DIGITAL AGRICULTURE e-Book

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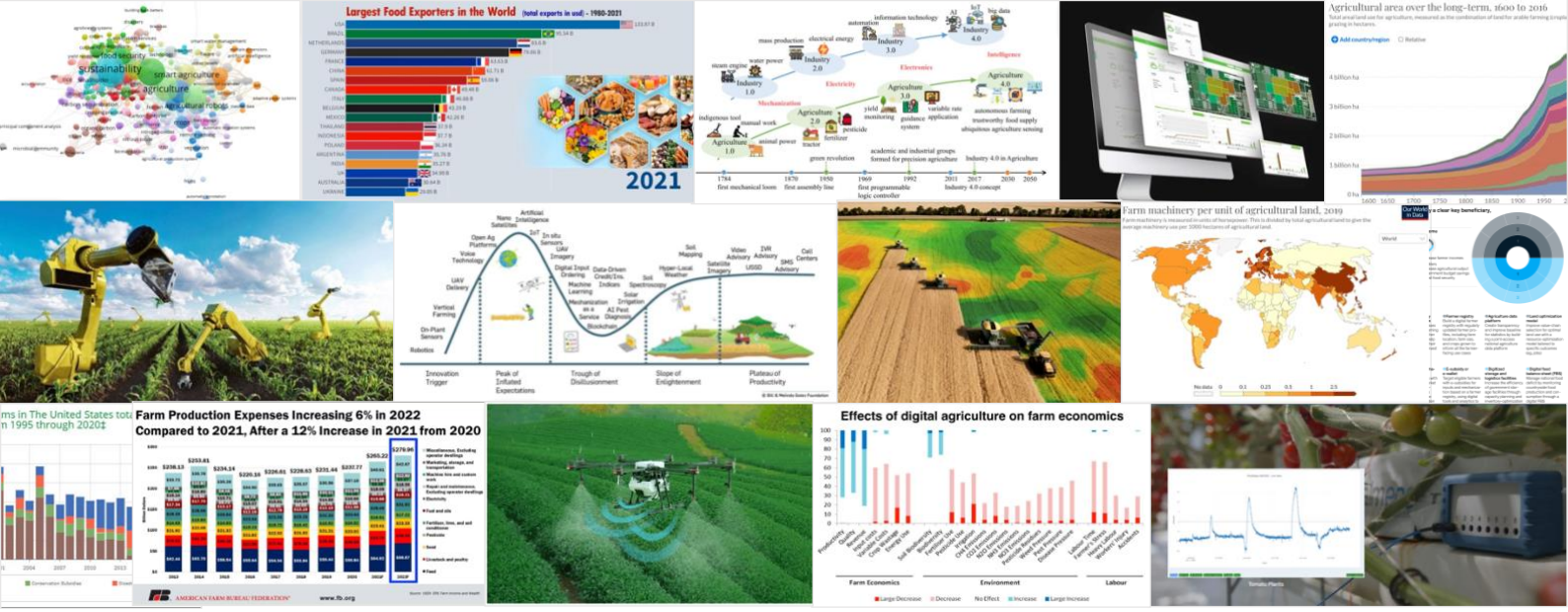

EASY
introduction to

DIGITAL AGRICULTURE

e-Book

January 2023

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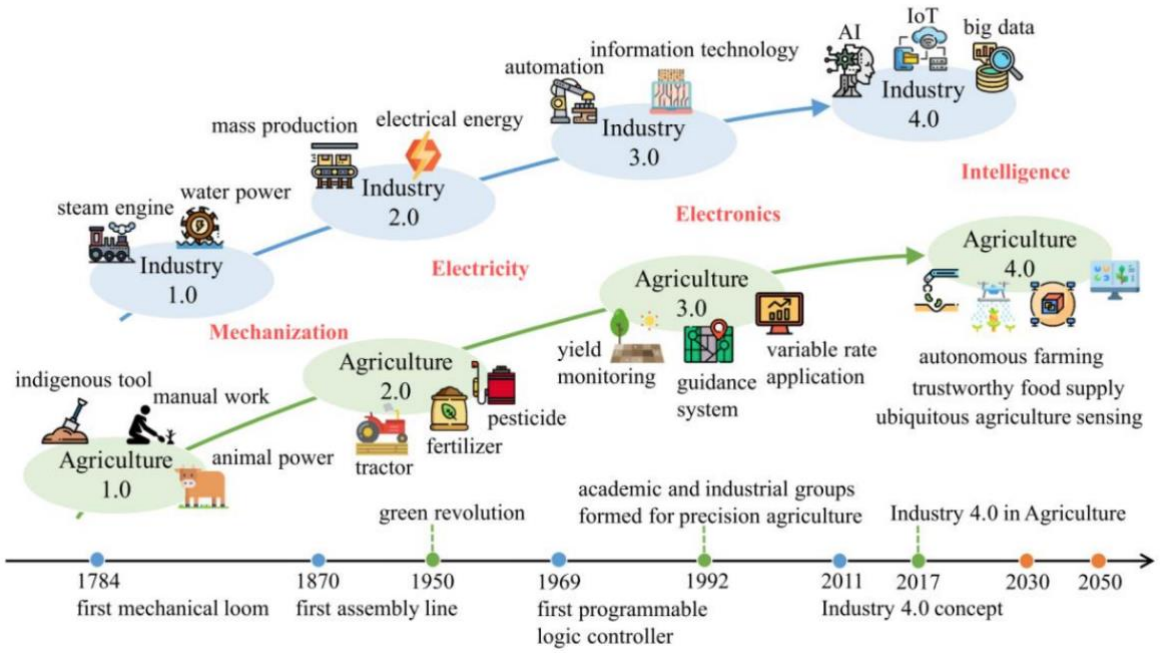
DIGITAL AGRICULTURE: WHY ADOPTING IT?

Connecting Water+Energy+Food → for a sustainable integrated food system



FOOD + WATER + ENERGY + DIGITAL = SUSTAINABLE FUTURE?

The food, water, energy resources are at the centre of sustainable development. Currently, agriculture accounts for 70% of all freshwater withdrawals globally (The World Bank)

Digital Agriculture can in the future effectively solve the challenges targeted in United Nations' Sustainable Development Goals, transforming the interconnections between food - water - energy - climate nexus, monitoring in real-time how water, chemicals, and energy are used for the production of healthy food:

▶ decreasing input costs (and therefore resource use) while protecting the environment

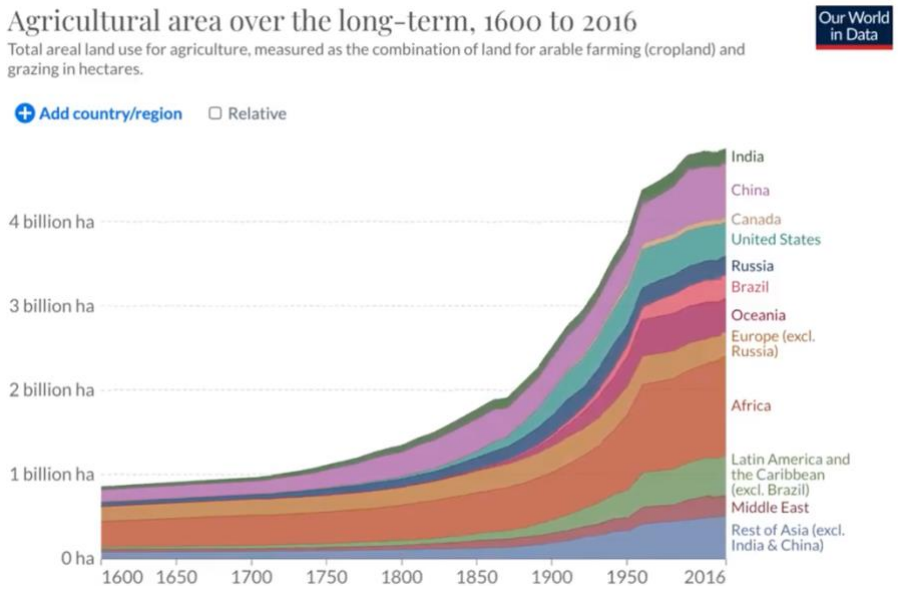
▶ supporting farmers' productivity overwhelming many of the economic, social, and environmental challenges that agriculture is facing today (including making the job more attractive to new generations);
▶ providing greater transparency for consumers on how food is produced.

The development of national and international policies, the implementation of strategies, and the control and supervision of processes will be needed.
Priorities:
- data & solutions interoperability;
- data ownership and privacy;
- robots clear (and possibly international) regulations

Although innovation is often conceived as techno-centric, the rise of Agriculture 4.0 thinking needs to consider also environmental and social sustainability perspectives.

Although data-driven technologies play a key role at all stages of the production of food and feed in agri-food systems of the future, none of this can happen without enough energy and water from farm to fork.

NO MORE LAND AVAILABLE → SUSTAINABLE FARMING INTENSIFICATION IS THE ONLY SOLUTION



TOTAL AREA LAND USE FOR AGRICULTURE (estimated):

year 1600: 856 millions hectares
year 1960: 4.380 millions hectares
year 2016: 4.870 millions hectares

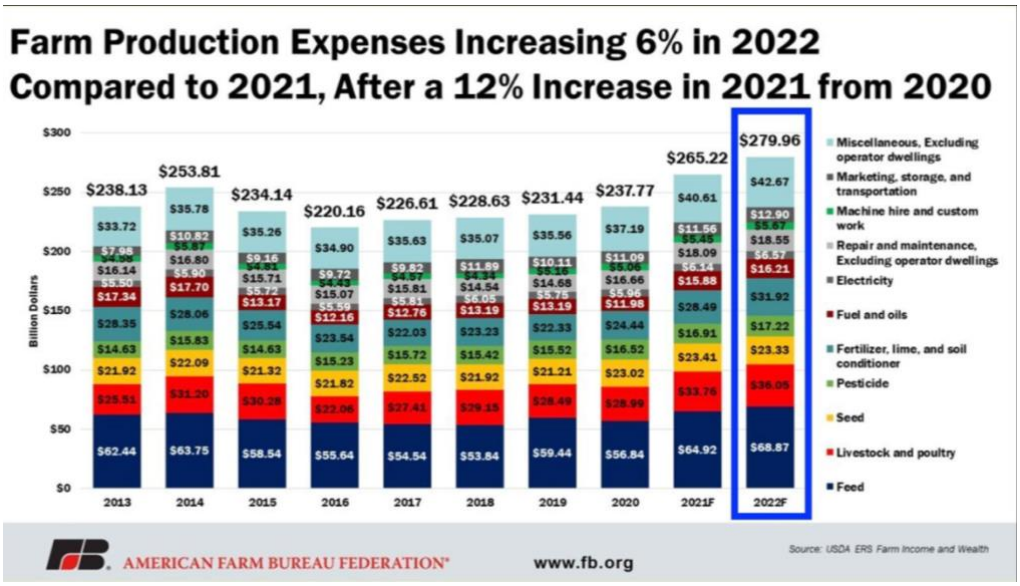
NO MORE LAND AVAILABLE FOR AGRICULTURE

We need to protect the biodiversity left in our forests.
We can't grow anymore the agriculture land.

WHAT TO DO? EFFICIENCY INCREASE

Achieving more with less.
Constant EFFICIENCY IMPROVEMENT should be the main focus from now on and DIGITAL AGRICULTURE promises just that (and it's already proving it).
Reducing the inputs and increasing the production is possible.

PRODUCTION COSTS RISING → SAVING $4.7 Billion/year? YES! adopting digital agriculture



PRODUCTION EXPENSES RISING

Production expenses continue to rise into 2022. Just from 2021 to 2022, USDA estimates total production expenses to increase 5%; that's after a 9% increase from 2020 to 2021

WHAT IS RISING MOST THE MOST? FERTILIZER

While the chart shows the farm's cost split, the largest expected production expense increase in 2022 is fertilizer, increasing 12% from 2021 to 2022, after a 17% increase from 2020 to 2021

WHAT CAN DIGITAL AGRICULTURE DO?

According to Association of Equipment Manufacturers (AEM), farmers consistently using various precision agriculture technologies achieved the following:

▶ 4% increase in crop production
▶ 7% increase in fertilizer placement efficiency
▶ 9% reduction in herbicide and pesticide use
▶ 6% reduction in fossil fuel use
▶ 4% reduction in water use (and therefore energy)
(According to several other sources (and my personal experience) these figures are quite conservative)

TOTAL ESTIMATED SAVING: $4.7B (in USA only)

Fertilizers saving $ 2.23 B (= total costs $ 31.92B x saving 7%)
Pesticides & herbicides $ 1.55 B (= total costs $ 17.22B x saving 9%)
Energy (fuel) $ 0.98 B (= total costs $ 16.21B x saving 6%)
These figures are not taking into account the increased productivity and the efficiency impact on the overall farm adopting ERP and other secondary technologies.

LEARNING FROM THE BEST → PRODUCTIVITY CAN BOOST VALUE BY 100 FOLD

Netherlands has 0.6% of US arable land, but is exporting as much as 60% of US. How? PRODUCTIVITY.

NETHERLANDS & DIGITAL AGRICULTURE?

"In the Netherlands digitalisation in agriculture and rural areas is already taking place in a rapid pace."

"... Also, other digital policies for the agricultural sector, such as the national digital policy by the Ministry of Agriculture, Nature and Food Quality, will both boost the digital transformation in agriculture even more. "

What is NETHERLANDS DOING NEXT?

National Policies influencing (rural) digitalisation:

1. Digital inclusion, increase of digital literacy
2. more data-driven agriculture
3. Increased investments & digital infrastructure in rural areas
4. OPEN DATA & cybersecurity for all

5. Increase biodiversity, resilience of farmers
6. Acceleration of adoption of precision technologies

SOME DATA

ARABLE LAND: NETHERLANDS vs. USA
Netherlands: 1 Million hectares
USA: 157 Million hectares

POPULATION
Netherlands: 17.53 Million people
USA: 331.9 Million people

NETHERLAND'S EXPORT: DETAILS

- €95.6 billion total EXPORT:
- €65.3 billion/$78.7 billion produced in the Netherlands
- €27.3 billion/$32.3 billion in re-exported products that have gone through little or no processing in the country.

By sector:

1. 1flowers (€9.5 billion/$11.4 billion)
2. 2 meat (€8.7 billion/$10.5 billion)
3. 3 dairy and eggs (€8.3 billion/$10 billion)
4. 4 vegetables (€7.1 billion/$8.6 billion)
5. 5 fruit (€7 billion/$8.4 billion).

FARM COST ANALYSIS → DIGITAL TOOLS → BETTER DECISION → HIGHER PROFITS (Kentucky USA)

FARMs INPUTS COSTS *(Kentucky 2016-2020)*

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fertilizer	149	139	135	122	109	94	98	112	105	118
Chemical	51	64	62	62	66	68	64	69	76	84
Seed	81	85	85	84	82	82	81	83	87	84
Fuel	40	41	38	26	20	24	27	26	21	29
Rent	183	195	189	194	188	184	182	188	189	197

Data from: Kentucky Farm Business Management program (five-year average: 2016-2020)

BETTER DECISIONS lead to HIGHER PROFITS

"many factors contribute to the profitability of the farms. Some, such as weather, cannot be controlled, but the management practices of each operation impact many other factors. Not one single factor will be the consistent main contributor to the difference in profitability. The goal of all producers should be to analyze personal trends and work toward improving their individual operations."

GOOD DIGITAL TOOLS enable BETTER DECISIONS

That's precisely what digital agriculture tools should constantly have in mind. Providing updated & aggregated information about the farm and the crop to help farmers in taking the best economic and agronomic decisions.

RESULTS OF THE STUDY:

LARGER THE FARM -> HIGHER THE PROFIT

"Farms in the higher profit group were larger, had higher corn and soybean yields"

WHY? SIZE & BETTER CHOICES

The larger farms are able to spread the fixed costs over more acres.

MANAGEMENT PRACTICES also impact the costs. The crop costs include seed, chemicals, and fertilizer.

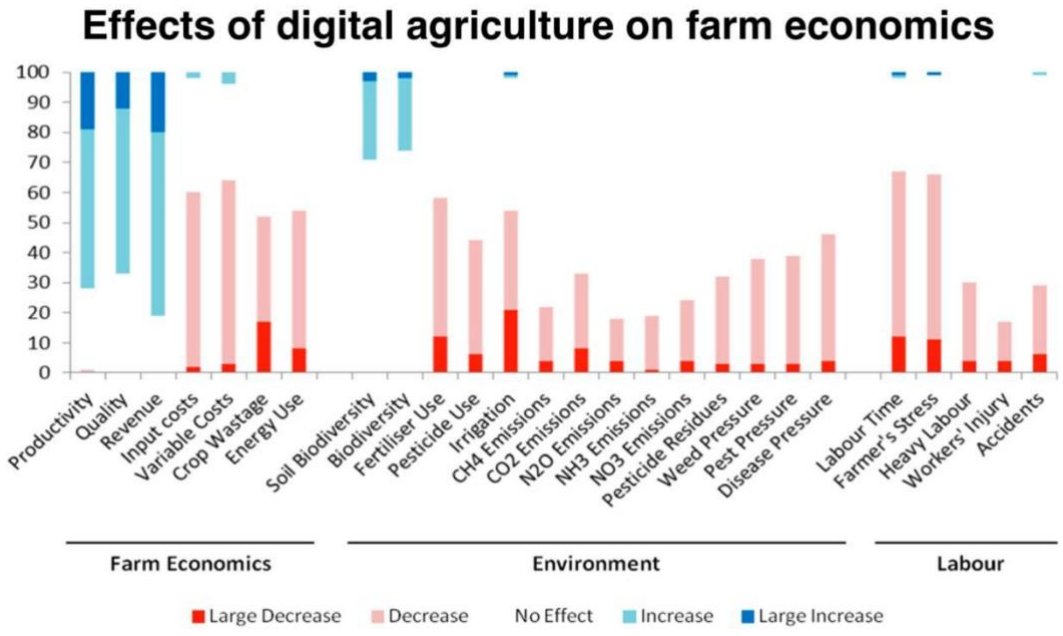
HIGHER PROFIT by LOWER INPUT COSTS

Crop costs for the higher profit farms...were lower than the lower profit farms. Fewer inputs to generate higher returns resulted in these farms being at the top.

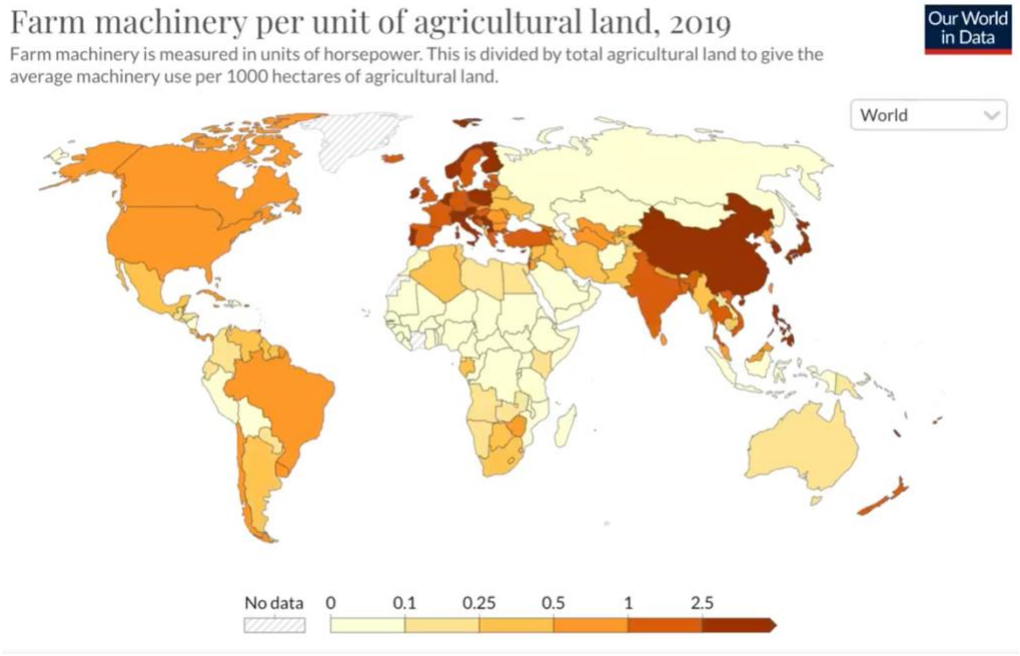
DIGITAL AGRICULTURE → ECONOMIC IMPACT AT FARM LEVEL

DIGITAL TOOLS viewed from their ECONOMIC IMPACT perspective

Digital agriculture aims to increase revenues and reduce costs & riks.
This chart focuses indeed on the economic impact rather than the tool functionalities.
You can find in this very interesting chart the scientific and market opinions about the benefits of the implementation of digital agriculture at farm level.



TARGET COUNTRIES? → WHERE CAN DIGITAL AGRICULTURE FIND "FERTILE MARKETS"?



DIGITAL AGRICULTURE PENETRATION BY COUNTRY?

Being curious about the market penetration and the potential of digital agriculture, while not having (yet) found any not having found any convincing figures about it, I approached it "by proxy".
(please share in the comments any other source that can answer this question)

MACHINERY PENETRATION AS A PROXY

Digital agriculture are tools to increase farm productivity as... machines are as well. Therefore analysing the market penetration and trend of machinery in farms, may give interesting clues about the opportunity for digital agriculture.

VALID ONLY AS A "BRAIN STORMING MATERIAL"

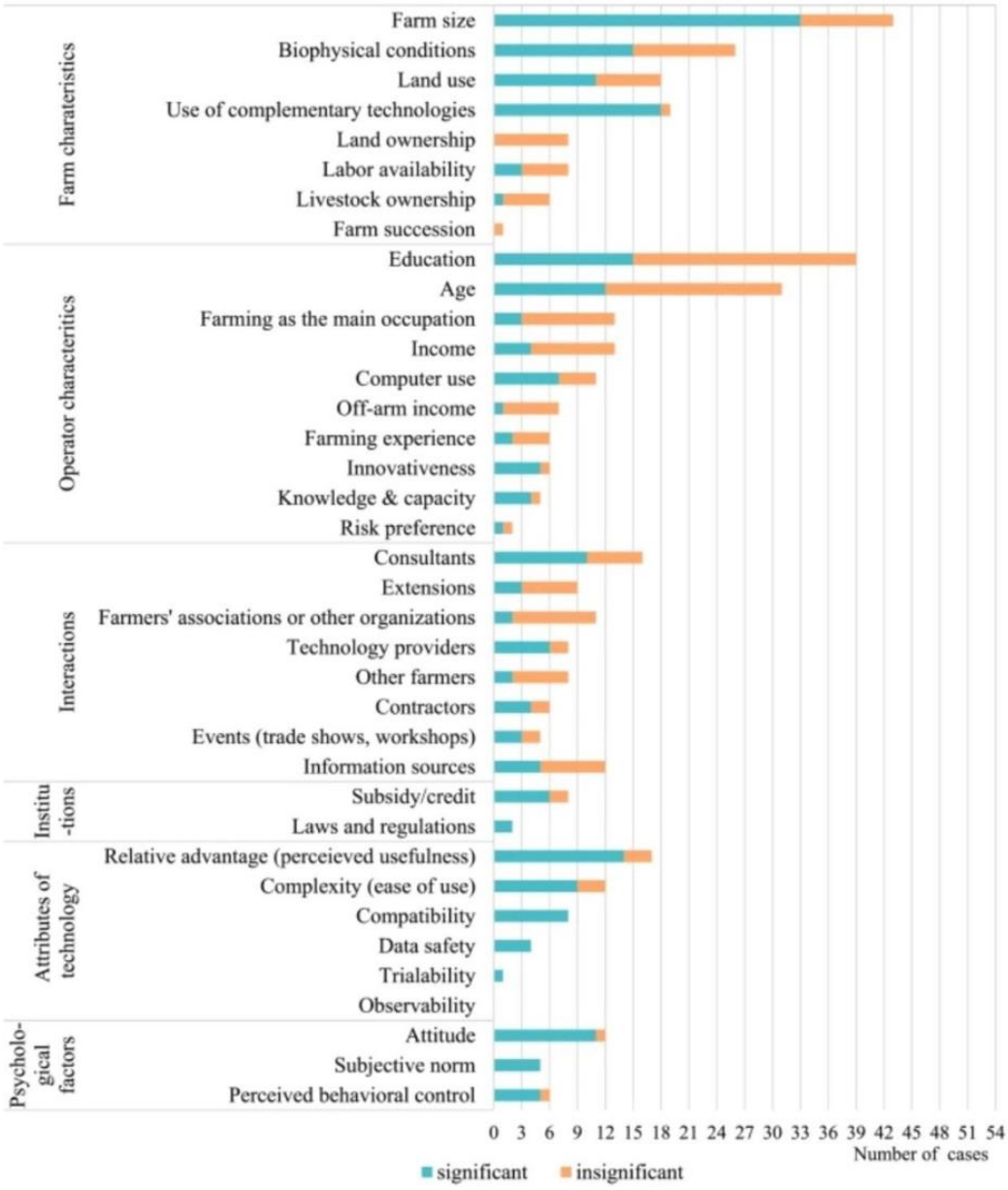
The video below shows the "Farm machinery per unit of agricultural land" over time.
Such evaluation has to be taken along with "side thinking" as it is: "units of horsepower" divided by "agricultural land", not considering the level of machinery sophistication. A better metric would have been "money invested in machinery".
Also the darker colours cannot be taken as a sign of larger market for digital agriculture. But, in my opinion, every country with a colour code above 0.25 holds a good potential for digital agriculture.

GEOGRAPHICALLY DIVERSIFIED OPPORTUNITY

Some countries such as the ones in south & east Asia, have a strong presence of small-holder farmers; this target market holds indeed a great untapped potential, but different solutions should be developed for it (ideally developed by developing countries).
Other countries such as USA, Brazil, Canada, Australia, South Africa, although are looking "lighter" in the map, are the ideal target market for most of the currently available solutions.

DIGITAL AGRICULTURE: HOW TO ADOPT IT?

DIGITAL AGRICULTURE ADOPTION: → WHO & HOW?



WHO?

Main adoption factors:
1. FARM SIZE
2. FARMER'S EDUCATION
result to be the most important factors in motivating the adoption of digital agriculture

The "neighbor effect" also plays an important role in informing and deciding.

"Farmers may learn about the technology from neighbors who already adopted it."
"impact of neighbors' negative opinions"
"the importance of obtaining information from other farmers"

HOW?

Step-by-step adoption & diffusion of digital agriculture:

(1) KNOWLEDGE STAGE: the farmer becomes aware of a technology's existence and eventually gets interested in it.

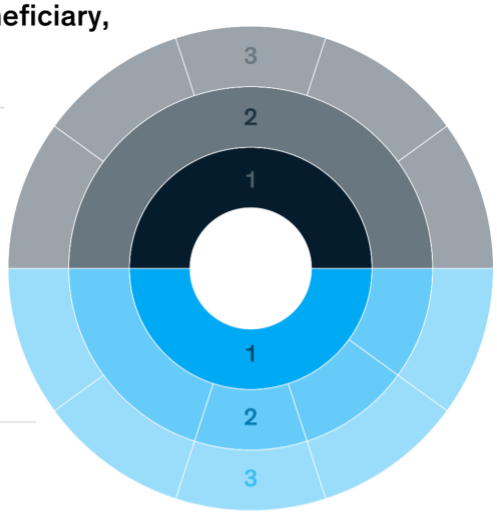
(2) PERSUASION STAGE: the farmer ascertains the potential value of adoption

(3) DECISION STAGE: the persuasion stage, where intention is formed, the farmer decides to adopt or reject at the decision stage.

(4) IMPLEMENTATION STAGE: is where production activities of a farm are carried out based on the farmer's adoption decision

(5) CONFIRMATION STAGE: refers to an evaluation based on whether the criteria initially set up for adoption/rejection has been met.

Each use case is defined by a clear key beneficiary, outcome, and digital tool.



1 Key beneficiary

- Smallholder farmers
- Governments

2 Outcome

- Increase farmer incomes
- Enablers
- Increase agricultural output
- Government budget savings
- Boost food security

3 Tools

Smallholder farmers

Governments

Pests and disease early warning system
Reduce crop losses with an early warning system for pest and disease outbreaks and advice on actions to protect crops

Weather early warning system
Reduce crop losses with an early warning system for weather fluctuations to help farmers adjust their planting and harvest plans

Farmer registry
Build a digital farmer registry with regularly updated farmer profiles, including farm location, farm size, and crops grown to inform all the farmer-facing use cases

Agriculture data platform
Create transparency and improve baseline for statistics by building a joint-access national agriculture data platform

Land optimization model
Improve value-chain selection for optimal land use with a resource-optimization model tailored to specific outcomes (eg, jobs)

E-extension platform
Improve farmer practices (eg, input use) by providing farmers with customized e-extension advice on an easily searchable platform

Market information system
Provide farmers with regular crop market prices from geo-located markets nearby to reduce market information asymmetries

E-subsidy or e-wallet
Target eligible farmers with e-subsidies for inputs and mechanization based on a farmer registry, using digital tools and analytics to improve performance of the subsidy program

Digitized storage and logistics facilities
Increase the efficiency of government storage facilities through capacity planning and inventory-optimization analytics

Digital food balance sheet (FBS)
Manage national food deficit by monitoring countrywide food production and consumption through a digital FBS

McKinsey & Company

WHAT DIGITAL AGRICULTURE TECHNOLOGY & for WHAT? → MAPPING TECHNOLOGIES WITH SERVICES

	Digital agricultural technologies										
	Management								Novel foods	Connectivity	
Ecosystem services	Big data	AI and machine learning	Robotics and automation	Genetics	Sensors	CEA	UAV and remote sensing	Precision agriculture	Cellular ag	Blockchain	Other
Air quality improvement	—	1	—	—	1	—	1	1	—	—	—
Biodiversity enhancement	4	2	2	7	3	—	3	4	—	1	—
Biomass production	—	—	—	2	—	—	—	—	—	—	—
Climate regulation	7	4	5	12	9	2	3	10	7	2	1
Disease reduction	2	—	—	5	1	—	—	1	1	3	3
Energy efficiency	—	—	—	1	1	—	—	—	2	—	—
Herbicide and pesticide reduction	3	5	3	7	4	—	3	6	1	—	—
Land footprint reduction	4	3	3	4	5	1	2	7	3	1	—
Nitrogen fixation	—	1	1	2	—	—	—	1	1	—	—
Nutrient management improvement	14	7	8	10	18	2	8	26	6	3	8
Pest reduction	—	4	2	6	4	1	3	3	—	—	—
Pollination enhancement	—	1	1	1	1	—	1	1	—	—	—
Soil health improvement	—	4	3	3	4	1	3	4	1	—	—
Waste reduction	3	1	2	4	2	—	1	4	1	4	4
Water management	2	4	4	2	6	2	3	5	1	2	1

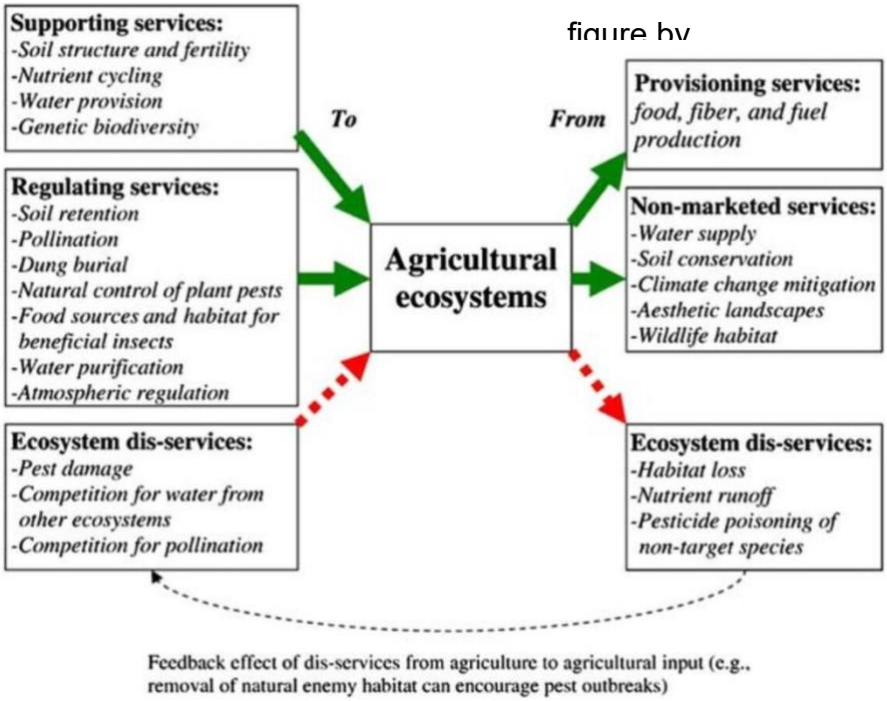
Colouring of cells show count percentiles, the darkest colours representing the 90th percentile of all recorded values in the table. AI, artificial intelligence, CEA, Controlled-environment agriculture, UAV, unmanned aerial vehicle.

"how digital agricultural technologies may enhance agriculture's support of ecosystem services ?"

ACADEMY COMMUNITY'S OPINION

The authors of this study created this map after have analysed several academic publications (2337 records) and correlating the digital agriculture technologies with the agriculture services.

Does ROI include all? → SERVICES vs. DIS-SERVICES



What are the DIS-SERVICES?

"...Agriculture also receives ecosystem dis-services that reduce productivity or increase production costs." (see picture)

Uncontrollable vs. controllable dis-services

Summer too hot? Winter too cold? Too much rain?...
There is nothing the farmer can do about other than trying to mitigate the effects.
But several others... are sort of byproduct of actions voluntarily taken (and often paid for) by the farmers themselves.
For instance, the illustration below shows an example of a vicious cycle:

SERVICE: pollinators insects

ACTION: pesticides
BY-PRODUCT: poisoning of non-target species (including pollinators)
DIS-SERVICE: less pollination occurring (higher costs)[1]

CAN DIGITAL AGRICULTURE HELP?

Agronomic recommendation tools have proven to reduce up to 50% the use of pesticides while even reducing the pest damage risk.
Even if that doesn't eliminate the problem, that's a concrete step into significantly mitigating it.

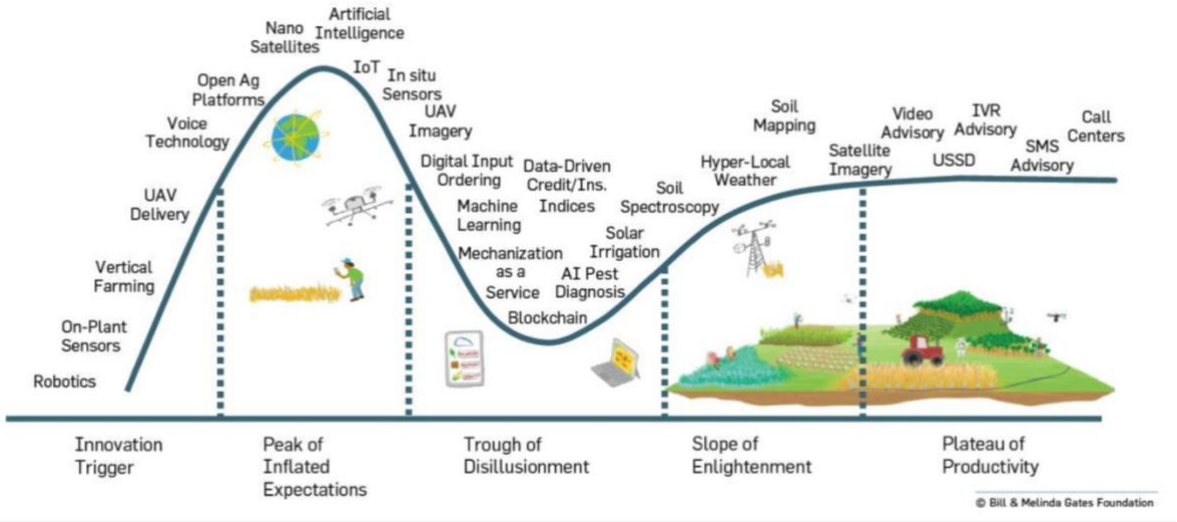
IMPACT ON DIGITAL AGRICULTURE ROI

Impacting this (and others) vicious cycle present in today agricultural practices has a positive (and OVERLOOKED) impact on the adoption of digital agriculture.

[1] "...annual value of four ecological services provided by primarily native insects in the United States to be more than $57 billion" Dr. John Losey (Cornell University) Mace Vaughan

SMALLHOLDER FARMERS AND DIGITAL AGRICULTURE

SMALLHOLDER FARMERS ADOPTION → TECH READINESS, ENABLERS & BARRIERS



ENABLERS TO ADOPTION (from smallholder farmers)

- Smartphone costs are rapidly decreasing
- Social media usage is rapidly growing
- Mobile money has enabled growth of digital services
- Mobile Internet coverage is increasing
- Digitization of services
- Voice and conversational AI

BARRIERS TO ADOPTION (from smallholder farmers)

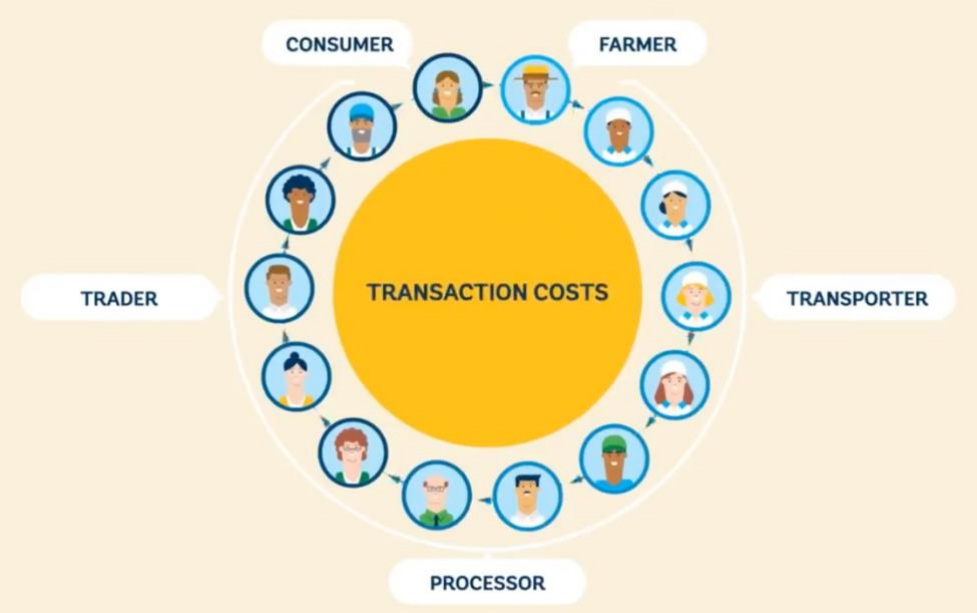
1. The majority of digital agriculture solutions aren't target this market segment.
2. The digital divide is still huge: 3.3 billion people who live in areas covered by mobile broadband but are not using mobile Internet services. Why?

- Connectivity and access
- Affordability
- Literacy and skills
....

TO DO

Adapting Digital Agriculture solutions to smallholder farmers requires:
- Solutions targeting aggregators
- Making solutions more affordable

DIGITAL AGRICULTURE for SMALLHOLDERS FARMERS? → WHAT? WHO? WHY? PRIORITIES?



On-Farm Digital Transformation

TOOLS (depending on the application):
- smartphones (apps, videos, social networks)
- traditional cellphones (sms and/or USSD).

SERVICE(s):
Improved access to information for knowledge transfer & skill acquisition (including low-cost extension advice);
SOLUTION PROVIDERS:
Wefarm, Access Agriculture, Farmerline Group, AgroCenta Technologies, Inc (Techstars 22), PlantVillage, Digital Green, Monsanto Company

SERVICE: Improving information processing and optimization to support on-farm decision-making (data about field conditions for fertilisers optimisation,...) and

accurate, timely, and location-specific weather information;
SOLUTION PROVIDERS: AfricaRice AfricaRice, IBM,

SERVICE: Early warning systems for crop and livestock health
SOLUTION PROVIDERS: Plantix, Vetafrica, Cowtribe Inc and FALL ARMYWORM MONITOR and GIEWS (FAO), iCow (Kenya), Vetware

SERVICE: Access to financial services
SOLUTION PROVIDERS: Dvara E-Dairy

Off-Farm Digital Transformation PRIORITIES:

1. reducing the costs associated with searching and gathering information
   WHY?
   The sum of transaction costs faced by a farmer creates a price band that determines the farmer's decision to purchase inputs or sell produce, thus limiting productivity and profitability.
   Transaction costs tend to be higher for farmers living in remote areas...
2. reducing information asymmetries: "The lemon problem"

WHAT is it?
Happens when the seller has more information than the buyer

CONSEQUENCES?
Market failures due to asymmetric information occur in all major agricultural markets

- FOOD BUYERS cannot distinguish between a high-quality and low-quality product, a low-quality product sells at the same price as a high-quality one. In the output markets, buyers of agricultural products from farmers may be uncertain about their quality, so farmers lose transactions or receive lower prices.

- FARMERS are discouraged to purchase quality input, contributing to suboptimal input use, and so to low farm productivity and profitability.
- FINANCE: Asymmetric information also limits cash-constrained farmers' access to credit, reducing their ability to purchase inputs or make quality-enhancing investments.

DIGITAL AGRICULTURE → Smallholder farmers technology adoption constraints

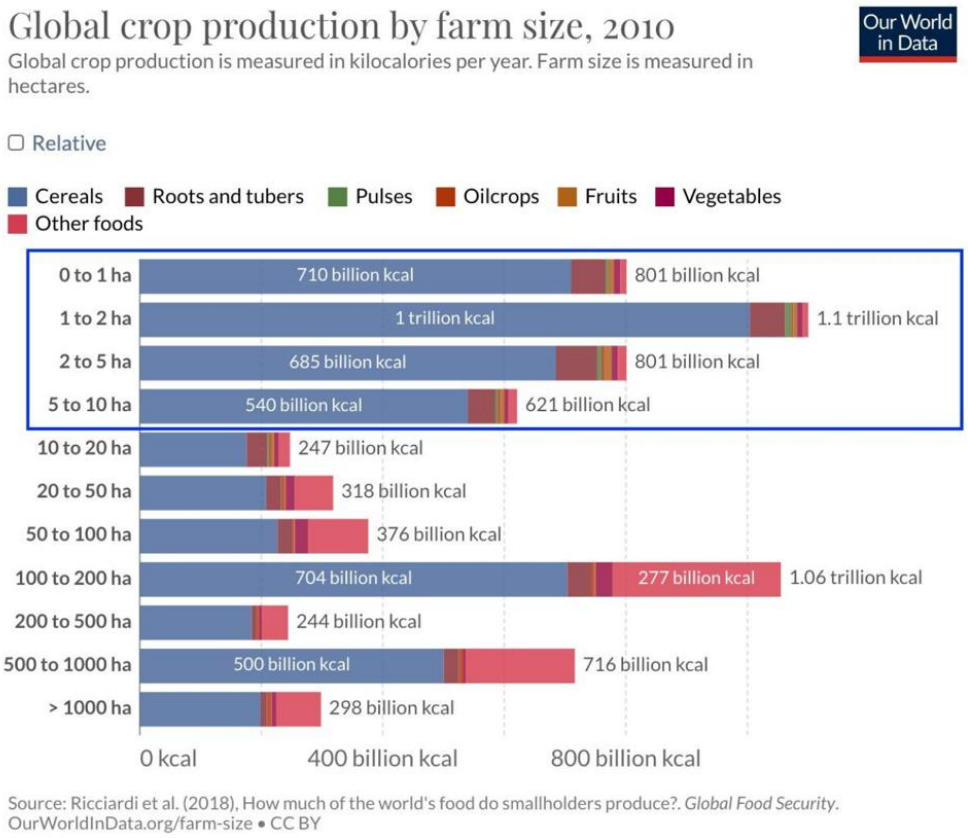
	Hardware and Architecture (Affordability)	Vision, Speech, ML/AI (Relevant Data)	Systems, Security (Connectivity Data Platforms)	Human Interface (Usability)
	Low-cost sensing (RF, audio), low-power sensors, sensing roots/carbon	Surrogate sensing Microclimate prediction Advisories, for example, water Livestock health, estrus	Low-cost IoT networks Secure data ingestion Reliable sensor system Data sharing	Display alerts Automated diagnosis Fault recovery
	High-res optical cams Satellites SAR probes LEO constellations	Cloud removal, SAR AI/ML for yield/disease/etc. Accurate super -res imagery	Satellite downlink speed Merging IoT + remote sensing Timely analysis	Visualizing form imagery and insights
	Battery life Wireless charging Low-cost robots	Localization below canopy ML without labeled data automation in mixed crops	Edge compute Shared robots Large data transfer Secure sharing	Low-tech operation Interpretation of results
	Low-power cams Low-cost multispectral	Livestock stress detection Cow health Pest detection	Broadband Edge compute Federated ML	Ease of use Theftproof
	Low-cost devices with rich UI	Local speech -to-text, digitizing knowledge	Internet systems (e.g., IFTTT) with phones	Geospatial insights on SMS, new apps
	Secure edge Low-cost sovereign data centers	Obtain ground truth data, AI on unlabeled data, multimodal data	Secure data sharing AI on encrypted data Data collaboratives Models	Ease of data sharing Awareness of misuse

This interesting table from Microsoft looks at the digital agriculture technologies from the adoption perspective of the smallholders farmers.

Red: much improvement is required
Yellow: some work still required
Green: ready to be adopted

It expands the evaluation beyond the relevant, but narrow, perspective of uniquely looking at the price.
Many digital agriculture solutions can indeed be implemented to smallholder farmers by local aggregators such as cooperatives and/or service providers that can split the cost among many farmers.

SMALLHOLDER FARMERS ADOPTION → Does FARM SIZE vs. CROP TYPE matter?



Source: Ricciardi et al. (2018), How much of the world's food do smallholders produce?. *Global Food Security*.
OurWorldInData.org/farm-size • CC BY

Smallhoder farmers produces mainly cereals, can this BARRIERS TO ADOPTION of digital agriculture?

- CEREALS-

In average cereals provide low % marginality.
What is the impact on the Digital Agriculture adoption?

- LARGE CEREAL FARMS-

✅ SIZE:
Large farms can achieve interesting economic results scaling in size and allowing

them to invest and increase the productivity.

✅ ATTITUDE:

Having been experiencing the benefits of technologies over the time (machinery,...) they show a positive (often enthusiastic) attitude toward technology innovation.

✅ ADOPTION:

Cash availability along with a positive attitude toward innovation makes them good adopters of Digital Agriculture.

- SMALLHOLDER FARMERS[2]-

Smallhoder farmers produces mainly cereals, can this BARRIERS TO ADOPTION of digital agriculture?

❌ Smallhoder farmers by definition don't scale and therefore can't have the equivalent cash availability for investments, while only partially benefit from technology tools (unless aggregators act as scaling factor).

❌ Smallhoder farmers didn't experience (yet) significantly the benefits of innovation and technology, not having therefore developed an attraction toward innovative technologies.

Please share your opinions and comments on this subject, I'll be happy to read and learn from them.

[2] FAO definition: "Smallholders are small-scale farmers, pastoralists, forest keepers, fishers who manage areas varying from less than one hectare to 10 hectares"

SOLUTIONS FOR DIGITAL AGRICULTURE

DIGITAL AGRICULTURE's STARTUPS TRENDS → 2022 Agri Trends, Tech & Innovations targeted by startups

Which digital agriculture solution is most needed by a medium-large farm?	
drone (spraying & surveying)	17%
ERP (farm management system)	41%
robot (harvesting, weeding)	15%
Agronomic recommendation	27%

1. Internet of Things

❓agri inputs optimisation, agronomic risk mitigation
✅ sensors ▶ real-time crop monitoring ▶ agronomic decision support

2. Agricultural Robotics

❓agri labor shortage, productivity
✅ robots ▶ fruit-picking, harvesting, planting, transplanting, spraying, seeding and weeding

3. Artificial Intelligence

❓productivity ▶ farmers to make informed decisions
✅ Forecasting AI ▶ weather data, crop yield, and prices.
✅ Chatbots ▶ easy interaction with farmers
✅ Recommendation AI ▶ disease recognition in plants and livestock.

4. Drones

❓productivity ▶ inputs optimisation, agronomic risk mitigation

✅ Spraying drones ▶ targeted spraying ▶ inputs optimisation

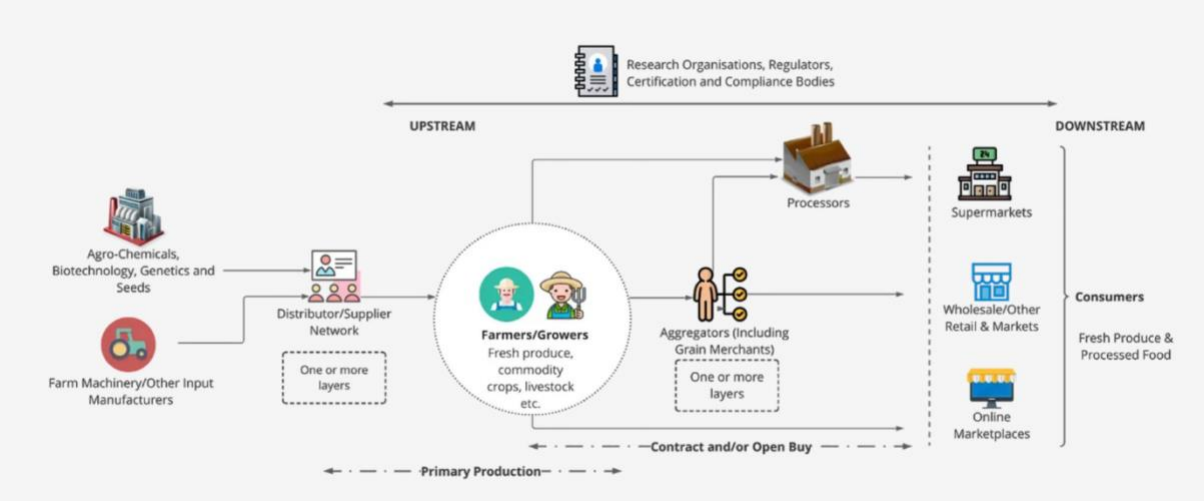
✅ Monitoring drones ▶ early detection of pests, diseases, nutrients deficiencies; harvest protection from stealing

5. Connectivity Technologies

❓technologies enabler ▶ necessary to several above technologies

✅ Lora, Sigfox, 5G

AGRI ERP → What for? FARM PRODUCTIVITY



Computers (digital) can support our activities performing the trivial and boring jobs for us in an efficient way.
While this is self-evident in our current daily life, it's not (yet) so at farm level where often today most of the farm information are either on paper or in the mind of the farmer.
Enterprise resource planning (ERP) software does precisely that (and much more).

ERP are at the core of digital agriculture and can represent the ideal connector of most the other digital agriculture tools.

While ERP software are widely used and consolidated in all sectors, they are still little used in agriculture.
Probably due to the high diversification in farms and because... "Implementing ERP is not about installing a piece of software, it is about working in a different way." (where the ERP helps to define and maintain the different way of working)

The right ERP is developed to trace the entire seed-to-sale journey.

"The key benefits of the ERP system are:
- higher productivity
- improved planning
- better forecasting
- automation through integration with other systems
- access to analytics and reporting
- easier regulatory compliance
- improved customer service
- increased reliability and robustness in the business processes."

FARM MANAGEMENT SOFTWARE → Better decisions digitally mapping all processes in the entire farm

WHAT: FARM MANAGEMENT SOFTWARE

farm data&processes ▶ farm management software ▶ better decisions

- captures farm's data & processes
- aggregates them in a smart way
- facilitates farmers in taking the best agronomic & business decisions

WHO: EVERY FARM

Every farm benefits from the use of a farm management software.
Every business (out of agri) currently already has a management software, taking advantage of it. Why shouldn't it work in agriculture?

HOW:

✅ good implementation = profits
❌ bad implementation = losses (waste of time)
A farm management software DOESN'T improves the farm by itself. It depends HOW YOU IMPLEMENT IT & USE IT.

Here is how:

1. define the priorities of your farm:
    - where is the pain?
    - which processes need more improvements?
    - where is perceived a waste of energy & resources?

2. define (quantifiable) expectations for each identified process
3. choose the software that responds best to the identified needs
4. implement STEP-BY-STEP:

    4a. Map in the software the essential to have it operational
    4b. Implement one process at a time
    4c. HARD PART: get used to it, it has to become part of the daily job routine; until everyone in the farm isn't making a diligent use of it, this step isn't fully executed, you shouldn't proceed further!
    4d. fine tune = adapt the software configuration to better map the wished change in the process (or the process itself if no changes are required)
    4e. MEASURE RESULTS: once the process has been mapped you should already be in a position to experience the benefits. If instead this process is preliminary to others, proceed.
    4f. you may proceed with the next process (next STEP)

5. track benefits: AT REGULAR TIMES
6. further adaptations: AT REGULAR TIMES

SOME SOFTWARE

(benchmark by PAT Research)

COMPANY USERS RATING

AgriWebb 8.3

AGRIVI 7.6

Agworld 7.5

Conservis 7.4

FarmLogs 6.7
Granular 6.3
FarmERP 6.3
Trimble Inc. 5.7
(this rating shouldn't be taken in absolute terms, as a farm management software addresses so many farm needs that some may perform much better than others in specific tasks that may be priority for your farm); a detailed benchmark can be found in the benchmark by PAT Research:
https://lnkd.in/e44Z8-nW

ROBOTS are already in the fields → ALREADY AVAILABLE & USEFUL

WHAT ARE THEY (MAINLY) DOING?

▶ Weeding (mechanically)

Benefits: no herbicides, continuous operation

▶ Targeted spraying

Benefits: saving up to 90% of chemical, continuous operation, early intervention

▶ Harvesting

Benefits: multiple harvest according to the ripeness, continuous and night operation, efficient.

SOME INTERESTING ROBOTS

1.Nexus Robotics

https://nexusrobotics.ca/

2.Guss Ag

https://gussag.com/

3.Harvest croo
https://lnkd.in/eta_R6BR

4.Agrobot
https://www.agrobot.com/

5.Tertill
https://tertill.com/

6.AVO
https://lnkd.in/ea98nQnM

7.Terra sentia
https://www.earthsense.co/

8.Farmwise
https://farmwise.io/

9.Thorvald
https://lnkd.in/eMPF4JxD

10.Dino
https://lnkd.in/eMPr6QAQ

ARTIFICIAL INTELLIGENCE FOR... → Yield prediction, pest & diseases, breeding, security and more

YIELD PREDICTION

Grundo

"Grundo's in house real-time yield prediction engine for various staple crops ... is currently deployed for our European customers and undergoing rigorous accuracy benchmarking."

https://lnkd.in/e8umq8FE

PEST & DISEASES

Agrio, Aerobotics, Prospera Technologies, AgroScout

Prediction, identification, treatment strategy

https://lnkd.in/evvNyjgf

CROP MONITORING

"keep track of the growth of your crops to optimise seed, crop production, reduce crop input costs, spend less time on field scouting"

Agremo

"ROBOTS BRAINS"

FarmWise, Carbon Robotics, Blue River Technology, Root AI, Harvest CROO Robotics, Fieldwork Robotics Ltd.

DRIVING/OPERATING MACHINERY OR DRONES

Cognitive Pilot, DroneUA

SECURITY:

Twenty20 Solutions

"A complete solution for round-the-clock theft and crime prevention on all of your agricultural properties."

https://lnkd.in/eM_R6NjN

BREEDING

Benson Hill "It accelerates breeding by enabling greater precision and fewer breeding cycles. It is like GPS for plant scientists and breeders. It takes the guess work out; getting to desired outcomes faster and more efficiently."

YIELD HEALTH AND RISK MITIGATION

Cropin "Providing critical intelligence for data-driven decision making powered by AI/ML"

PREDICT AGRICOMMODITY PRICES? → ARTIFICIAL INTELLIGENCE + DATA = PRICES IN ADVANCE

PROBLEM

Fluctuations in agricultural commodity prices affect the supply and demand of agricultural commodities and have a significant impact on FARMERS.

OPPORTUNITY

Accurate prediction of agricultural commodity prices would facilitate the reduction of risk caused by price fluctuations.

CHALLENGE

A study conducted by Sejong University in South Korea achieved fairly good predictions on cabbage and radish using meteorological information for the dynamic main production area.

ACHIEVEMENTS

The researchers achieved a more accurate prediction of 2.8% to 5.5% than that of the conventional model that uses meteorological information for the static main production area.

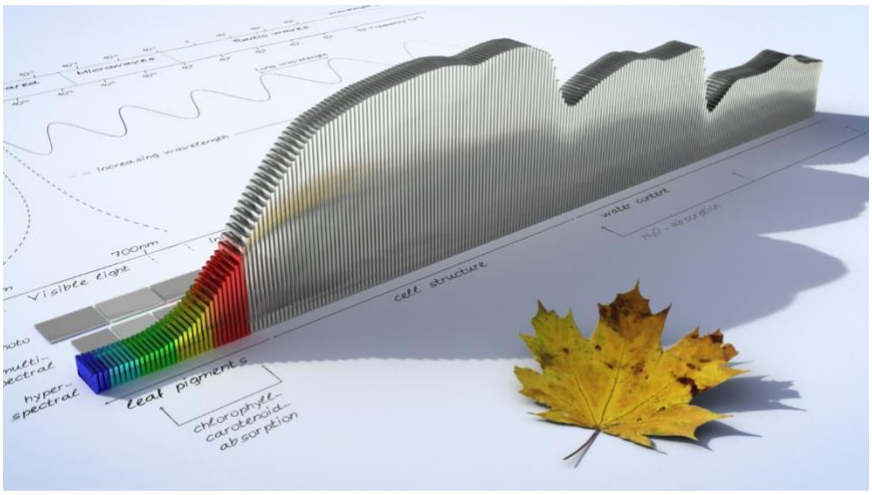
TECHNICAL DETAILS

Recurrent Neural Networks (more precisely: DIA-LSTM) have been trained using various variables that affect the price of agricultural commodities (meteorological data, trading volume data) to identify the feature correlation and temporal relationships.

MORE DETAILS: DIA-LSTM

The data used are known as "time series", in other words: data where the order matters. When training a neural network from such sequences of data, different strategies should be used.
What is known as SHORT TERM MEMORY becomes useful for taking into account the ordered context. For this, machine learning researchers have long turned to the recurrent neural network, or RNN (LSTM are a type of RNN and DIA-LSTM are a type of LSTM).

SENSING FROM THE SKY → Hyperspectral imaging = "looking at the plants from a magic mirror"



WHAT IS HYPERSPECTRAL IMAGING? (IN SIMPLE TERMS)

Image yourself searching in the garbage of your kids/friends to guess what they have eaten.
That's more or less what hyperspectral imaging is. As your kids/friends throw out the leftover, plants reflect the sunlight they aren't using. From that we can guess how healthy they are. From the quantity of garbage your kids/friends generate you can guess HOW MUCH they ate. A similar situation happens with the sun wavelengths. (a formal definition below (*))

A LITTLE MORE

Leaves "eat" especially blue & red light, therefore green light gets reflected (495–570 nanometers), while more is happening beyond the visible light: leaves exhibit high reflectance values in near-infrared (NIR: 700 to 1300 nm) and the water level along with other biochemical components present in leaves can be guessed

by the reflectance in the shortwave infrared region (SWIR: 1300 to 2500 nm).

HOW WELL THE SATELLITE EYES SEE?

Four parameters are key for agriculture:
1. SPECTRAL RESOLUTION: number, width, and location on the electromagnetic spectrum of spectral bands in the sensor system.
2. SPATIAL RESOLUTION: measure of the smallest object that can be resolved by the sensor
3. TEMPORAL RESOLUTION: frequency with which a sensor revisits the same area of the Earth's surface
4. RADIOMETRI RESOLUTION: spectral precision of the measurements.

INTERESTING SATELLITES FOR AGRICULTURE:

➞ SENTINEL 2 European Space Agency - ESA
https://lnkd.in/eZzNPn4g.
➞ LANDSAT 8 NASA - National Aeronautics and Space Administration
https://lnkd.in/es96Pyfm
➞ ENMAP German Aerospace Center (DLR) (the most recent)
https://lnkd.in/enV8fVaU
Repeat cycle 27 days
Spectral range: 420 nm - 2450 nm
Spectral sampling distance: 6.5 nm (420 nm - 1000 nm; VNIR)
10 nm (900 nm - 2450 nm; SWIR)
Radiometric resolution: 14 bits

DEFINITION OF WHAT IS HYPERSPECTRAL IMAGING

Hyperspectral imaging collects and processes information from across the electromagnetic spectrum. Whereas the human eye sees color of visible light in mostly three bands (RED, GREEN, BLUE), spectral imaging divides the spectrum into many more bands. This technique of dividing images into bands can be extended beyond the visible. (Wikipedia, the Free Encyclopedia)

GIS "maps data" → MACHINERY + DIGITAL = EFFICIENCY

Data need to be associated to points on the plane of the farm parcels.
Without this association, data about temperature, soil humidity, fertilization levels, NDVI... will be useless and just floating on the data lake.

GIS[3] is responsible for associating each data to a point in space.
We can therefore generate data maps that can program machines to perform precision agriculture.
The concept is an old one, but the quality of its execution depends on the combination of several factors:
- data density
- data quality
- machines readiness to act accordingly

The underlying (invisible) glue, is GIS.

[3] GIS: Geographic Information System (GIS) is a tool that creates visual representations of data and performs spatial analyses in order to make informed decisions

PASTURE MONITORING → Can digital agriculture support sustainable pasture?

Grazing pasture and croplands occupy a significant portion of land surface in the world. In the last decades, many countries, such as Australia, France, United States of America and Brazil.

Adequate grazing management is of critical importance to ensure greater forage production to the livestock component of ICLS. Thus, understanding the spatiotemporal dynamics of forage resources in grazed areas is fundamental to support grazing management decisions, especially in intensively managed fields.

SOLUTIONS

Rising plate meters (RPMs) also known as a Pasture Plate Meter

Platemeters platemeters.co.nz

www.swarmhub.co.uk
themeterman.com.au
Grasstec Group www.grasstecgroup.com
Pasture Meters www.pasturemeters.co.uk
https://lnkd.in/evWdfkbU
www.cropsol.com.au

C-Dax pasture meters
www.c-dax.com/measure

Field Sensor (combined with Satellite)
Farmote Systems www.farmote.com

MANAGEMENT SOFTWARE
PastureMap pasturemap.com

SENSOR TO MOUNT ON VEHICLE
pasturereader.com.au

SATELLITE
Pasture.io Pty Ltd pasture.io

INTERESTING RESEARCHES
(PlanetScope imagery for estimating pasture aboveground biomass (AGB))
... the prediction accuracy of AGB and CH models compared to the performance obtained using spectral bands or vegetation indices...
... our models were able to predict the spatiotemporal changes in pasture AGB and CH with moderate (R2 = 0.65) to high (R2 = 0.89) prediction accuracies, respectively.
https://www.mdpi.com/2072-4292/12/16/2534

PLANET & FarmShots

Planet imagery can quantify the amount of pasture in each paddock. Pasture variations is represented by color with dark grass implying an abundance of pasture, while yellow shows less pasture.

https://www.planet.com/pulse/advanced-pasture-management-solutions/

Interesting booklet:

https://betterburnett.com/wp-content/uploads/2016/05/BookletFinal.pdf

SPRAYING DRONES → up to 70% SAVING (on grains)

Spraying services (focus on grains) BENEFITS:

▶ No crop damage:
- Traditional: >4%-10% crop destroyed by traditional spraying methods (human driven or GPS operated)
- Drones: 0% destruction

▶ Fuel saving:
- Traditional 3-8 litre/ha (depending on the tractor)
- Drones: much less electric energy consumed

▶ Water saving (to create the spraying solution):
- 300 l/ha with traditional methods
- 15 l/ha with drones (where less water is required)

Overall saving: 70%

OTHER APPLICATIONS:

Multispectral camera drones:

- assess plants health (diseases detection)
- Harvest time assessment

GPS drones to map the soil:

- Soil erosion (3D models)
- Set automatic flying for spraying

Infrared cameras:

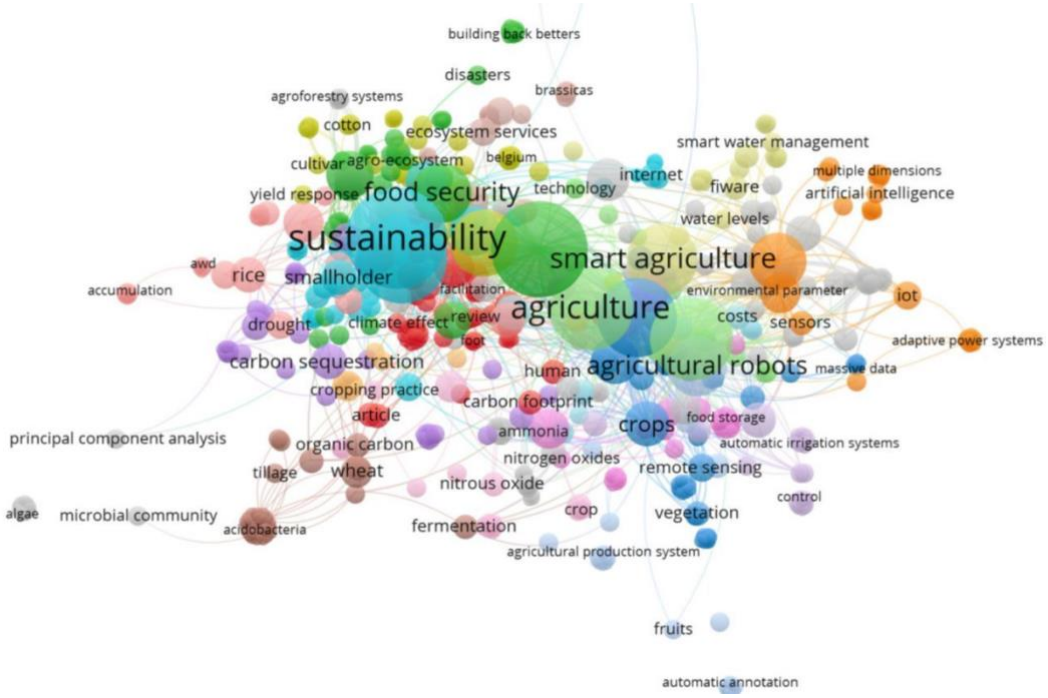
- Anti-theft during harvest time

MORE INFO

Most commercial drone applicators are currently charging $11-14 per acre — rates that are competitive with traditional aerial applications.
To operate your own drone may only cost $1 per acre, but there is the upfront investment of the drone itself, a trailer to haul it,

DIGITAL AGRICULTURE: POLICY MAKERS

DIGITAL AGRICULTURE & SUSTAINABILITY → mapping digital agriculture & sustainability with more...



SMART AGRICULTURE & SUSTAINABILTY

A scientific studies bibliometric analysis[4] on the 'smart agriculture' and 'sustainability' provided this interesting interrelationship map (sizes represent the relevance) highlighting among different (sub)topics.
In addition, the analysis produced more results worth to evaluate:

[4] Bibliometric analysis is a scientific computer-assisted review methodology that can identify core research or authors, as well as their relationship, by covering all the publications related to a given topic or field
(Journal of Biomedical Informatics, 2020)

POLICY RECOMMENDATIONS

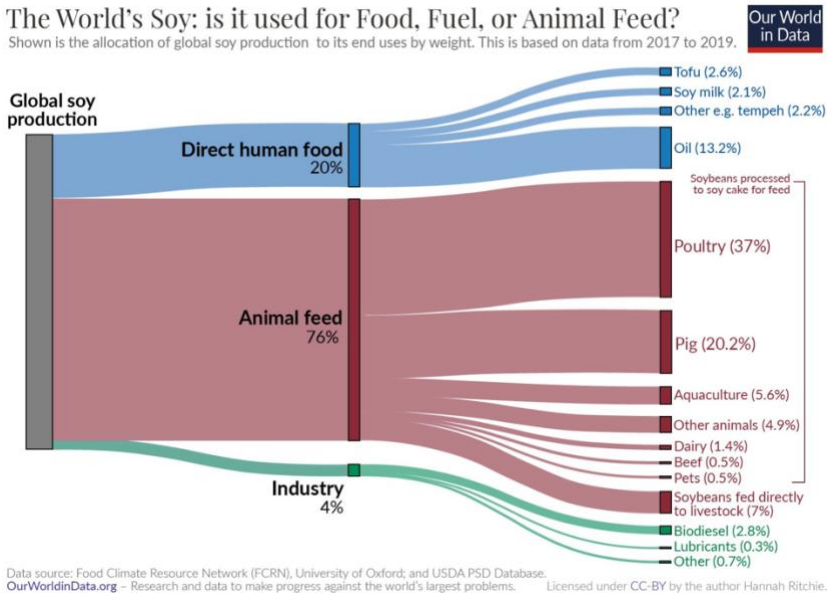
1. Design new policy instruments that promote the smart agriculture practices in a more integrated way, namely through a greater involvement of the women in the farms.
2. Create programs to standardize the perceptions about the smart agricultural approaches.
3. Promote courses to train and raise awareness of the farmers about the advantages and disadvantages of the smart approaches in the farms.
4. Involve deeper the interrelationships between the actors for a better understanding about the integrated-smart agriculture approaches.

SOLUTIONS HIGHLIGHTED FOR A MORE SUSTAINABLE AGRICULTURE

- Fodder banks
- Fermentation of agricultural waste
- Models to identify tomato ripeness
- No-tillage, waste management, and agricultural diversification
- Conservation agriculture
- Based on conservation tillage systems
- Nanotechnology
- Including for carbon management in soil
- Drought-tolerant seeds
- Integrated pest control, combined crop-animal agriculture and organic composting
- Fertilizer trees and shrubs
- Terrace landscapes
- Annual crops planted with coconuts
- Agroforestry structures
- Microalgae
- Dambo cultivation
- Valorization of agro-food byproducts

- Traditional agriculture
- Integrated farming systems
- ‘4R’ approach (right source, right rate, right time, right place)
- Agronomic rotations and cover cropping
- “Positive Deviance” (identifying practices from farms with higher performance)
- Genetic strategies
- Vertical farming
- In the cities
- Crop residues management through principles of bioeconomy
- Certification strategies

DIGITAL AGRICULTURE AGGREGATES DATA ENABLING INFORMED DECISION MAKING



DIGITAL AGRICULTURE IS ALSO MACRO DATA

How can farmers, corporates and policy makers take informed decisions without aggregated data available?

Digitalisation simplifies: data collection, data aggregation and data analysis allowing to produce and share overall figures essential to take informed decision.

Let's take a (notable) example: SOYA (or SOYBEANS).

Wether you are a manager of an international agri operator, or you are in charge of the Soy supply for your food corporate, or you are a policy maker of a country, you need to access complete, updated, aggregated data to take the best decisions.

Here is an example of aggregated info made possible by the data digitalisation:

SOYA (or SOYBEANS)

Soya is among the top 10 most traded commodities in the world (*) along with Oil, Gold, Steel, copper, silver, Corn,...
It's that relevant! Not only for agriculture but for the world financial and economic sectors as well.

SOY IS USED FOR:

- Direct human consumption (20%)
- Animal feed (76%)
- Industry (4%)

(92% of it gets processed, while only 8% directly consumed by human & animals)

PROFITS CHAMPIONS

Countries achieving best average profitability in producing Soya:

1. Brazil
2. Argentina
3. Ukraine

SOYA YIELDS/Ha CHAMPIONS

1. Argentina
2. USA
3. Brazil

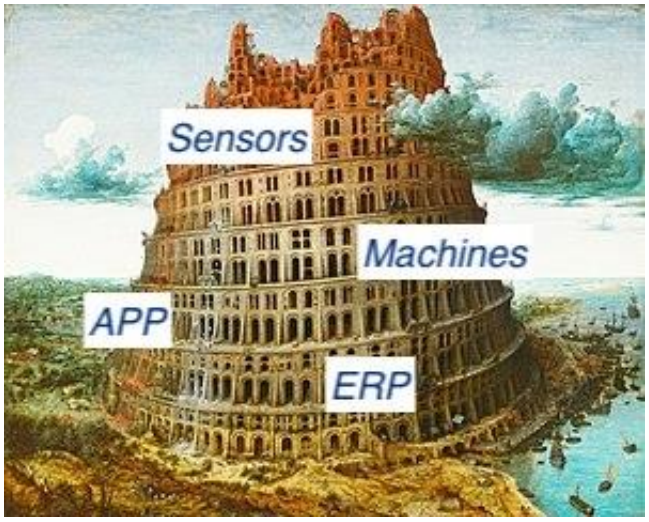
LARGEST PRODUCERS:

1. Brazil 121.8 million tonnes
2. USA 112.5 million tonnes
3. Argentina 48.8 million tonnes
4. China 19.6 million tonnes
5. India 11.2 million tonnes
6. Canada 6.3 million tonnes

Data by: Food climate resource network, FAO, University of Oxford, USDA

(*) based on an analysis of the top 40 most exchanged agricultural, energy and metal futures contracts of 2017, using figures from the Futures Industry Association (IG)

THE RISK OF BABEL TOWER → AgTech SOLUTIONS TALKING their "OWN LANGUAGE"



PROBLEM:

Farmers are adopting new AgTech solutions.
Each one promises (and often delivers) benefits.
But... the solutions don't talk with each other, making farmer's life more complicated instead of easier!

SOLUTIONS:

We may like it or not, but having english as a lingua franca (or bridge language) make it easy and possible for people from different countries to communicate with each other.
Machines, sensors, software, apps, ... need an equivalent lingua franca and/or "automatic translators" (software that convert and aggregate data coming from different sources).

LINGUA FRANCA = STANDARD

In digital terminology, a lingua franca is a standard.

There are already efforts in this direction, for instance:
Farm Foundation https://lnkd.in/eZvbUQNP

AUTOMATIC TRANSLATOR = universal computer dashboard

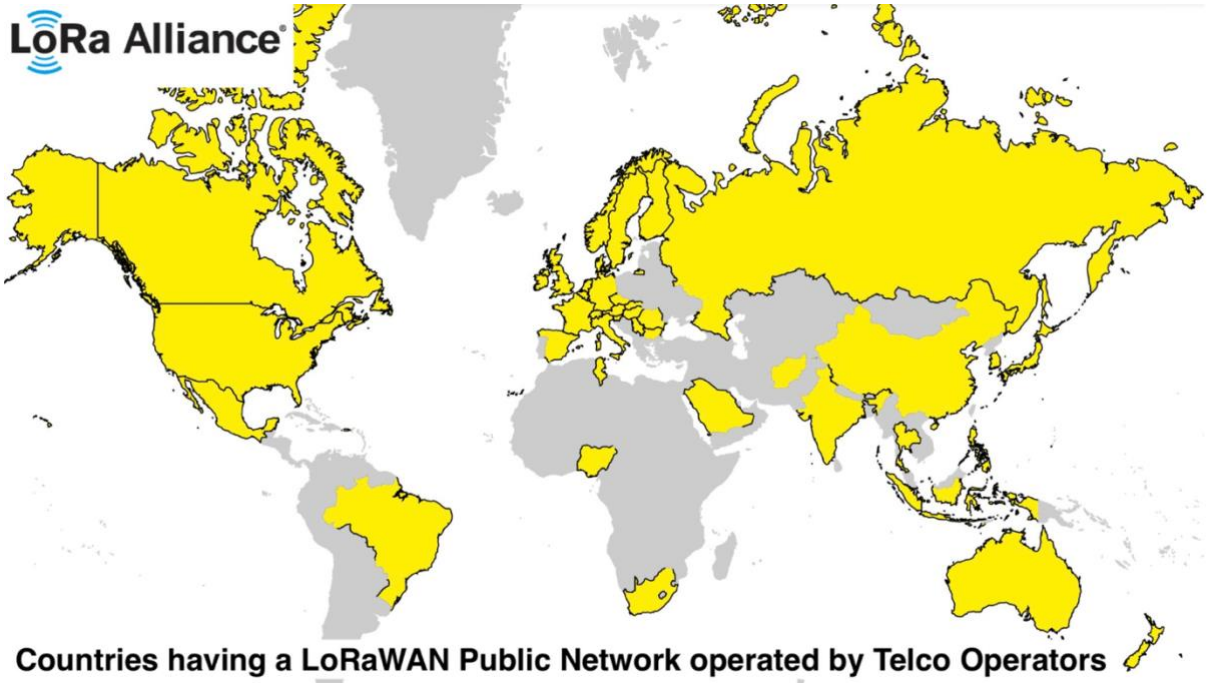
Automatically translating data and having all of them together on a single dashboard is the effort (and offer) of:
Pairtree Intelligence https://pairtree.co/

MORE DETAILS

"As a part of the digital revolution of agriculture, advances in digital technology are making it easier to capture and manage data, and importantly, gain insights... but we're in the early days of this revolution, and people... are facing obstacles ... principally around DATA SHARING."

"The main barrier to the digitization of food and agriculture has been the lack of commonly shared structural and semantic interoperability. In many parts of the supply chain, companies are already maintaining expensive databases and collecting large amounts of ultimately disparate data. The industry... lacks the framework to CONNECT THOSE SOLUTIONS and bring all that data together in a way that maintains data sovereignty and appropriate confidentiality."

HOW to reduce SENSORS ADOPTION COSTS by 90%? SENSORS TELECOMMUNICATION INFRASTRUCTURE



Imaging buying a smartphone and be required to purchase, install and operate also the nearby cell towers.
How many people would buy a smartphone?
That's, more or less, what has been happening in the IoT for digital agriculture over the last years. Let's see how and the solution.

SENSORS MADE EASY

Every smart-sensor:
1- SENSES data (transducer)
2- (pre)PROCESSES data (microcontroller & firmware)
3- SENDS data to... internet (RF radio)

While the smart sensors are getting more and more affordable, sending data is still the most expensive task as requiring...

HOW SENDING DATA TO INTERNET?

The sensor requires "something, somewhere receiving their data".
They need a COMMUNICATION INFRASTRUCTURE.

What is that concretely?

"Old style" solutions require additional devices to be installed locally. These devices are called GATEWAYS and are responsible to receive data from the smart-sensors and sending them over the internet (often using GSM, 4G, 5G networks).

DOWNSIDE

Even though one single gateway can serve multiple sensors, these devices are more expensive to buy, to install, to operate and to maintain, significantly increasing the overall implementation cost.
Summing up all costs, the implementation total cost may increase up-to 900%.

SOLUTIONS: PRE-EXISTING IOT NETWORK INFRASTRUCTURE

LoRa Alliance is proposing a "sensor telecommunication network".
In area already covered by LoRaWAN, farmers can buy LoRaWAN sensors and... simply switching them on as if the farmer was switching on the smartphone.

LoRaWAN COVERAGE

Most countries in the world have already a running service.
Some countries even have a global coverage: Netherlands, Switzerland,..

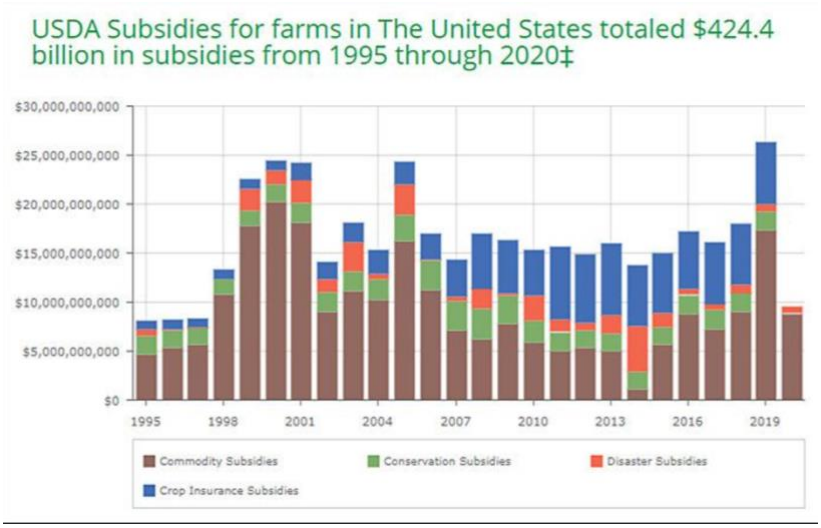
LoRaWAN-READY SENSORS

Several new products are available on the market that can automatically connect to a pre-existing LoRaWAN.

In these areas the adoption cost (buy, install, maintain, operate) of smart-sensors is significantly lower.

DIGITAL AGRICULTURE vs. SUBSIDIES

“If you give a man a fish, you feed him for a day. If you teach a man to fish, you feed him for a lifetime.”



DATA (world)

DIGITAL AGRICULTURE SAVING: 6%-30% COSTS
AGRICULTURE SUBSIDIES: US$800 BILLIONS/year
DIGITAL AGRICULTURE MARKET: US$12.8 B

COMPARING (world)

TOTAL spent for digital agriculture = 1.6% of AGRICULTURE SUBSIDIES

QUESTION:

Why not use (at least some) subsidies for tools aimed to save agri inputs & farms costs while mitigating the impact on the environment?

DIGITAL AGRICULTURE has proven to save a minimum 6% overall costs (up to 30+%).

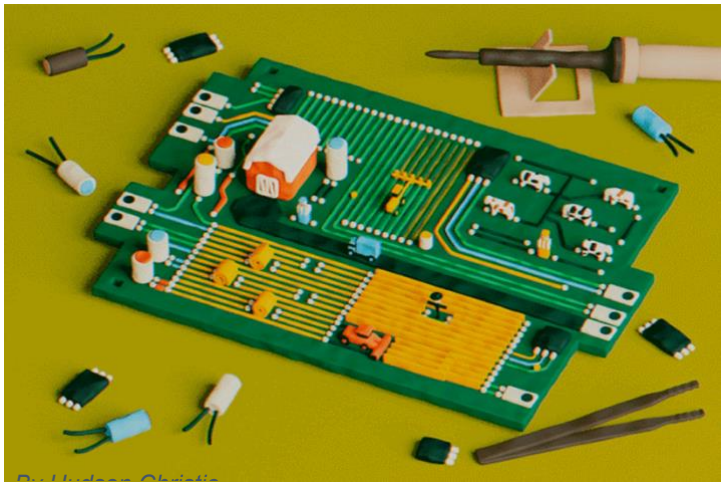
DIGITAL AGRICULTURE MARKET (world): US$12.8 B
The Global Market revenue was valued at USD 12.8 Billion in 2021.

SUBSIDIES (world): US$ 800 BILLIONS/year (2019-2021)
"that’s how much governments worldwide provide in some form of subsidy to their agricultural sectors."

DIGITAL AGRICULTURE: WHAT'S AHEAD?

THE FUTURE OF (DIGITAL) AGRICULTURE

DIGITAL is enabling a new level of diversification in agricultural practices. The future of Food production is going to surprise us.



How do I see it?

1. Large farms & conventional will remain with us and will be fully automatic. Digital agriculture will allow to optimize inputs while reducing the environment impact.

2. Urban/vertical farming is catching up and will focus on fresh vegetables and berries. These production facilities will be fully integrated with supermarket (actually most of them will be inside supermarket) that will operate them through service providers remotely connected. The level of automation here will be maximum.

3. Intensive greenhouses cluster will pop up around the world copy pasting

Greenport West-Holland. The digital and automation will make it simple to setup such area, limited only by water presence.

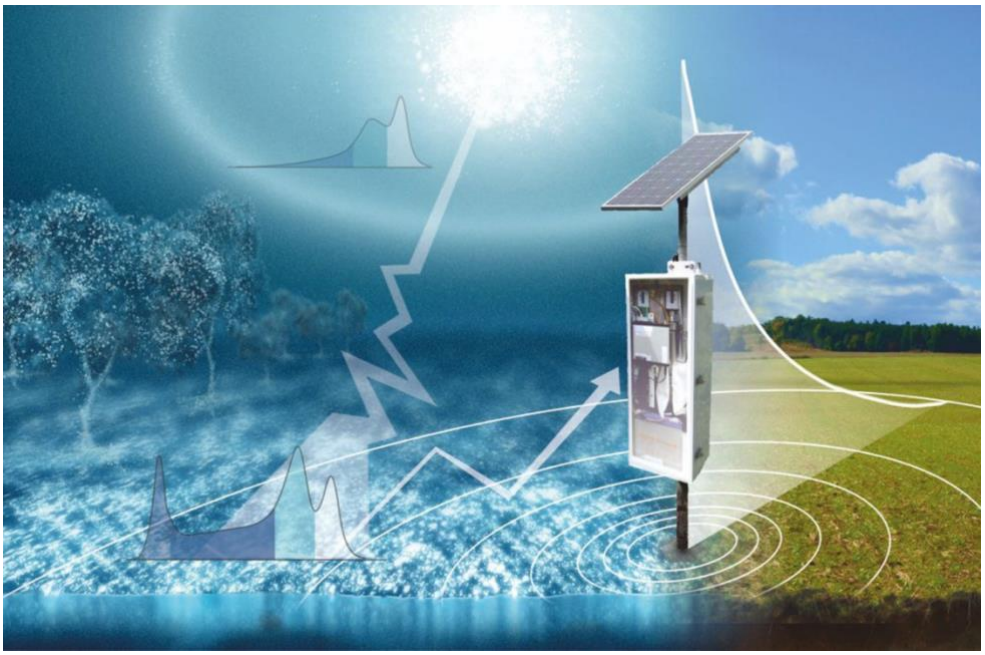
4. Orchard will make heavy use of robots for most of the activities, starting from weeding up to harvesting.

5. Small holders in developing countries will reduce in number leaving place to aggregation by larger and more automated farms.
They will remain though, combining ancient successful practices with new affordable technologies that will be more and more available. Open hardware and open software will boost local custom solutions, including robotic.

CONVENTIONAL vs. ORGANIC

The ratio between conventional and organic will move toward organic pushed by a higher consumer demand, higher premium on prices and environmental constraints.
Digital will be a strong enabler of this transition.
The main commodities (soya, corn, millet, wheat, rice) will remain largely conventional, but with more environmentally friendly practices also helped by digital tools.
More extreme practices such as PERMACULTURE will also grow. Their current limit is indeed due to high labor costs, but the support of robots will make them more sustainable as well.

DIGITAL AGRICULTURE → COSMIC RAY SOIL SENSOR for WATER SAVING



PROBLEM: WATER SAVING
INNOVATION: COSMIC-RAY SOIL SENSOR

Soil moisture sensors:

The current sensors measure single points. Given the soil heterogeneity, multiple sensors are required to optimise the irrigation.
While easier and cheaper sensors are coming to the market, this interesting alternative approach holds promises.

How does it work?

This new sensor leverages the different interaction that neutrons present in cosmic rays have with water. Sensing and analysing the data, it provides an excellent assessment of the water present in the soil, supporting decision making on irrigation.

Benefits:

- one sensor covers 20 ha
- scans underground up to 80cm
- low maintenance

Disadvantages:

- still too expensive
- not yet available on the market

Development phase: pilot implementations
Market/products: not yet commercially viable

INNOVATIVE PLANTS TRANSLATOR → Can plants ask to farmers directly what they need? Yes! How

IS THE PLANT THIRSTY? A BUG OR A DISEASE IS ATTACKING IT?

Thanks to a very innovative solution the plant can indeed alert the farmer in real-time: https://vivent.ch

PLANTS CONSTANTLY COMMUNICATE, DO WE LISTEN?

While the current digital agriculture solutions are based on sensors analyzing the environment around the plant to guess plant's need (soil & air)... is it possible to have a direct information from the plant itself? Short answer: YES.

SENSOR + TRANSLATOR + ALERT

VIVENT, a Swiss innovative startup, combines an innovative sensor to advanced data analytics translating in real time the plants needs that are sent in a matter of seconds to the farmer's smartphone.
That is the earliest and most precise alert.

"By tapping into plant signaling networks and decoding them using artificial intelligence, we enable growers to increase yields and to reduce inputs like water, fertilizer, energy and pesticides."

DIGITAL AGRICULTURE TOWARD THE METAVERSE?

Aurich Lawson | Getty Images

The METAVERSE is considered the next big thing into digital.
What is the impact of it on agriculture?

What is METAVERSE? (some simple definitions)

"Imagine a virtual world in which people live, work, shop and interact with others -- all from the comfort of their couch in the physical world. This is known as the metaverse"
Neal Stephenson
“It's a persistent, live digital universe that affords individuals a sense of agency, social presence, and shared spatial awareness"
Cathy Hackl

What is METAVERSE? (other definition)

"The metaverse is a future persistent and interconnected virtual environment where social and economic elements mirror reality. Users can interact with it and each other simultaneously across devices and immersive technologies while engaging with digital assets and property."
World Economic Forum

What is the IMPACT of the METAVERSE on AGRICULTURE?

That's still hard to say and I'd like you sharing your opinions here.
Up-to-date, I found the most interesting opportunities in:
digital twin farms

What is a DIGITAL TWIN?

“Digital twins are a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning, and reasoning to help decision-making.” IBM

Which benefits can we expect form a DIGITAL TWIN FARM?

"One of the major benefits of deploying a digital twin system particularly for farmers is that the timeframes in agricultural settings are often measured in long increments like months and seasons. Testing a change in soil inputs on the physical field is never instantaneous. It can take weeks before meaningful results emerge. On a digital system, that same test can be run in minutes."

"A producer would regularly consult the Digital Twin to keep track of production, issue interventions (probably remotely) and create a future management schedule"

"The Benefits of Digital Twins in Agriculture

-Greater yields on the same acreage
-Profitability maximization
-More resilience to weather

-More sustainable operations
-Faster time to market"

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