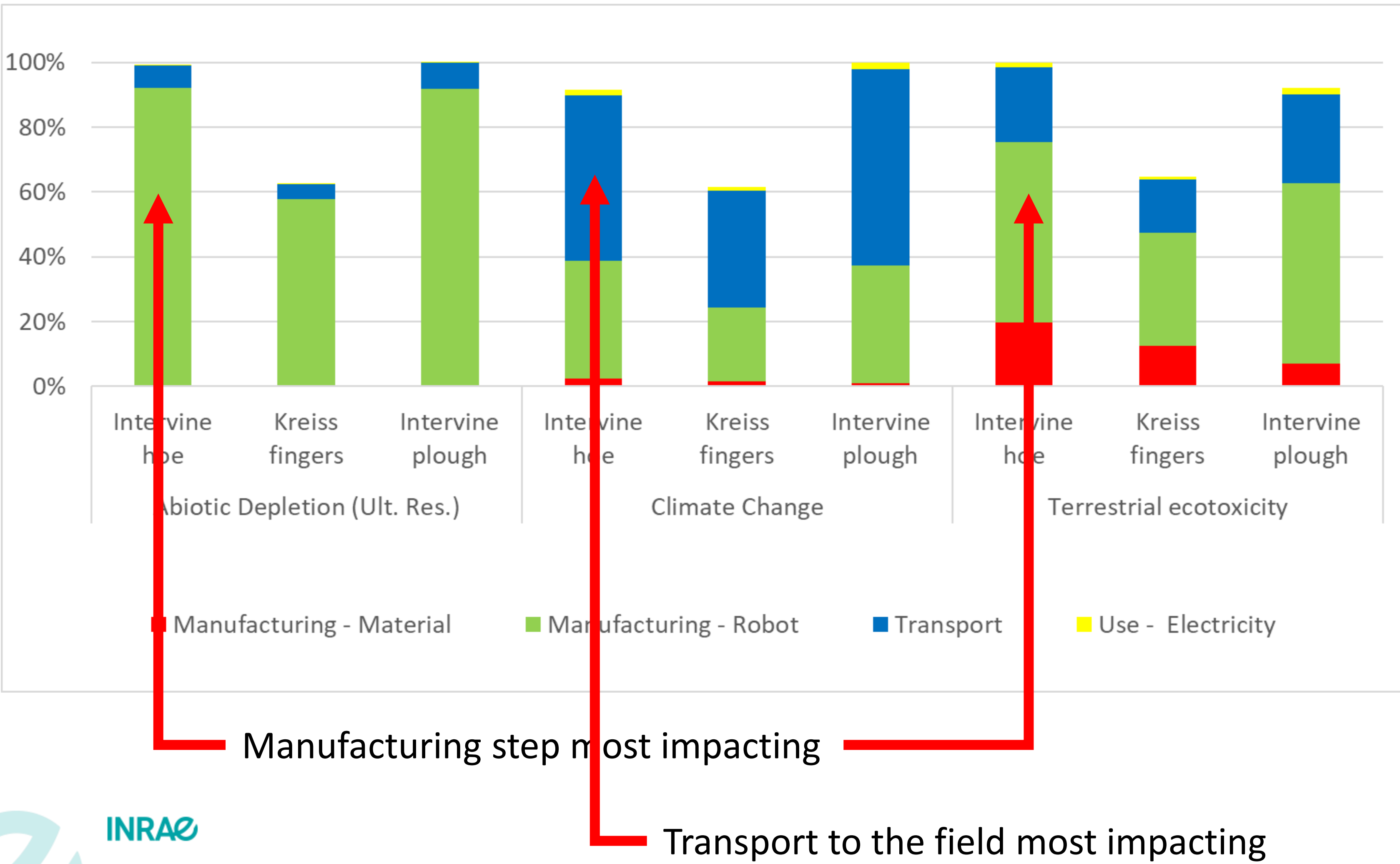
VL5 : Mechanical weeding (T: 7) / Mowing (T: 2)

VL8 : Mechanical weeding (R: 7) / Mowing (T: 2)

VL9 : Mechanical weeding (R: 7) / Mowing (R: 2)

- Production Agricultural machinery
- Production Fuel
- Production Electricity
- Production Robot
- Production Herbicides
- Production Tap water
- Transport Robot
- Emissions Fuel
- Emissions Tire abrasion
- Emissions Herbicides

Environmental impact of robots used for a intra-row mechanical weeding operation in Cognac vineyard (CML-IA)



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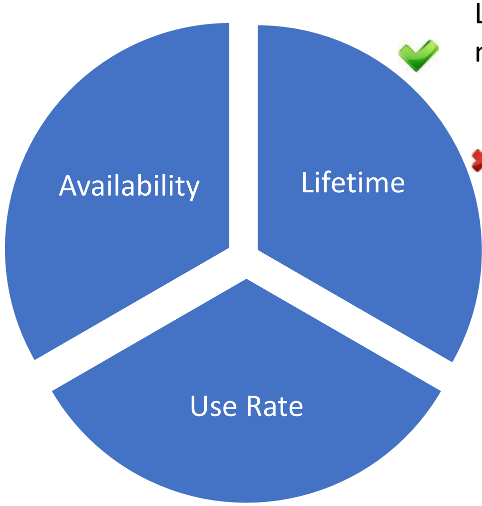
Improving agriculture robots through ecodesign

EcoDesign – main contributions
to Robots impact



Less material input
needed per hour of use

Risk of oversized
components,
More resources
depletion

- Lifetime increase: from prototypes to first serial batches and to a mature technology

Robots = still impactful on HT and MRD

Equivalent results or slightly lower than conventional for CC and FRD

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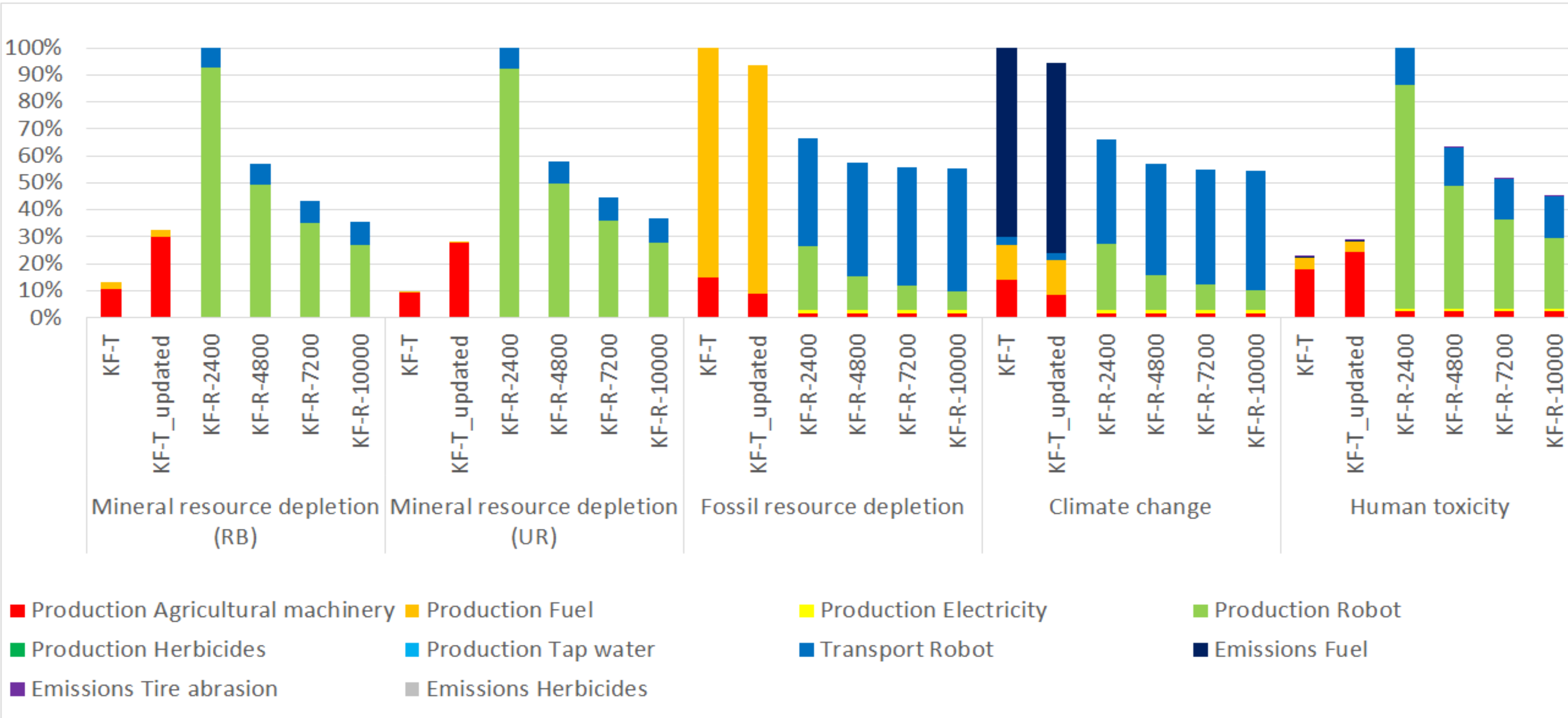
Impact of robot lifetime increase on LCA results (CML-IA)



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The longer the lifespan, the lower the impact

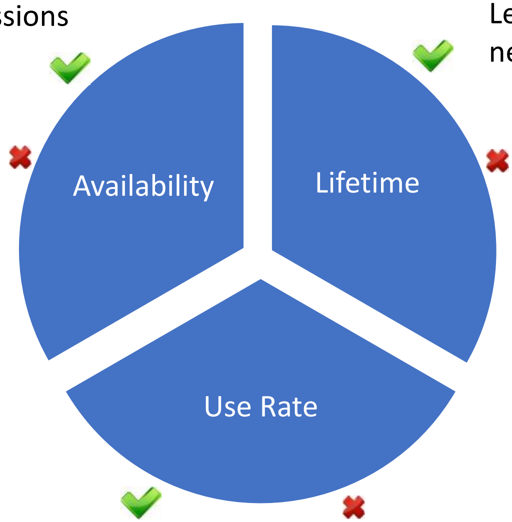
Improving agriculture robots through ecodesign

EcoDesign – main contributions
to Robots impact

Less logistic,
Less GHG emissions

Less material input
needed per hour of use

Additional batteries
or infrastructure,
More pressure on
resources



Risk of oversized
components,
More resources
depletion

Less material input needed
for one hr of operation

More wear = Reparation factor
may rise

- Lifetime increase: from prototypes to first serial batches and to a mature technology

Robots = still impactful on HT and MRD

Equivalent results or slightly lower than conventional for CC and FRD

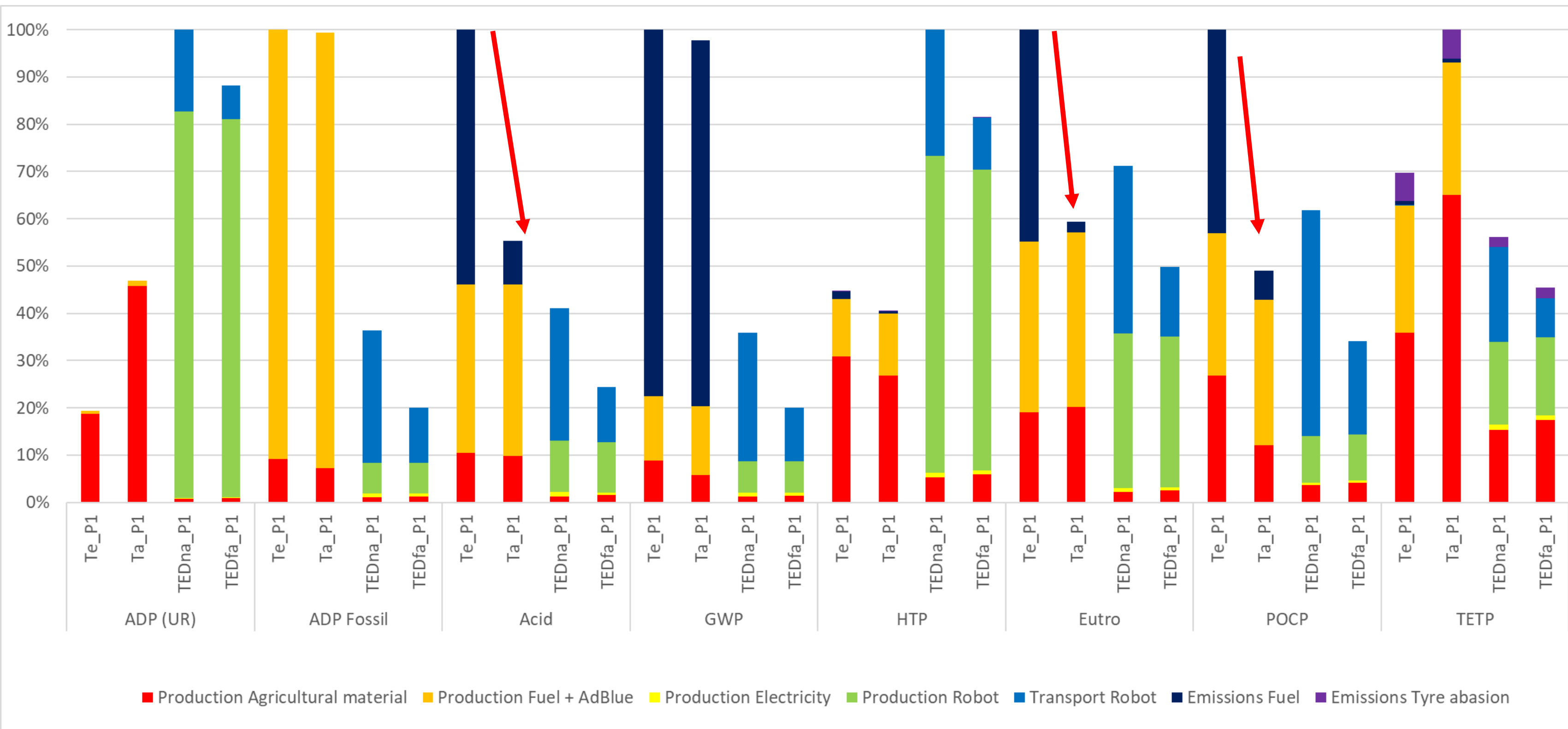
- Versatility and modularity increase
- Lifetime ➔ related to technology renewable rate
- ↗ in use rate = ↘ impact of weeding operations (relatively less material input is consumed during an operation)
- Multiplying the operations (implements wider range, additional operations like scouting,…) is a relevant way to increase the use rate

- Availability on the field optimization
- Logistic and transportations of the robot leads to additional emissions. Increasing the availability of autonomous mode leads to an improved impact on Climate Change

Future methodological challenges to be faced

- There is a need for **references** to compare the impact of these alternative technologies to conventional ones
  - Providing accurate and updated LCI data on conventional agricultural machinery (tractors…)
  - Providing LCI data for the whole life cycle of the agricultural robot (manufacturing, use, recycling)

Emissions reduced by depollution system (DOC+DFP+SCR)



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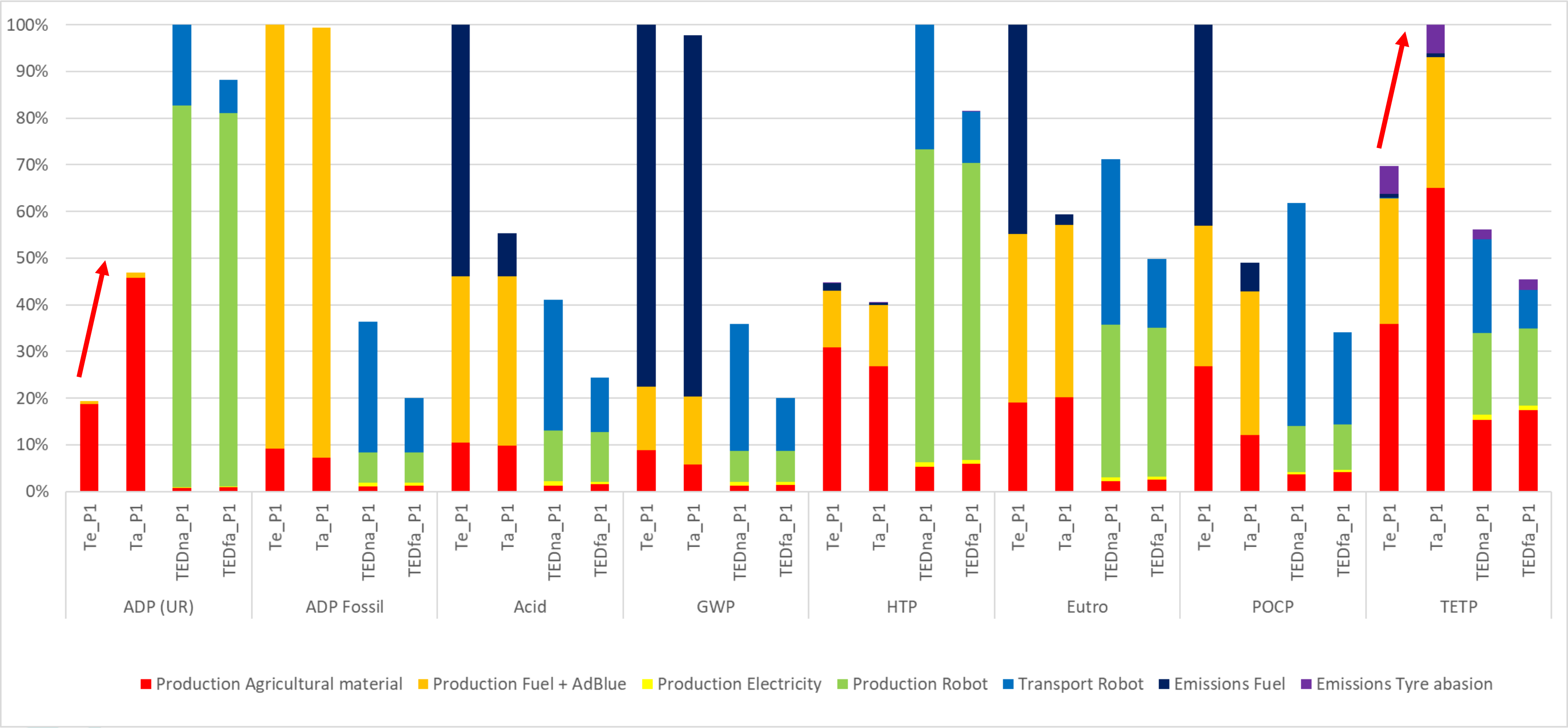
Manufacturing impacts increased by electronic componants (sensors, electronic board…)



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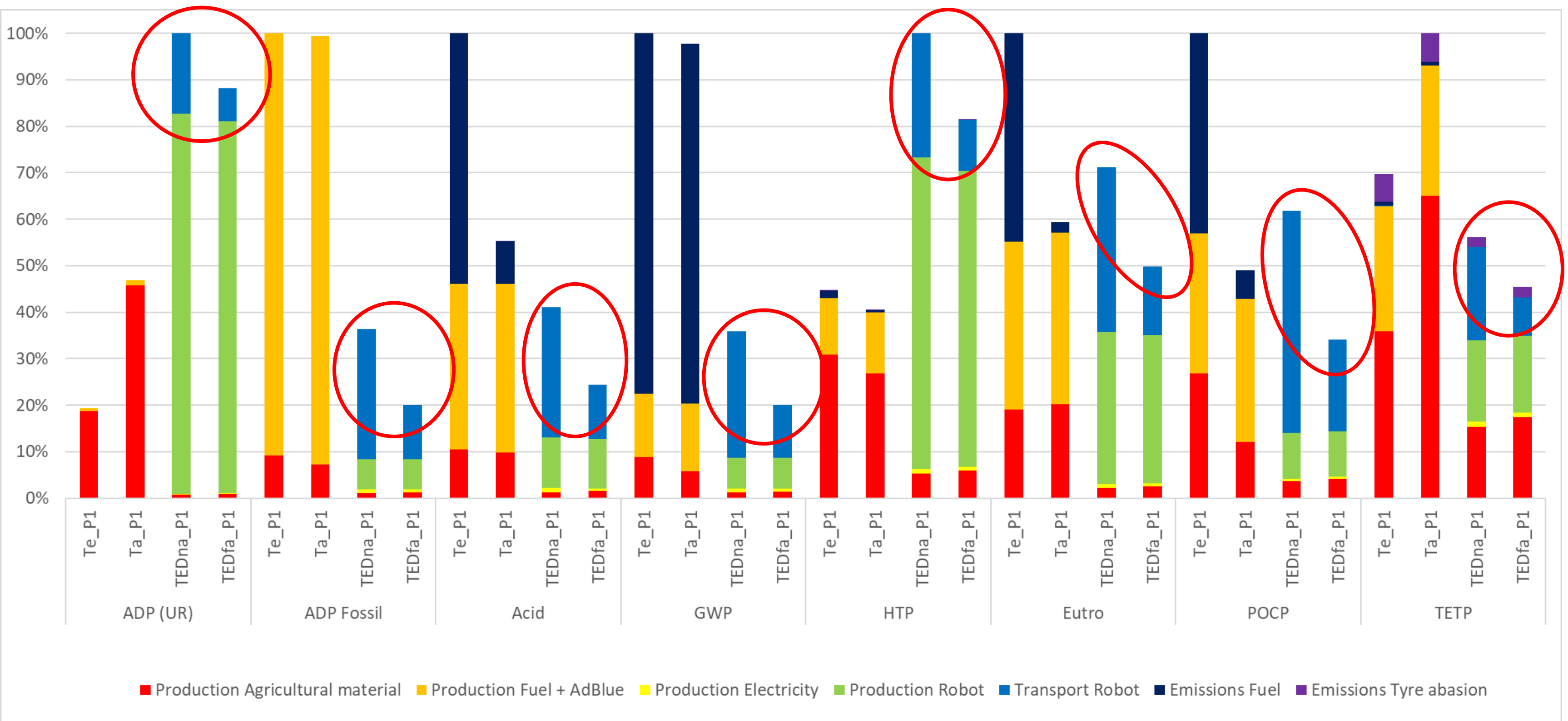
Robot in autonomous mode without local human operator on the field reduces all impacts



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- Methodological challenges linked to :
  - Additional services provided by robots such as more security for the operator, less accident risks → FU ?
  - Additional functions that are provided by the robot (monitoring…) → multifunctionality? Scenario comparison with current technologies?

- Local effect on soil were not taken into account as no characterization can assess these impact such as soil compaction or specific biodiversity => a need to assess the impact for agricultural robot in a system perspective

- Future studies need to consider social and economic indicators in addition to the LCA indicators to assess agricultural robot sustainability as services such as reduction of the hardship at work or ability for robots to overcome the labor shortage were not assessed

- A need to quantify the overall impact of the use of robotic solutions in agroecological systems

Thanks for your attention

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For more informations:

- Pradel, M., de Fays, M., Seguineau, C., 2022. Comparative Life Cycle Assessment of intra-row and Inter-row weeding practices using autonomous robot systems in French vineyards. Science of The Total Environment, 838(3), 156441.
- Pradel, M., 2023. Life Cycle Inventory data of agricultural tractors. Data In Brief, 48, 109174.
- Pradel, Marilys, 2023. Life Cycle Inventory of agricultural tractors, https://doi.org/10.57745/JYXPHZ, Recherche Data Gouv, V11