AI-Autonomous Robots for Agriculture – Weeding with Laser

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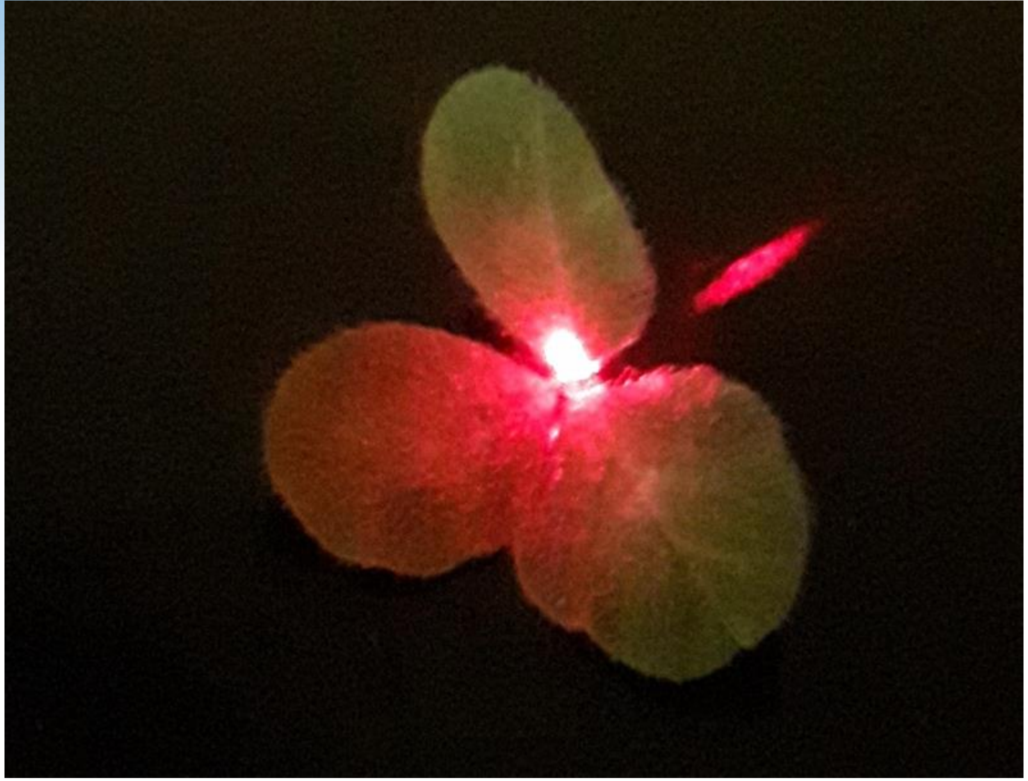

Precision agriculture: farm economics and B2B management

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Overview

1. Short bio
2. Farmers' adoption and willingness to adopt field robots and unmanned aerial vehicles
3. PESTLE review and SWOT analysis of autonomous vehicles with laser treatment for weed control
4. Farmers' preference for laser weeding techniques
5. Setting up the business model: the business model canvas

1. Short Bio

Overview

- **Joachim J. Schouteten, PhD**
  - ❑ Joachim.Schouteten@ugent.be
  - ❑ Post-doctoral researcher @ Ghent University (Belgium)
  - ❑ Lecturer for several courses related to entrepreneurschip and innovations of agri-food products
  - ❑ Daily management of 4 EU projects (WeLASER, Cropdiva, FAIRCHAIN and SmartProtein)
- **Research topics**
  - ❑ Agri-food innovations
  - ❑ Entrepreneurship
  - ❑ Sensory analysis
- **Div. Agri-food marketing and chain management**
  - ❑ Website: https://agecon.ugent.be/agri-food-marketing-and-chain-management/
  - ❑ Thanks to Margo Degieter, Duc Tran, Hans De Steur and Xavier Gellynck for shared efforts and materials

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2. Farmers' adoption and willingness to adopt field robots and unmanned aerial vehicles

Background

- FOOD insecurity => increased agricultural production needed BUT

  big impact of our agri-food system on the environment

- Emerging new technologies to decrease footprint of agriculture (Araújo et al., 2021; Dayioglu and Turker, 2021)

  → Agriculture 4.0 (da Silveira et al., 2021) ,

  → **e.g., robotics and unmanned aerial vehicles (UAVs)**

  - Multiple purposes, e.g., soil preparation, sowing, plant treatment,... (del Cerro et al., 2021; Oliveira et al., 2021)
  - Majority of robots still at research stage (Oliveira et al., 2021)
  - Multiple benefits, e.g., higher yields while using less inputs, replacement of heavy machines can lead to less soil compaction, replacement of human labor,... (Aravind et al., 2017; Sparrow and Howard, 2021)

- BUT, overall adoption still low (Dayioglu and Turker, 2021; Klerkx et al., 2019; Lowenberg-DeBoer et al., 2020)
- Some existing reviews on intention to adopt precision agriculture, innovations, technologies (Feyisa, 2020; Olum et al., 2020; Tey and Brindal, 2012) BUT review specifically focussing on robotics/UAVs is missing
- Objectives:

  (1) insight into farmers' readiness for the uptake of robotics and UAVs

  (2) identify the factors that influence the acceptance

Methodology

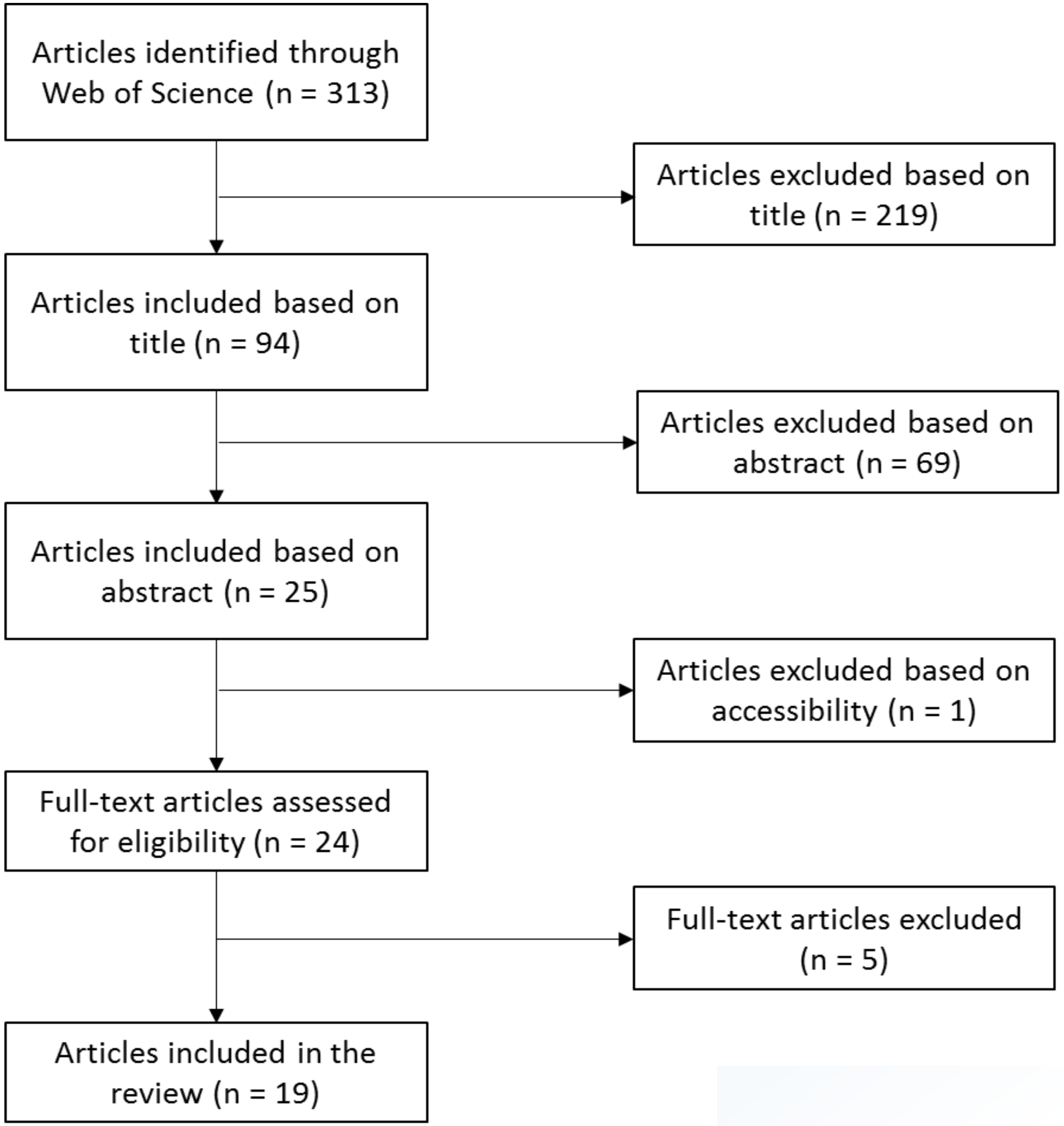
Systematic Review

Syntax:

(1) Adoption/ acceptance

(2) Farmer

(3) Robotics/ UAVs



Results – Adoption (Intention)

UAVs

- **Some adoption, depending on country**
  - 22% of German farmers (Michels et al., 2020)
  - 8% of farmers in Missouri (Skevas and Kalaitzandonakes, 2020; Skevas et al., 2022)
- **Some intention, depending on country**
  - 20% of farmers in Missouri (Skevas and Kalaitzandonakes, 2020)
  - 66% of Chinese farmers (Wachenheim et al., 2021)

Field robots

- **No adoption**
- **High intention** **(Spykman et al., 2021; von Veltheim and Heise, 2021)**

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Results – Factors affecting intention

- **Only 7 studies used a theoretical model to explain the intention to adopt**
- **Internal factors**
  - 3 categories: socio-demographics, farm characteristics, perceptions/ knowledge

→ Most identified factors

Socio-demographics/ farm characteristics	Age	Negative	Groher et al. (2020); Michels et al. (2020); Skevas and Kalaitzandonakes (2020); Skevas et al. (2022)
	Gender (male)	Positive	Groher et al. (2020); Michels et al. (2020); Wachenheim et al. (2021); Zheng et al. (2019)
	Income	Positive	Skevas and Kalaitzandonakes (2020); Skevas et al. (2022); Wachenheim et al. (2021); Zheng et al. (2019)
	Farm size	Positive	Michels et al. (2020); Wachenheim et al. (2021); Hansen (2015)*
Perceptions/ knowledge	Perceived usefulness/ expected economic and environmental benefits	Positive	Caffaro et al. (2020); Michels et al. (2021); Wachenheim et al. (2021); Zheng et al. (2019); Barrett and Rose (2020); Carolan (2020); Spykman et al. (2021); Skevas and Kalaitzandonakes (2020); Skevas et al. (2022); Hashem et al. (2021); Silvi et al. (2021); von Veltheim and Heise (2020); Hansen (2015)

Results – Factors affecting intention

- **External factors**
  - Less studied than internal factors
  - 2 categories: social factors & socio-technical landscape

→ Most identified factors:

- Price (Barrett and Rose, 2020; Hansen, 2015; Hashem et al., 2021; Silvi et al., 2021)
- Compatibility with other software/ equipment (Silvi et al., 2021; Spykman et al., 2021; von Veltheim and Heise, 2020)
- Labor scarcity (Carolan, 2020; Hansen, 2015; von Veltheim and Heise, 2020)

Discussion

- **Similar results found in other reviews (e.g., on the intention to adopt precision agriculture, agricultural innovations/ technologies)**

- **Some differences:**
  - Education only identified as important in a limited amount of studies BUT often in other reviews (Dissanayake et al., 2022; Olum et al., 2020)
  - Mixed results in literature for age of the farmer (Feyisa, 2020;Tamirat et al., 2018)
  - Mixed results in literature for gender (Olum et al., 2020)

Limitations/ Opportunities

- Limited amount of studies
  - → limits generalizability of results
  - → Lots of potential for future research
- Most studies focus on Europe and USA
- Future research could apply different models or combine models
- More focus on external factors needed

Conclusion

- Current usage is still limited
- This study underlined the potential of these technologies
- Limited use of technology adoption models in studies
- Internal factors most often studied
- Most identified factors: age, gender, income, farm size, perceived usefulness, price, compatibility with other equipment and labor scarcity

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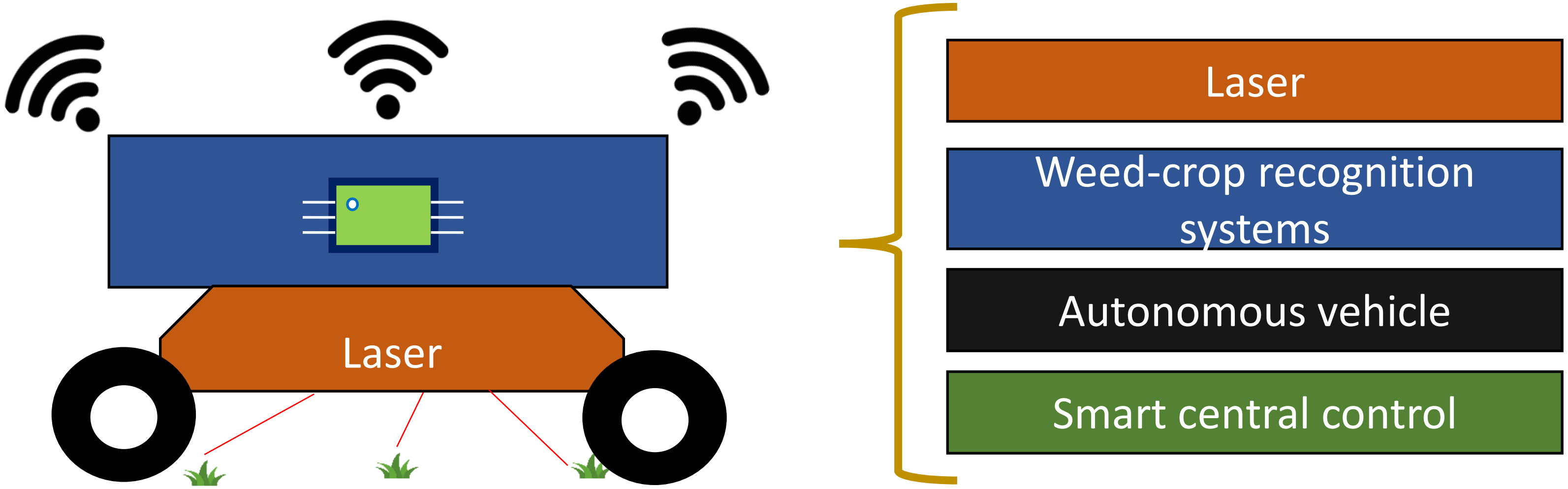
3. PESTLE review and SWOT analysis of autonomous vehicles with laser treatment for weed control

Full article: https://doi.org/10.1007/s11119-023-10037-5

Introduction

- **Issues with conventional weed control**
  - ❑ Chemical weed control (herbicides): clear negative environmental impacts
  - ❑ Mechanical weed control: soil turbulence & compaction, nutrient degradation, harm to soil animals.
  - ❑ Manual weed control: high cost, labor demanding.
- **A new solution with Autonomous Laser-Weeding Solution (ALWS)**



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Methods & Materials

Stage 1: PESTLE analysis

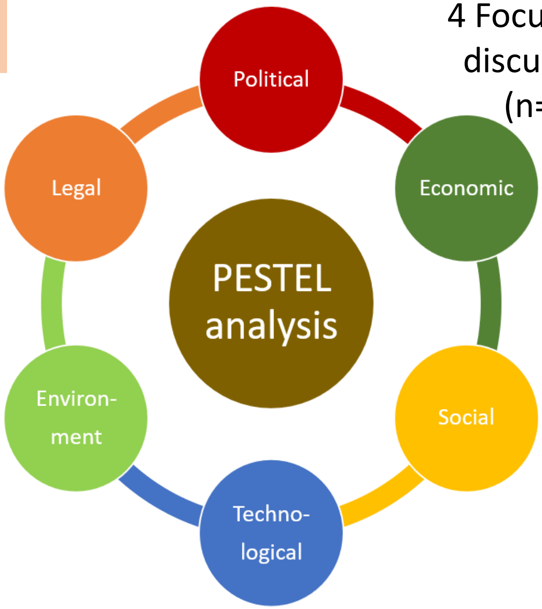
Expert's opinions ➔ **Macro-environmental factors**
(Politics, Economics, Society, Technology, Legislation, Environment)

Data collection | Data analysis

Scientific literature

Grey literature

Lecture notes, legal documents, press releases, etc.



Stage 2: SWOT analysis

Stakeholders' perception

Data collection | Data analysis

4 Focus group discussions. (n=55)

Strengths	Weaknesses
Opportunities	Threats

Stage 3: Merging

	S	W	O	T
P				
E				
S				
T				
L				
E				

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Focus group procedure

Introduction of ALWS → Add SWOT factors as sticky notes on a whiteboard → Discussion → Vote for 3 factors per category of SWOT (1 vote/factor)

Add SWOT factors as sticky notes on a whiteboard:

Strengths	Weaknesses
Opportunities	Threats

Discussion: Clarify, group, and remove sticky notes

Vote for 3 factors per category of SWOT (1 vote/factor):

Strengths 3	Weaknesses 3
Opportunities 3	Threats 3

4 focus groups (n=55)

- English
- Dutch
- Spanish
- Polish

Translations into English

Online. Dec21-Feb22. Wide range of stakeholders.

SWOT data analysis

(1) Convert votes into %

(2) Group similar factors

(3) Reflect with facilitators

(4) Rank top 5 (grouped) factors

SWOT analysis (shown as percentages of votes)

	Strengths	Weaknesses	Opportunities	Threats
Political			Favoured policies (Green Deal, CAP)	Insufficient policies (e.g., farmers' incentives).
Economic	Labour reduction.	High cost.	High demand (demand for non-chemical weeding in organic farming). High agricultural labour cost.	Crises (COVID-19, energy). Fierce competition.
Social	Positive impact on food safety.	Lower the rate of low-skilled employment.	High farmers' awareness of innovative weed control. Establishment of specialised companies.	Human safety (users, right to roam). Insufficient knowledge and farmers' education. Low willingness-to-adopt of farmers and related service.
Tech	Precision (in-row weeding). Efficient production (24/7).	Short (optimal) treatment period. Uncertainty due to novelty. Limited capacity. Automation issues (e.g., low connection in remote areas). Dependence on external services.	Advancement of other precision agriculture development to learn and/or combine.	Theft, vandalism. Laser igniting fire. Data security.
Legal			Favoured regulations (e.g., stricter chemical use).	Insufficient regulations (e.g., lack of regulation for argi-robots, farming data protection).
Environmental	Organic farming. No chemicals. Less soil compaction & disturbance. Preserve biodiversity.			Undesirable weather. Uneven farmland.

Brown = only PESTLE, blue = only SWOT, black = combined.

Conclusion & Recommendations

- **Academia**
  - ❑ Combining PESTLE & SWOT analysis = comprehensive landscape for the adoption of ALWS and other precision agriculture (to some extent).
- **Machinery producers**
  - ❑ Take advantage of favored policies & regulations + high demand for organic farming solutions + high labor cost & scarcity.
  - ❑ Accelerate the development process (due to fierce competitions in the agri-machinery market)
  - ❑ Concise communication on operational and technical indicators
  - ❑ Proof of viable return on investment
- **Policymakers**
  - ❑ Timely financial support with ease of administration.
  - ❑ Schemes to improve farmers' understanding of precision agriculture.
- **Legislators**
  - ❑ Address the gaps in farming data protection/sharing, liability for agri-robots.

Limitation & Future studies

- Personal biases → call for confirmatory studies
  - A survey for perceptions regarding farmers' preference with a quantitative approach
  - Field tests for perceptions regarding technical performances
- More advanced analyses: SWOT-AHP (Analytical Hierarchy Process) or SWOT-SOR (Strategic Orientation Round).
- Alternative method: Delphi with experts.
- European context cannot be generalized for other regions.
  - Future studies in different contexts

4. Farmers' preference for laser weeding techniques

Introduction

Issues with conventional weed control

- ❑ Chemical weed control (herbicides): clear negative environmental impacts
- ❑ Mechanical weed control: soil turbulence & compaction, nutrient degradation, harm to soil animals.
- ❑ Manual weed control: costly and labour intensive.

A new solution with laser weeding

WeLASER
(EU project)

Carbon Robotics
(US company)

Materials and methods

Data collection

Online survey
Convenience sample
Growers in 4 countries: Denmark, Italy, Spain, and Poland.

Linear regression

Independent variables

- Socio-demographics of farmers
- Farm characteristics
- Perceived usefulness (PU)
- Perceived ease of use (PEU)
- Environmental concern (EC)
- Technological interest (TI)
- Social influence (SI)

Dependent variable

- Intention to adopt

(in different given scenarios)

Materials and methods

Choice experiment

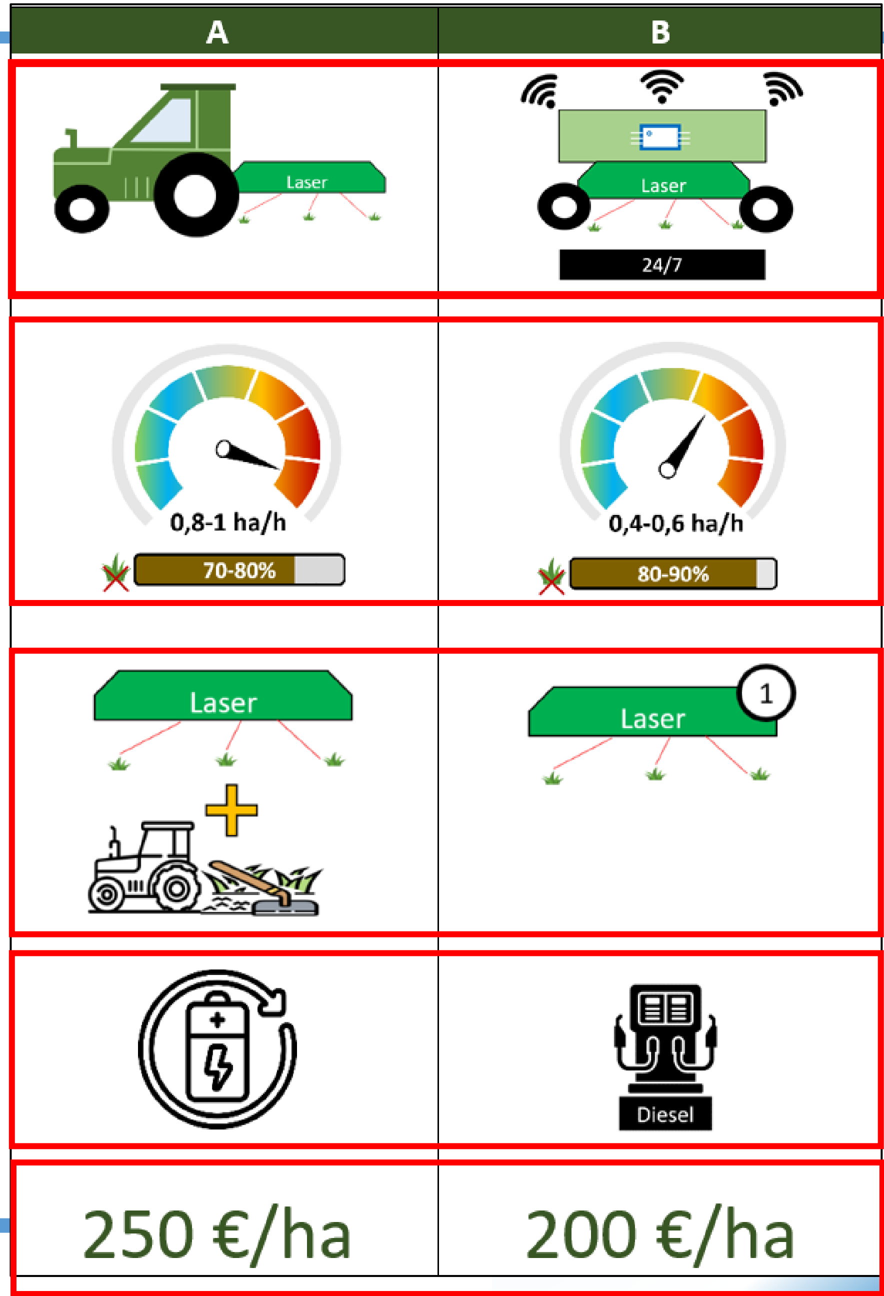
8 choice sets.

Each set = 2 options A, B & 1 status quo.

D-optimal orthogonal design = Ngene

Random parameter logit (RPL) models = Rstudio

Mobility	- Autonomous vehicle - Mounted on tractors	(0) (1)
Efficacy	- Slow – 80-90% kill rate - Fast – 70-80% kill rate	(0) (1)
Service	- Alone service - Hybrid service	(0) (1)
Energy	- Fossil fuel - Rechargeable battery	(0) (1)
Cost	- 100€; 150€, 200€, 250€/ha	



Besides cost, all are dummy coding.

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Result 1: Sample descriptive (n=203)

Farmers' characteristics	Percentages (%)
Age	**Mean = 39.89**
18 - 30	31.53%
30 - 40	25.62%
40 - 50	18.72%
50 - 60	13.30%
Above 60	10.84%
Country	
Denmark	25.62%
Poland	24.63%
Italy	26.11%
Spain	21.67%
Netherlands	1.48%
UK	0.49%
Gender	
Male	64.04%
Female	33.50%
Other	0.99%
Prefer not to tell	1.48%
Experience	
0 -> 5	30.05%
5 -> 10	20.69%
10 -> 15	10.84%
15 -> 20	11.82%
Above 20	26.60%
Education	
High school or below	48.28%
Bachelor's degree	27.09%
Master's degree/Study diploma	21.67%
Doctorate	2.96%
Agricultural training/education	
Yes	40.89%
No	59.11%

Mostly from 4 countries

Mostly male

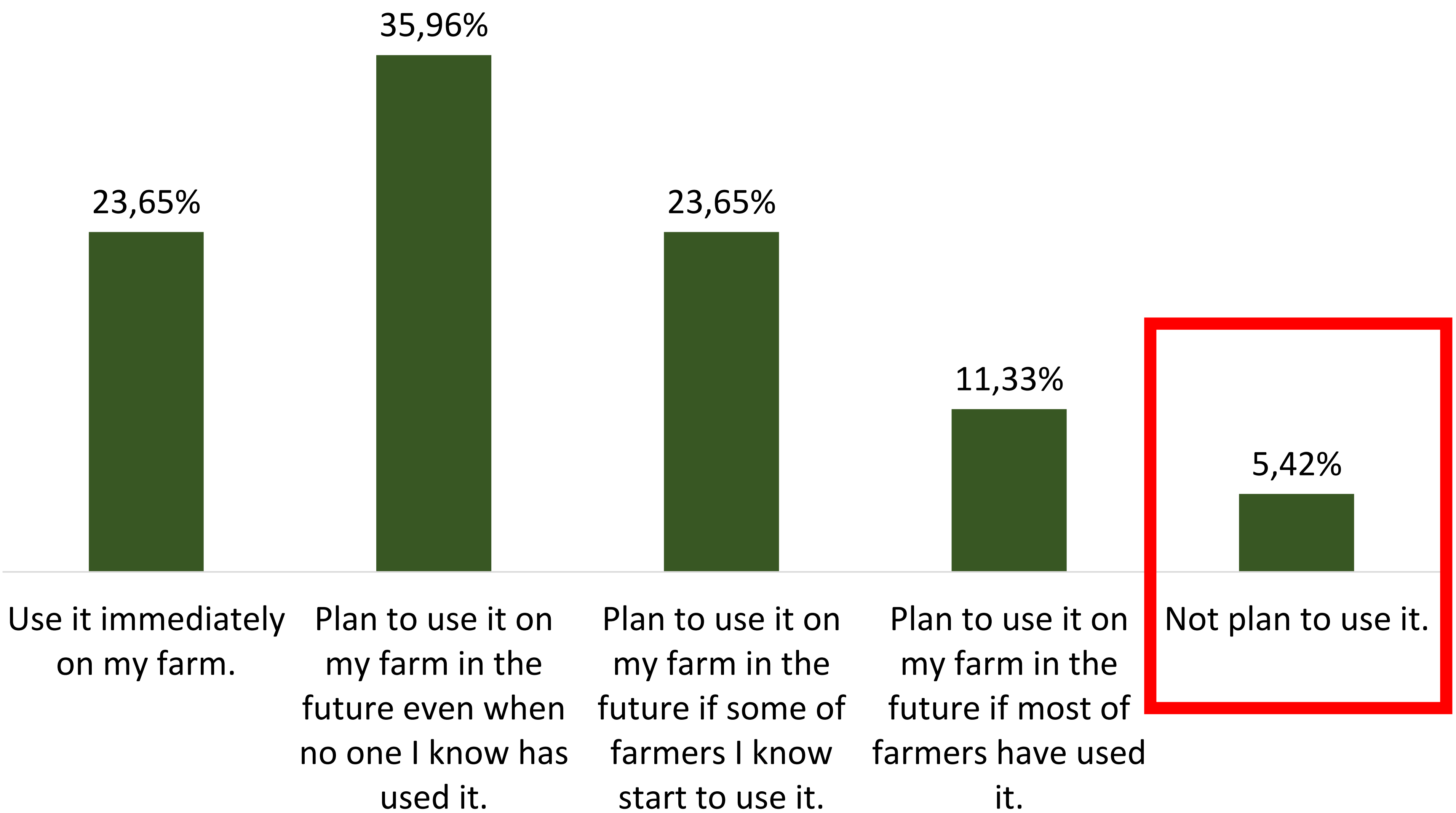
Young farmers

½ higher education

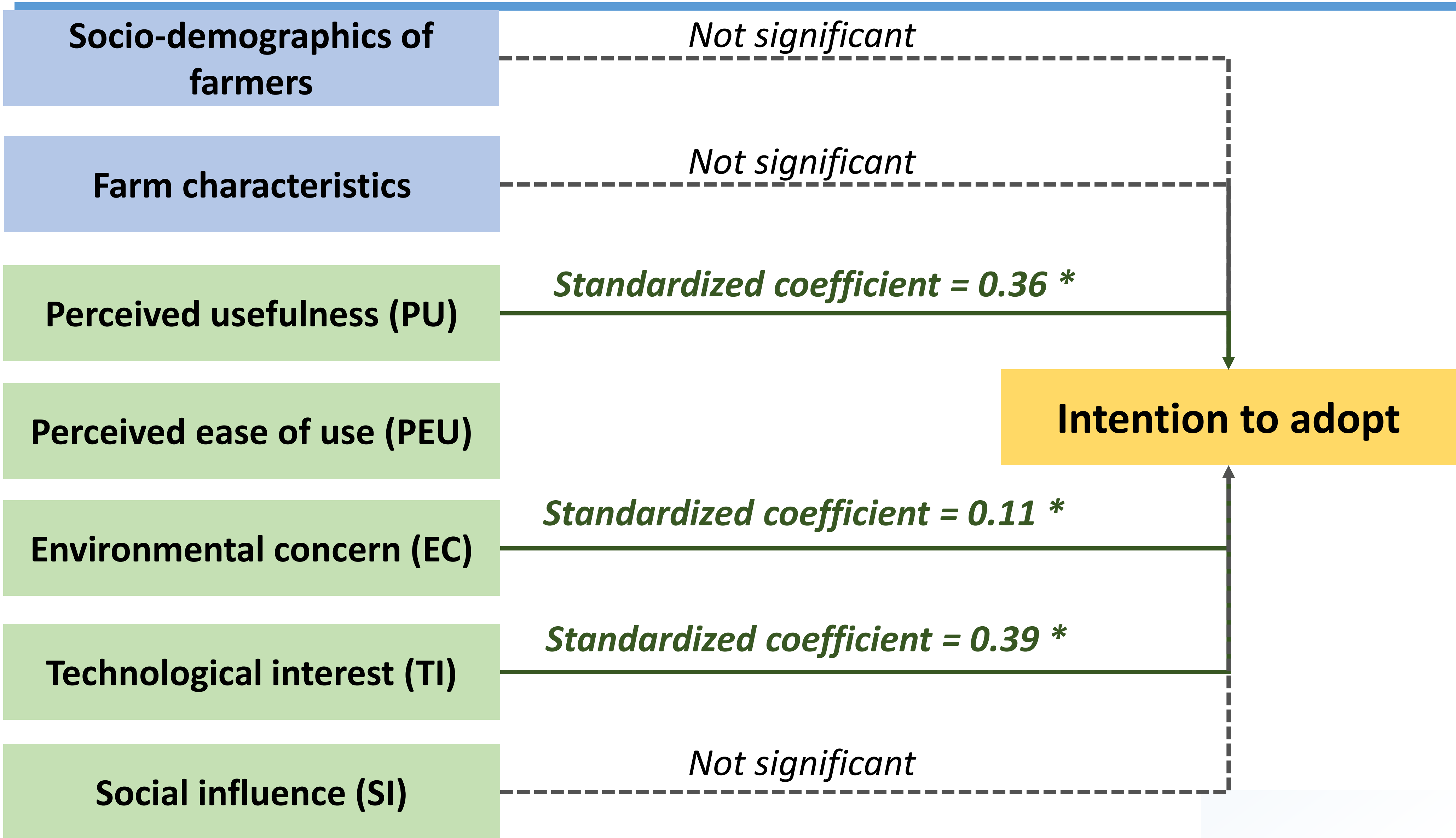
Farm's characteristics	Percentages (%)
Crops	
Cereals (e.g., wheat, maize, …)	36.45%
Root crops (e.g., potatoes, sugar beets, …)	23.65%
Oilseeds	16.26%
Fruits	32.02%
Vegetables	33.99%
Vineyard	26.11%
Olives	26.11%
Seedlings	15.27%
None	0.00%
Others, please specify ...	6.90%
Farm type	
Conventional	37.44%
Regenerative	12.81%
Organic	32.02%
Converting to regenerative/organic	6.90%
Mixed (conventional and regenerative/organic)	10.84%

Diverse crops and farming types
Nearly 50% of farms are organic/regenerative

Result 2: Intention to adopt (descriptive)



Result 3: Intention to adopt (linear regression)



$R^2 = 0.60$; F-test is significant (p-value<0.001)

* significant at 0.05

Result 4: Choice experiment

	Total sample (n = 203) β (SE)		Adoption group* (n= 68) β (SE)		Non-adoption group* (n=139) β (SE)	
Cost	-0.004	***	-0.01	***	-0.002	*
Status quo	-1.68	***	-3.35	***	-1.00	***
Mobility	-0.06		-0.18		0.01	
SD Mobility	*0.89*	***	*1.22*	***	*0.76*	***
Efficacy	-0.03		-0.05		-0.02	
SD Efficacy	*0.59*	***	*0.54*	**	*0.63*	***
Service	-0.01		-0.09		0.03	
SD Service	*0.54*	***	*0.49*	**	*0.60*	***
Energy	0.01		0.37	*	-0.13	
SD Energy	*0.94*	***	*1.10*	***	*0.84*	***
Goodness-of-fit						
AIC	*3215*		*942*		*2230*	
BIC	*3269*		*985*		*2280*	
Observation	*1624*		*544*		*1080*	

Cost is critical

Preferred laser-weeding

Preference heterogeneity

Rechargeable battery = preferred by prospective adopters

*Cut-off of the ***Intention to adopt*** variable ≥ 4 (likely to adopt laser-weeding).

***,**,* significance levels at 0.001,0.01, 0.05

Discussions and conclusions

- **Relatively high intention to adopt** laser-weeding.

→**Promising, but need suitable support actions** (policies, regulations).

- **Critical factors for intention to adopt:** (1) **Technology interest** > (2) **Perceived usefulness** > (3) **Environmental concerns**.

→**Education and communication** (to improve awareness and interest) **are key.**

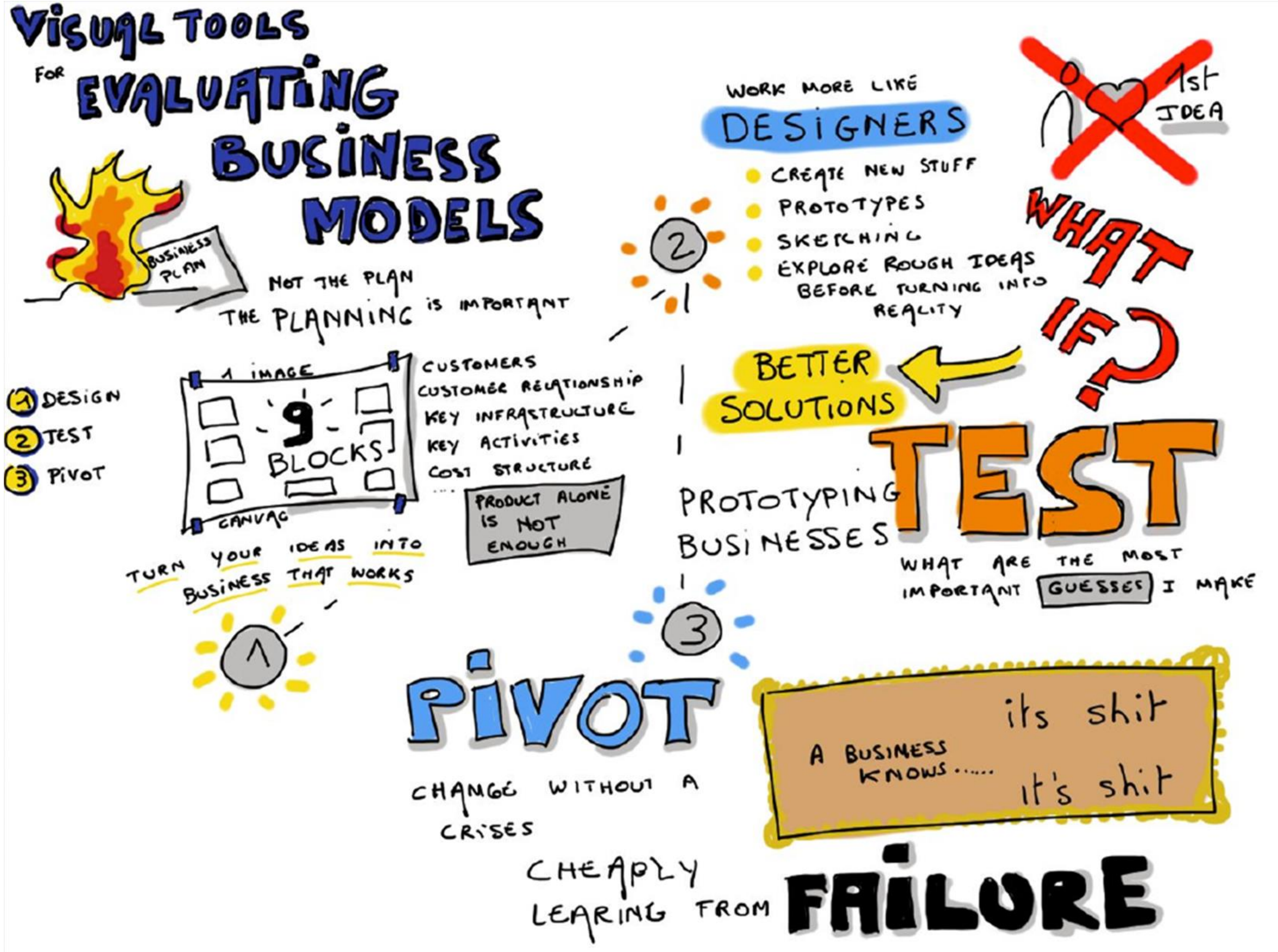
- **Heterogeneous preferences** for **mobility mode, service and efficacy/speed** of laser-weeding solutions.

→**Larger sample size is needed to explain.**

- **Green energy** source is important for prospective adopters.

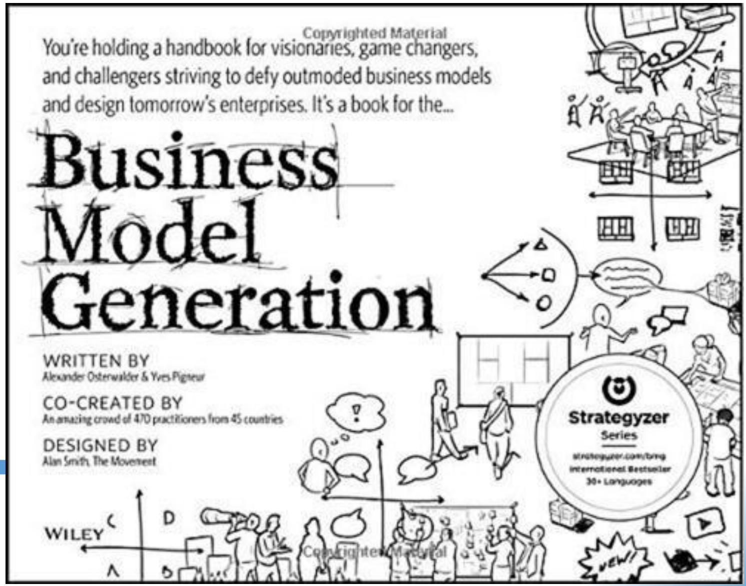
5. Setting up the business model: Business model canvas

Business model canvas

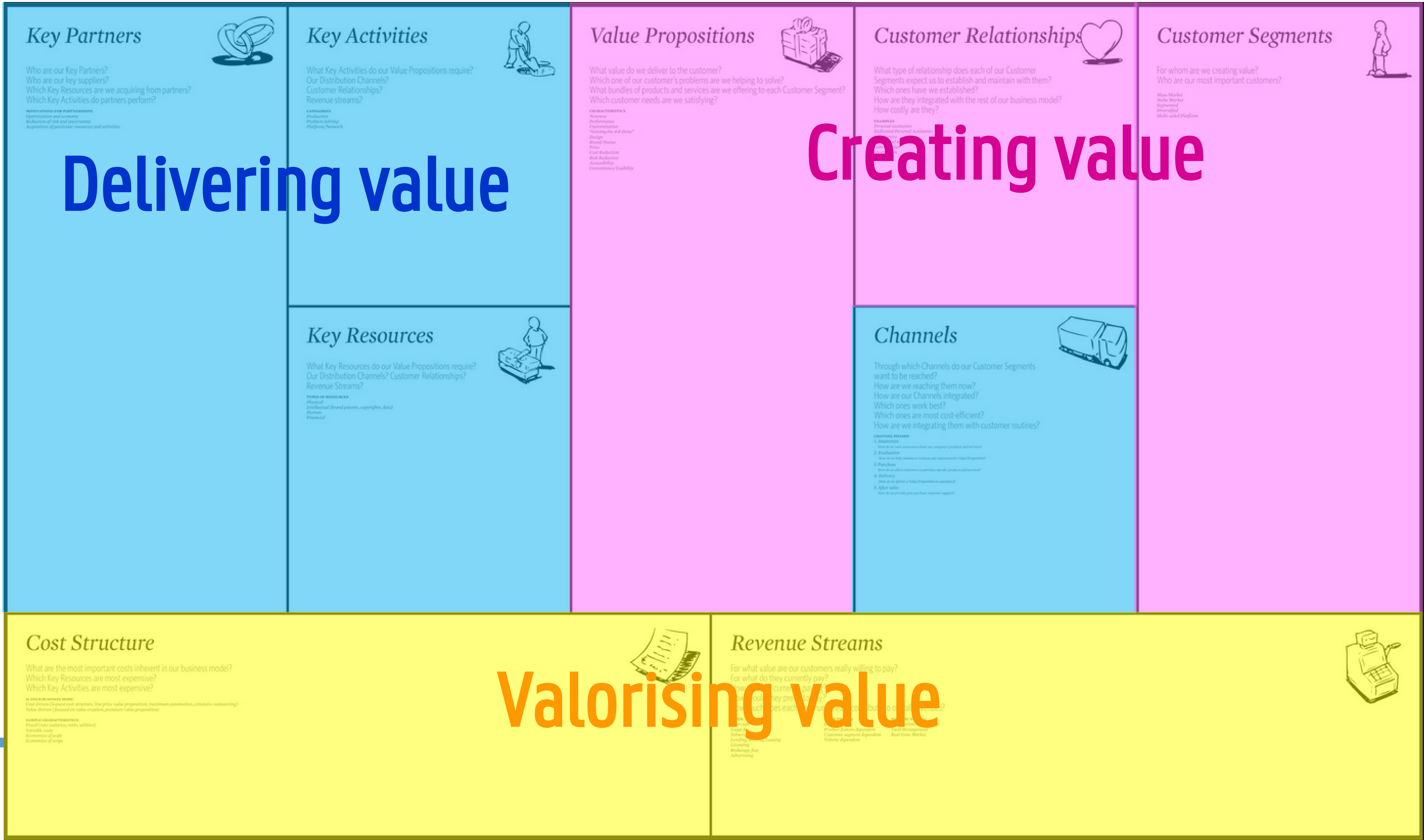


Business canvas model

- Shared language to describe, visualize, asses and change your business model
- Create new strategic alternatives
- Frequently applied in industry
- Facilitates the process of challenging assumptions and successful innovation
- Nine building blocks
- Osterwalder & Pigneur



Business model canvas



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Business model canvas

Key Partners

OEMs (original equipment manufacturer)

algorithm developer

writing of mathematical algorithms

Key Activities

R&D

develop new soil research technology

Key Resources

knowledge in soil research

skilled people

Value Propositions

long term value of land in terms of future revenues and discounted to present value

technology to estimate future value of land and model to calculate it back to today's value

Customer Relationships

maintenance contract

e.g. annual calibration by technique developer

Channels

specialised soil research equipment (web)store

Customer Segments

soil research agency

Cost Structure

people

manufacturing

Revenue Streams

technology sales

revenues are determined by the fraction of added (or lost) value of a land sale that farmers are willing to pay for soil research of the land for sale

Thank you for your attention!

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