Considerations on a Stepwise Data-Driven Innovation to Support Sustainable Dairy Transformation in small-holder dairies

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ICAR Annual Meeting – Anand – April 2025

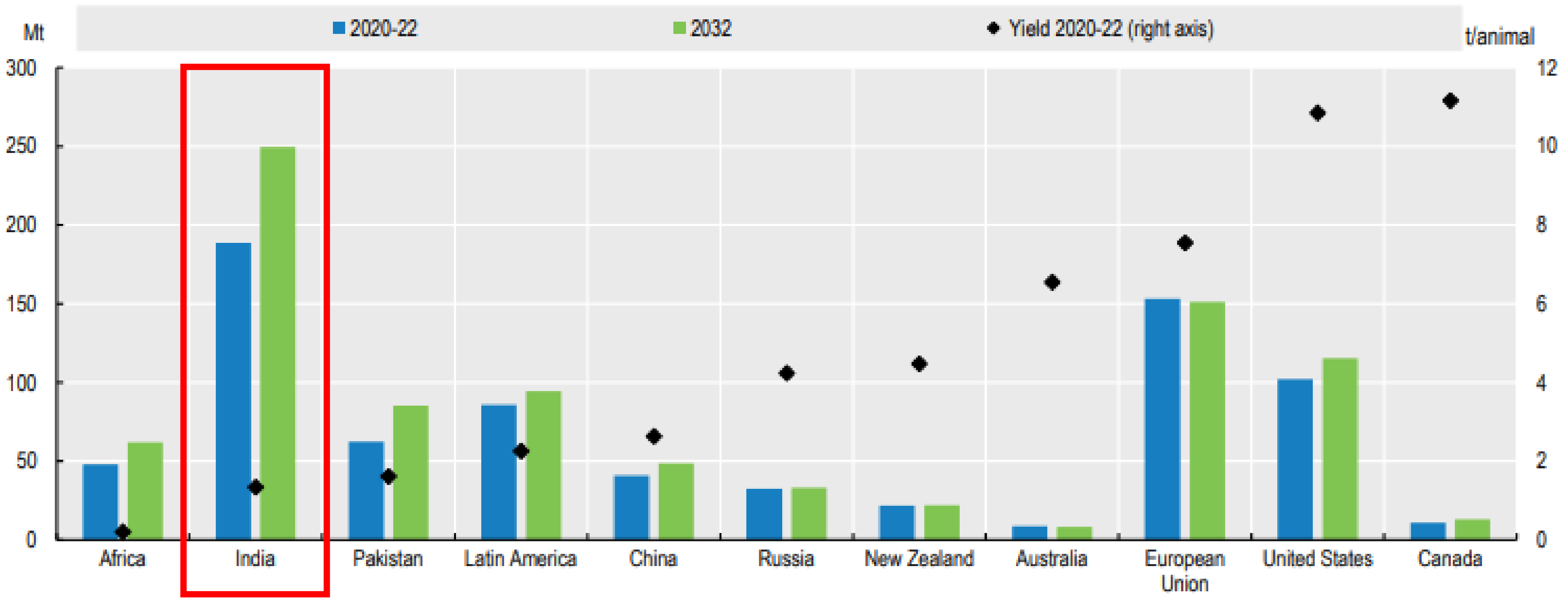
Aim

Food and Agriculture Organization of the United Nations

Building on observations from the **FAO Regional Forum on Innovations for Sustainable Livestock Transformation in Asia and the Pacific**, we discuss a phased implementation strategy in progress in developing regions.

This approach focuses on **practical solutions** that evolve with **farmer capabilities** and **resources**.

Figure 7.4. Milk production and yield in selected countries and regions



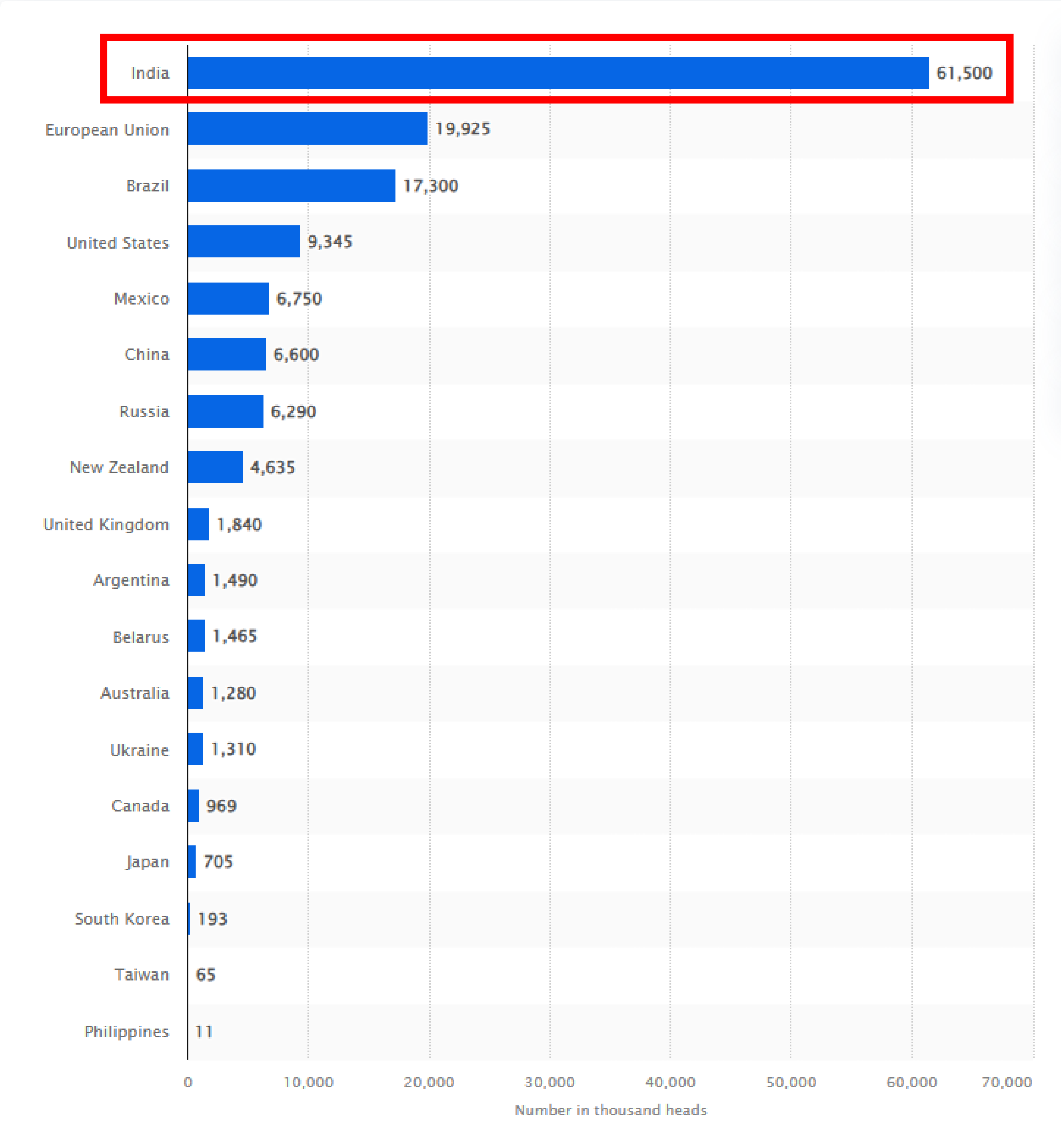
Note: The yield is calculated per milking animal (mainly cows but also buffaloes, camels, sheep and goats).
Source: OECD/FAO (2023), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

StatLink https://stat.link/pcnb83

Number of milk cows worldwide in 2024, by country

(in 1,000 heads)

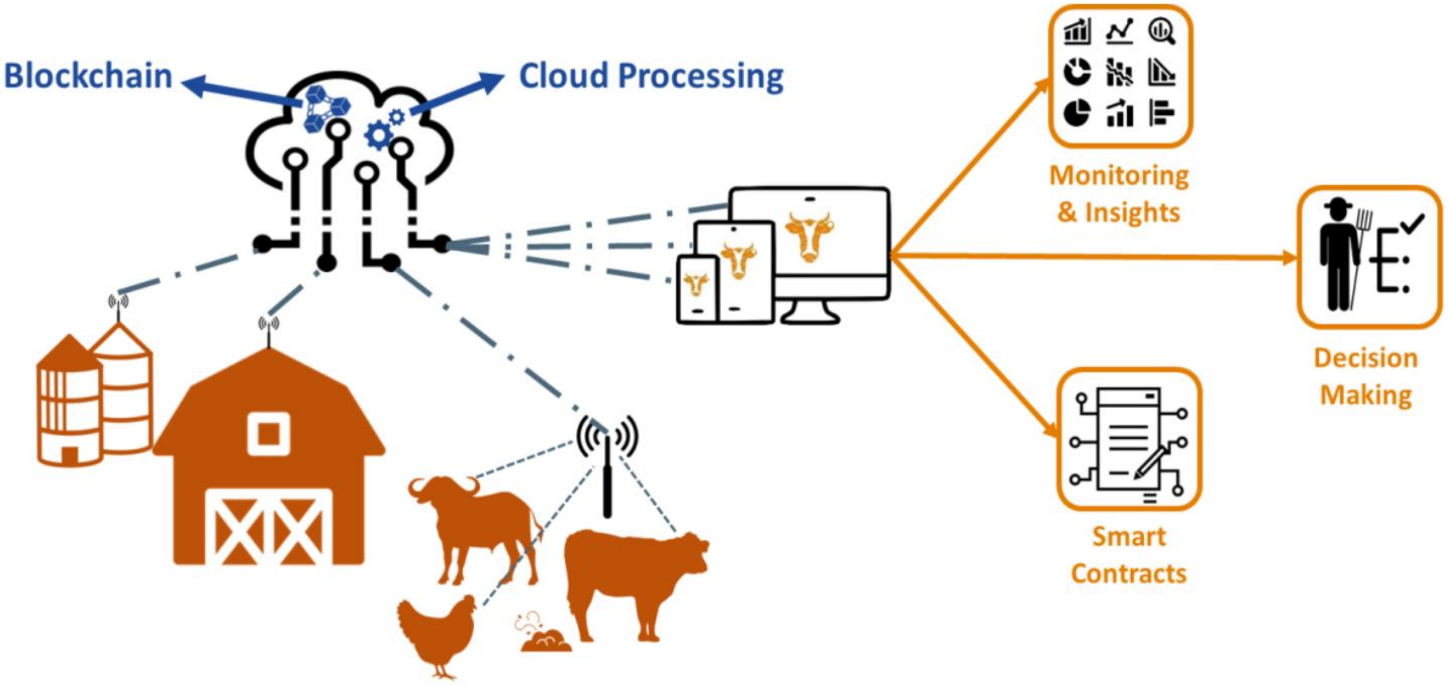
High number of cows in India …



https://www.statista.com/statistics/869885/global-number-milk-cows-by-country/#:~:text=India%20is%20home%20to%20the,at%20about%2020%20million%20head.

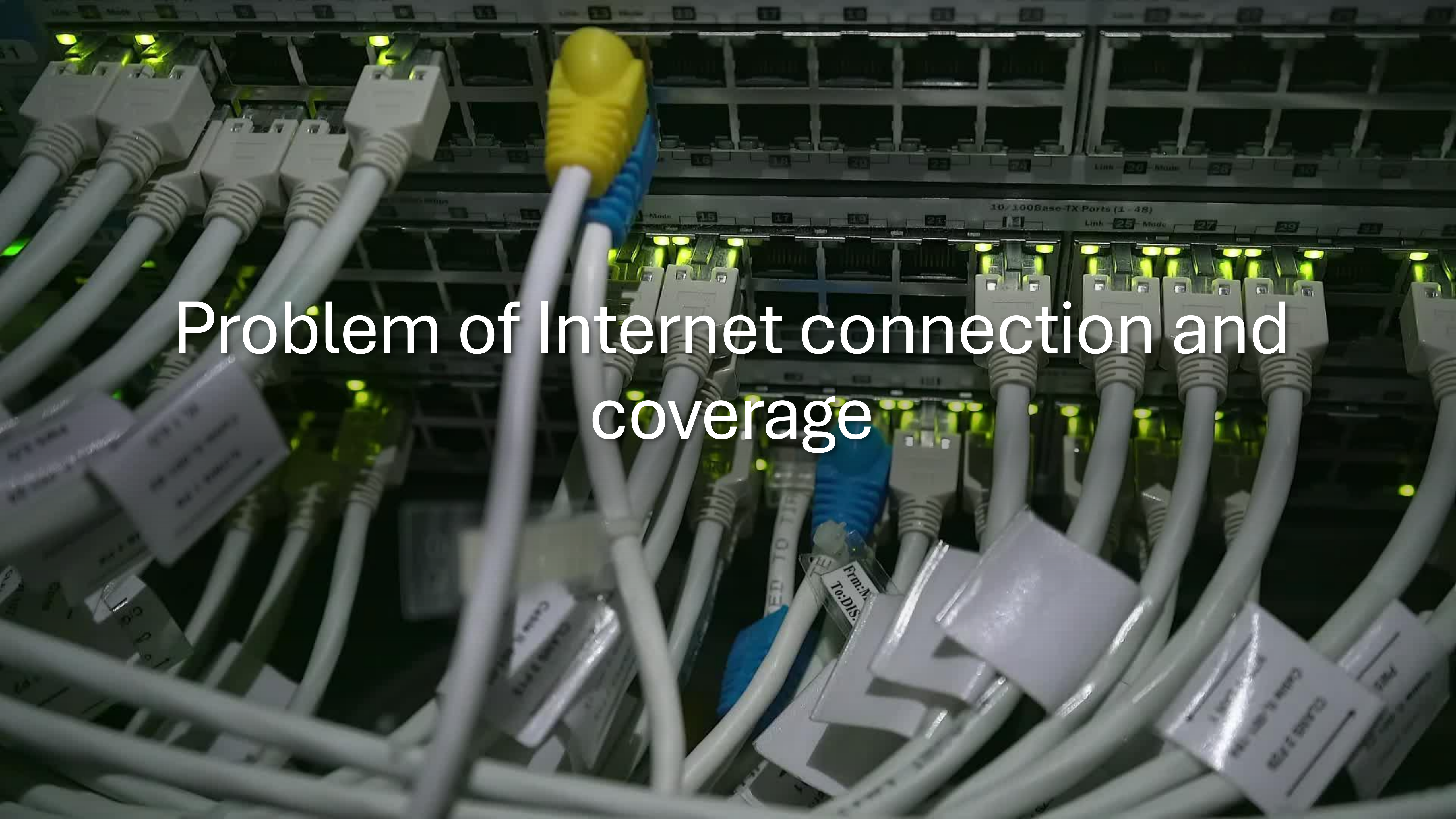
How to help farmers to increase their productivity and improve if needed the composition of their milk ?

Appropriate smart livestock farming ?



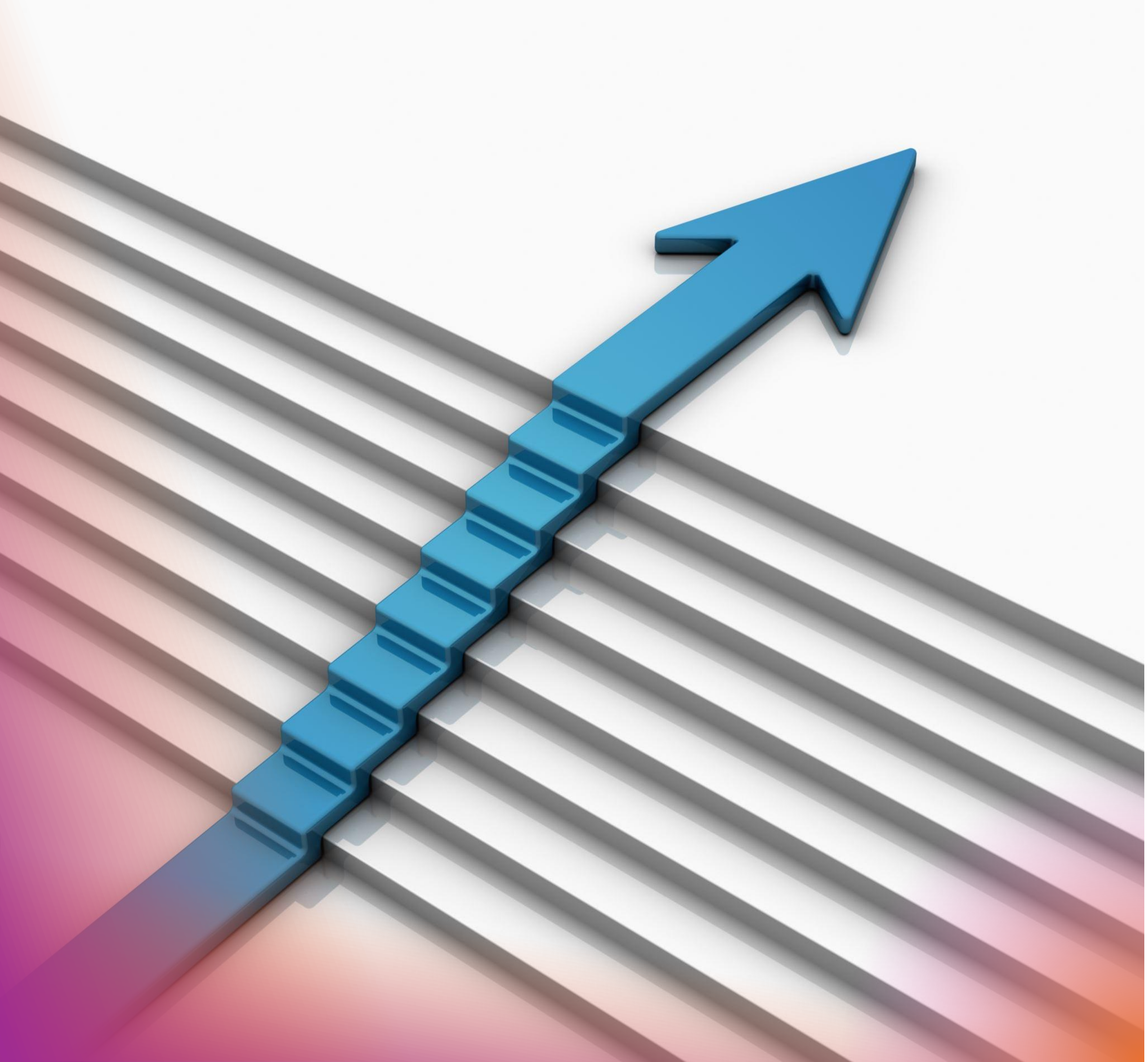
https://www.era-susan.eu/content/farmsustainabl-enabling-smart-livestock-farming-technologies-environmental-sustainability

Problem of Internet connection and coverage



Do we need always internet connection ?

Not available even if it can speed the process



Stepwise data-driven solutions

Keep the motivation of farmers by giving direct outputs

Stepwise data-driven solutions

1. Establishing Fundamental Data Practices

2. Introduction of appropriate Technological Intervention

3. Scaling up with advanced techonologies

4. Policy and Institutional Support

To start, take a simple example with high potential which minimizes the initial investment …

Stepwise data-driven solutions

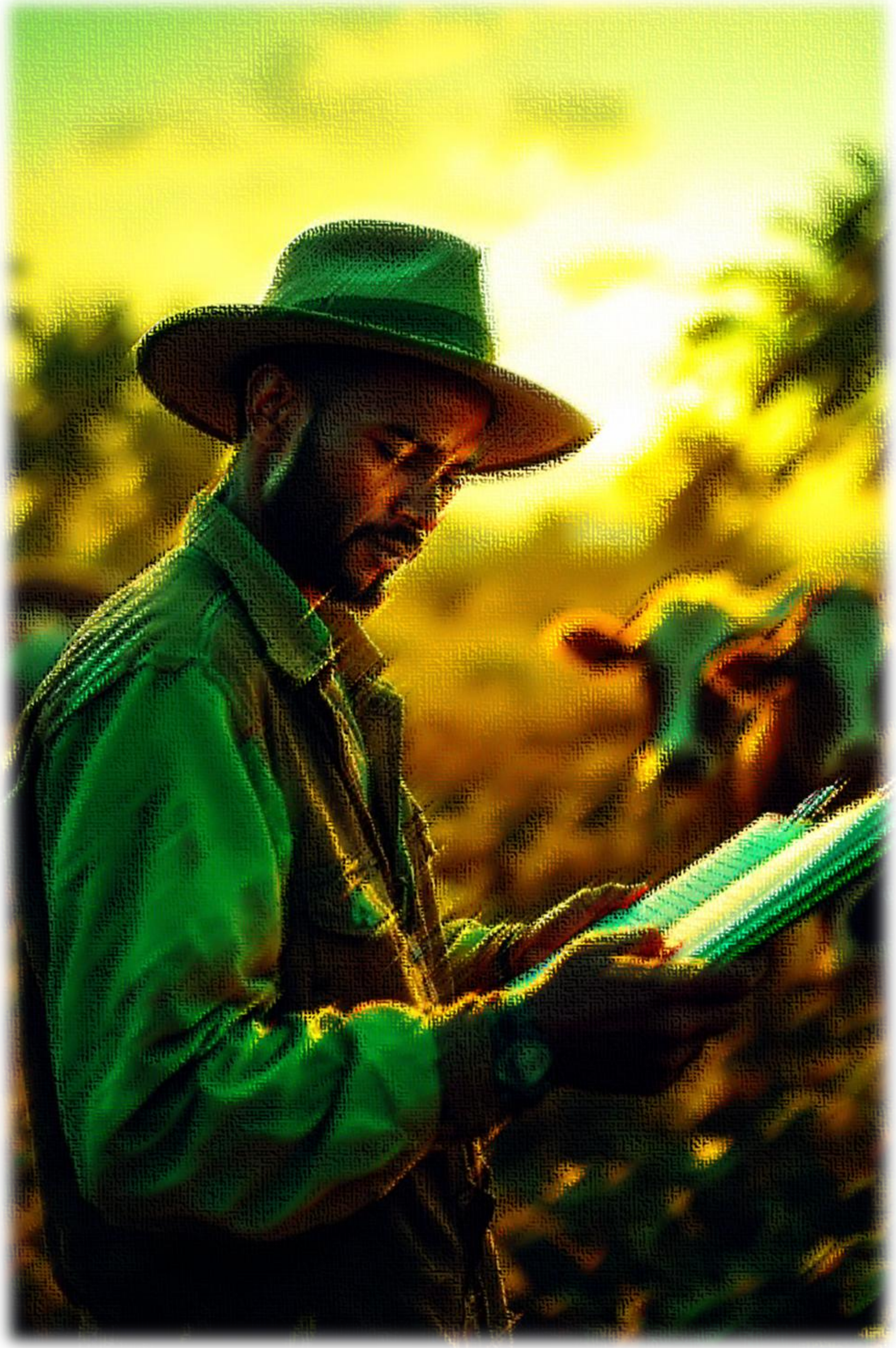
1. Establishing Fundamental Data Practices

1. Establishing Fundamental Data Practices

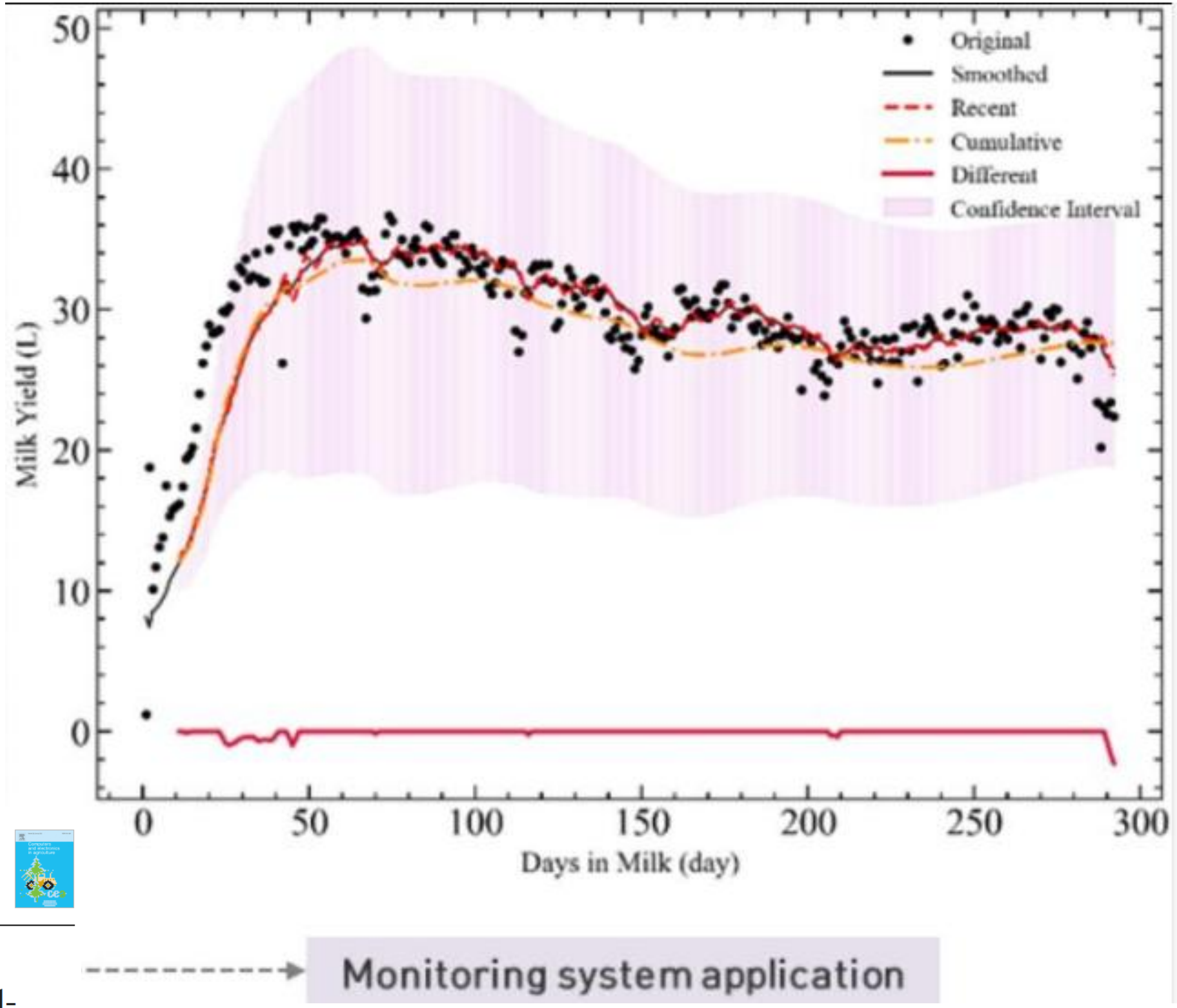
- **Robust Animal Identification:** ICAR can play a rule!

- **Basic Record-Keeping Systems:** Encourage farmers to maintain **manual or digital records using low-cost tools (spreadsheets)** of milk production

- Collaborate with local organizations to provide **hands-on demonstrations** of effective record-keeping techniques.



Motivation is improved when you have rapid results …



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Development of individual models for predicting cow milk production for real-time monitoring

Jae-Woo Song [a], Mingyung Lee [b], Hyunjin Cho [b], Dae-Hyun Lee [a c], Seongwon Seo [b], Wang-Hee Lee [a c]

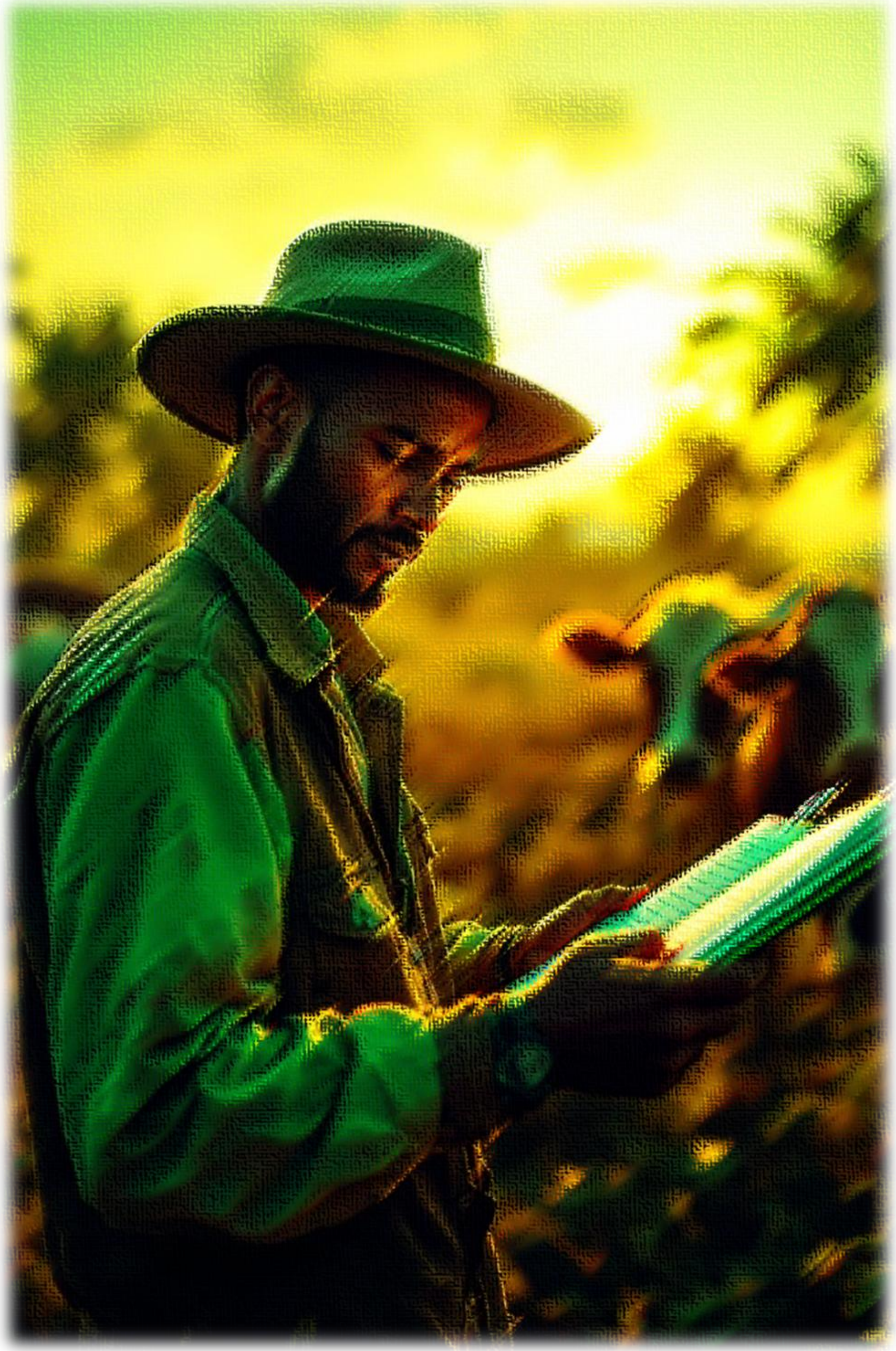
1. Establishing Fundamental Data Practices

- **Robust Animal Identification:** ICAR can play a rule!

- **Basic Record-Keeping Systems:** Encourage farmers to maintain **manual or digital records using low-cost tools (spreadsheets)** of milk production

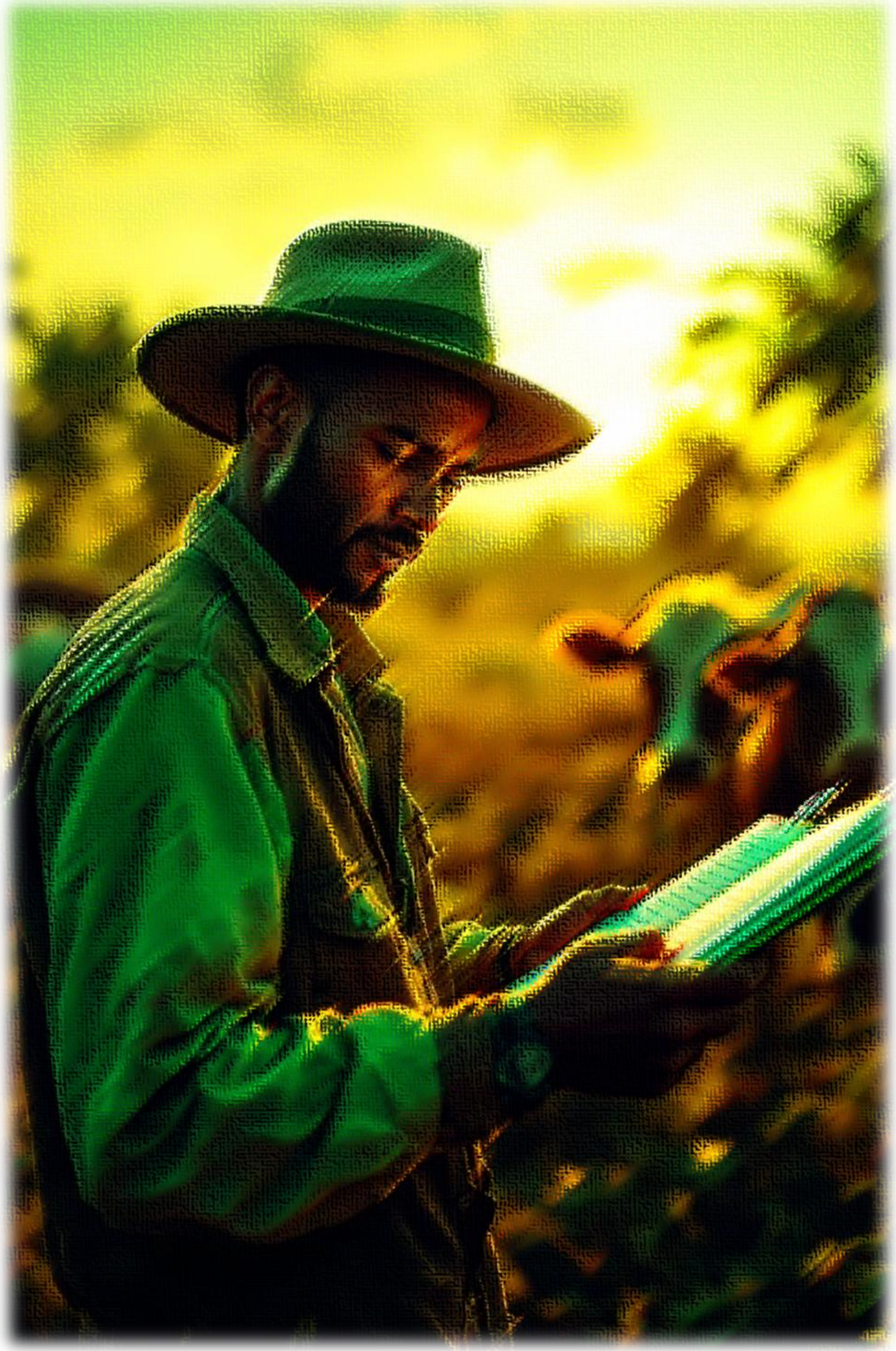
- Collaborate with local organizations to provide **hands-on demonstrations** of effective record-keeping techniques.

- **Improve the farmer's motivation :**
    - Help farmers to develop **basic data interpretation using on-site training** to enhance decision-making regarding feeding, breeding, and disease management.
    - Use visualization (**pictures**,**charts, graphs**)



1. Establishing Fundamental Data Practices

- **Robust Animal Identification:** ICAR can play a rule!
- **Basic Record-Keeping Systems:** Encourage farmers to maintain **manual or digital records using low-cost tools (spreadsheets)** of milk production
- Continue to collaborate with local organizations to provide **hands-on demonstrations** of effective record-keeping techniques.
- **Improve the farmer's motivation :**
  - Train farmers on **basic data interpretation using on-site training** to enhance decision-making regarding feeding, breeding, and disease management.
  - Use visualization (**charts, graphs**) to communicate trends of milk yield
- **Community based data sharing :**
  - Inform about the performances obtained by other farmers to exchange good practices.



Stepwise data-driven solutions

1. Establishing Fundamental Data Practices

2. Introduction of appropriate Technological Intervention

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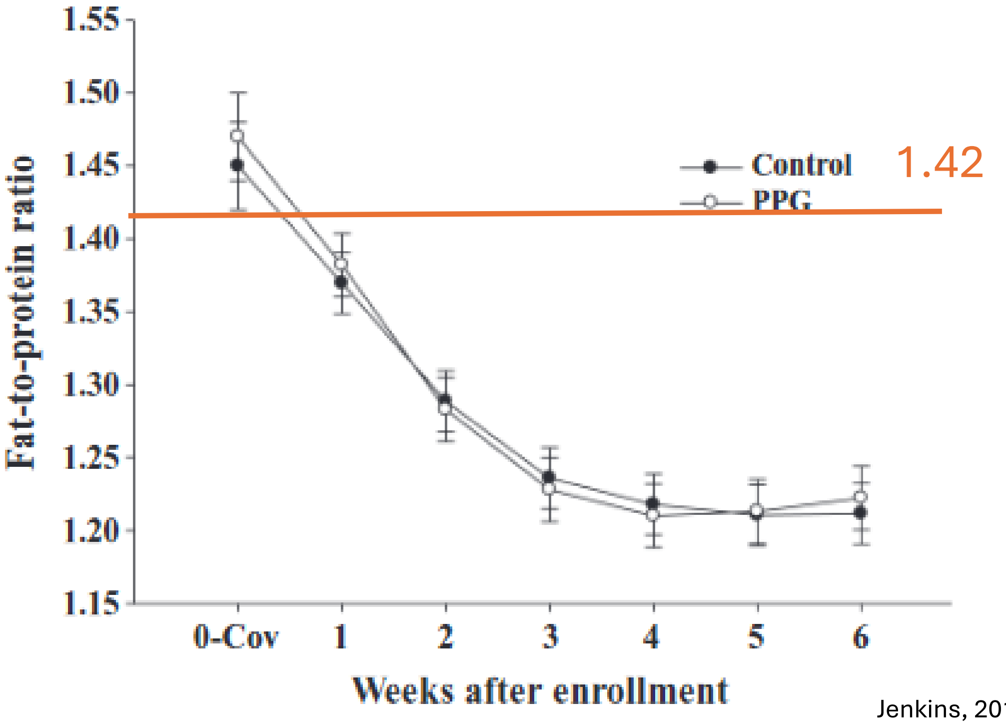
- Farmers are motivated as already developed a first data acquisition

  ➔ **we can go further**

- **Affordable precision Livestock farming :**
  - Milk MIR spectrometry is an example

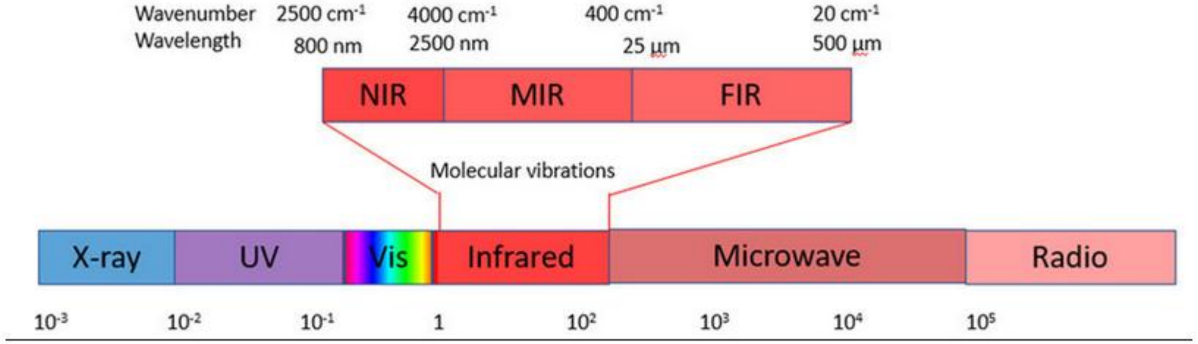
Milk composition is the mirror of the animal and its changes reflect its health status

Knowing its composition is therefore of interest



Jenkins, 2015

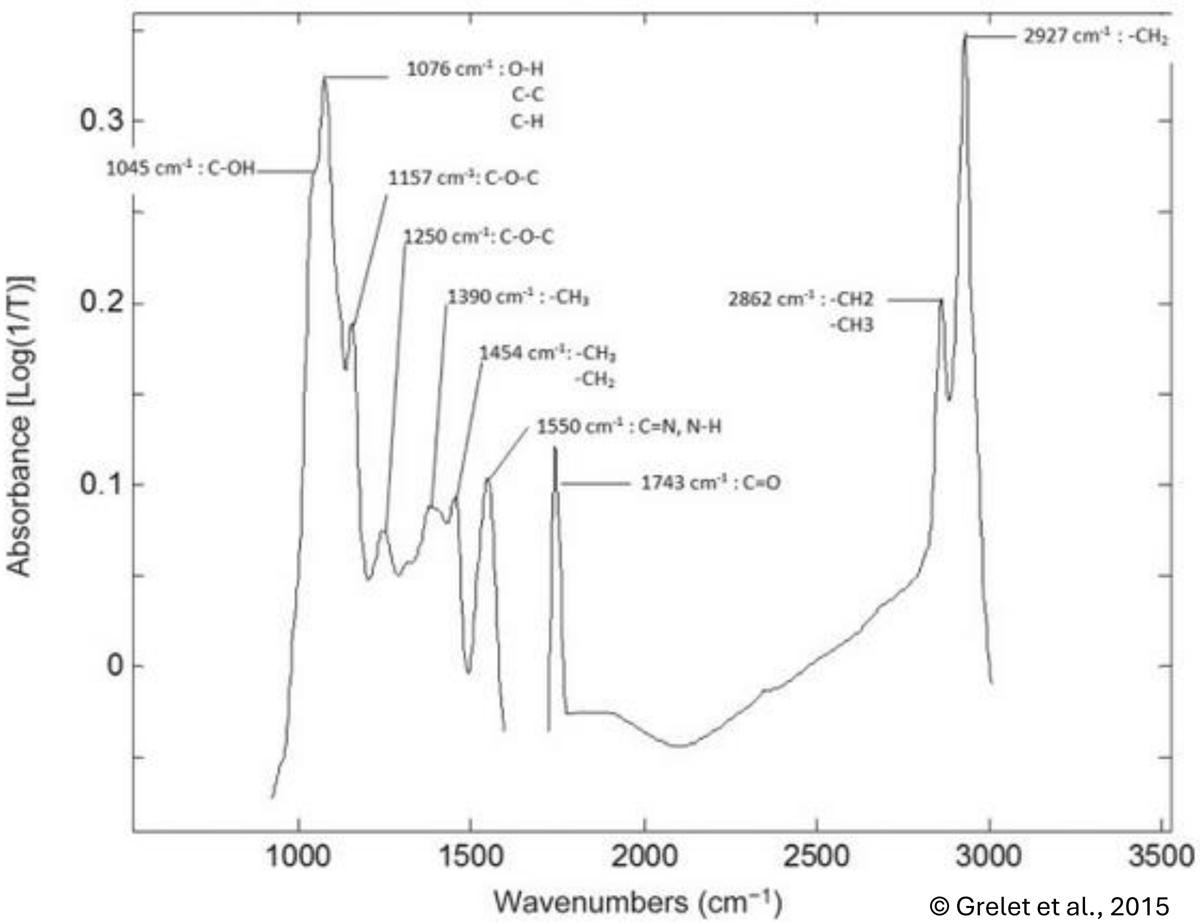
Milk Analysis



Milk MIR spectrum

=

Absorption of infrared ray at frequencies related to the vibrations of specific chemical bounds in milk

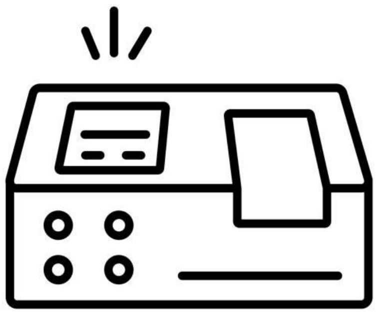


Milk Analysis

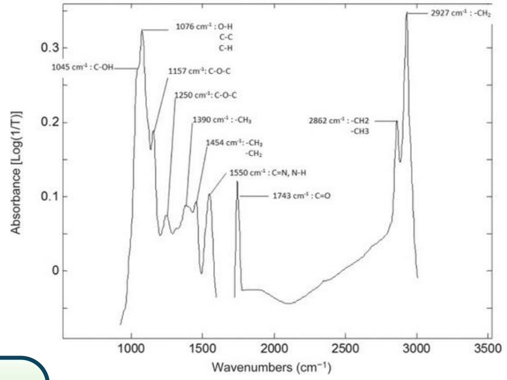
©Avelino Calvar Martinez

Milk payment : 1-3 days (Bulk tank milk)
Milk recording : 4-6 weeks (individual cow milk)

Milk samples



Milk FT-MIR



© Grelet et al., 2015

Usually,
Fat and Protein contents

Predictive model = Equation

But we used the same spectral information, could we go further ?

What exists ?

All in one analysis !

Nutritional quality

Fat, protein, lactose, fatty acids, Ca, lactoferrin,…

Technological properties

Cheese yield, yoghurt yield, butter yield, spreadability …

Animal Health

Na, lactoferrin, Energy balance, body weight, dry matter intake, acetone, BHB, citrate …

Environmental fingerprint

Methane, P, urea …

Sustainability

Consumption index, nitrogen efficiency …

Abnormal milk samples

2. Introduction of appropriate Technological Intervention

- Farmers are motivated as already developed a first data acquisition
  ➔ **we can go further**

- **Affordable precision Livestock farming :**
  - Milk MIR spectrometry is an example

- **Digital farm management tools**
  - with and/or without internet connection

- Continue to increase the use of Artificial Insemination to increase genetic improvement

Stepwise data-driven solutions

1. Establishing Fundamental Data Practices

2. Introduction of appropriate Technological Intervention

3. Scaling up with advanced techonologies

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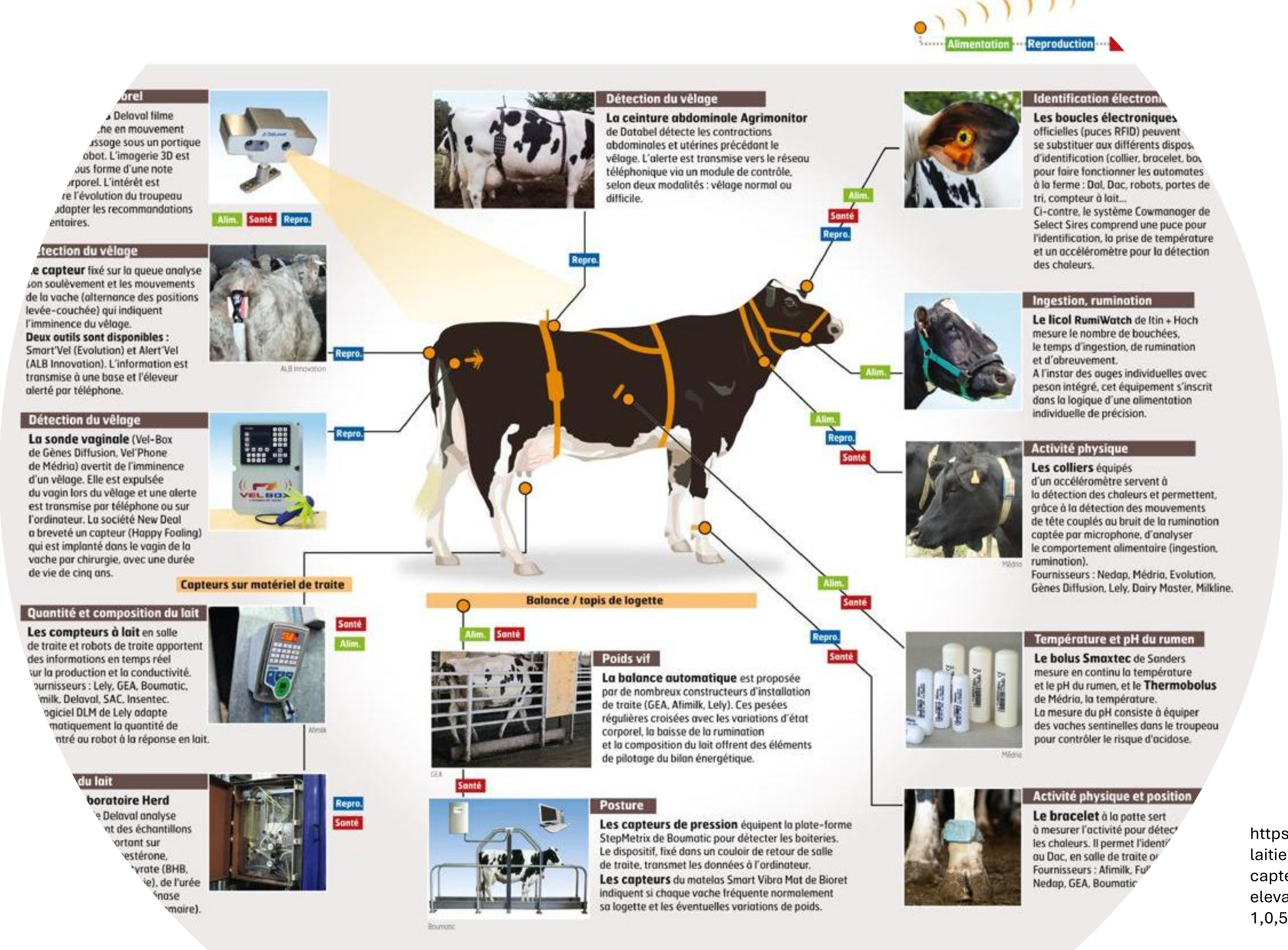
- IoT and smart farming?

Directly on the cows ...



https://www.eleveur-laitier.fr/dossier/des-capteurs-au-service-de-l-elevage-de-precision-1,0,549358506.html

3. Scaling up with advanced techonologies

- IoT and smart farming?
- Machine learning and Artificial Intelligence (AI) for dairy management?
- Blockchain for supply chain transparency?

Stepwise data-driven solutions

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4. Policy and Institutional Support

4. Policy and Institutional Support

- Subsidized technologies
- Access to cooperative funding mechanisms
- Expert advisory services
  - Continuous technical support also helps maintain equipment and ensures proper data management and interpretation.

Take home message

- Start simple and fix the pipeline – focus on farmer needs

- Awareness campaigns, **farmer training** programs, and **cooperative support** networks to help farmers progress through each stage of this transformation.

- **Standardized data collection and analysis** protocols ensure that the data generated are reliable, comparable, and actionable across various contexts.

- Through coordinated efforts involving **governments**, **research institutions**, **non-governmental organizations, and private stakeholders**, the dairy sector can enhance productivity, efficiency, and economic stability, contributing to a resilient and sustainable agricultural landscape

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Methods

Volume 186, February 2021, Pages 97-111

Large-scale phenotyping in dairy sector using milk MIR spectra: Key factors affecting the quality of predictions

C. Grelet [a], P. Dardenne [a], H. Soyeurt [b], J.A. Fernandez [a], A. Vanlierde [a], F. Stevens [a], N. Gengler [b], F. Dehareng [a]

Cluster	RPDcv	Relative RMSEcv	R^2cv	Interpretation for application
1	> 6	<5%	> 0.97	Any application
2	4.2–6	<10%	0.94–0.97	Quality control
3	3–4.2	<10%	0.89–0.94	Quantitative screening
4	2–3	<25%	0.74–0.89	Rough screening
5	1.5–2	<25%	0.55–0.74	Allows to compare groups, discriminate high or low values
6	1.5–2	>25%	0.55–0.74	Highly imprecise, can be used to detect extreme values
7	< 1.5	–	< 0.55	Not recommended

From our experience ...

Table 1
Datasets used in the study.

Traits	N records	N cows	N countries	Sampling years	References
Milk Fatty acids, 30 models	1822	1822	7	2005–2015	Soyeurt et al. [39,40]
Milk Minerals, 5 models	1340	1340	4	2005–2015	Soyeurt et al. [41]
Milk Lactoferrin	3906	3906	3	2005–2009	Soyeurt et al. [42]
Methane emitted (CH4)	1089	299	7	2010–2019	Dehareng et al. [43] and Vanlierde et al. [18]
Milk Fresh Cheese Yield (FCY), Coagulation time r, Time when the curd is firm enough for cutting (k20)	283	283	1	2011–2014	Colinet et al. [44]
Milk Casein	996	*	1	2011–2014	Not published
Milk Acetone, β-hydroxybutyrate (**BHB**) and Citrate	566	346	3	2013–2014	Grelet et al. [45]
Blood BHB, Non-Esterified Fatty Acids (NEFA), Insulin Growth Factor I (IGF-I), Glucose	387	241	6	2014–2016	Grelet et al. [6]
Nitrogen efficiency (NUE), Nitrogen losses, Dry matter intake (DMI), Body weight	1034	129	3	2014–2015	Grelet et al. [14]
Milk Glucose free, Glucose-6-phosphate, Uric acid, Iso-citrate, Progesterone	2175	241	6	2014–2016	Not published

*The casein model was constituted by 790 samples from individual cows and 206 samples from bulk tank.

	Phenotype	Min	Max	Mean	SD	R^2cv	Relative RMSEcv	RPDcv	Cluster
Any application	Milk SAT FA(g/dL)	0.31	6.97	2.70	0.75	0.99	3%	10.22	1
	Milk C18_1cis9 (g/dL)	0.08	2.69	0.76	0.29	0.95	8%	4.35	
	Milk Casein (g/100 g)	1.61	4.05	2.66	0.34	0.95	3%	4.46	
	Milk LCFA (g/dL)	0.19	4.79	1.59	0.52	0.95	7%	4.52	
	Milk MCFA (g/dL)	0.22	5.48	2.00	0.60	0.97	5%	5.53	
Quality control	Milk MONO FA (g/dL)	0.12	3.42	1.08	0.35	0.97	5%	5.83	2
	Milk Tot18_1cis (g/dL)	0.09	2.77	0.82	0.31	0.95	8%	4.58	
	Milk Total_C18_1 (g/dL)	0.10	2.98	0.94	0.33	0.96	7%	5.18	
	Milk UNSAT (g/dL)	0.14	3.86	1.25	0.39	0.97	5%	5.75	
	Milk C10 (g/dL)	0.02	0.32	0.11	0.04	0.91	9%	3.37	
	Milk C12 (g/dL)	0.02	0.41	0.13	0.04	0.92	9%	3.62	
	Milk C14 (g/dL)	0.05	1.20	0.45	0.13	0.93	7%	3.88	
	Milk C16 (g/dL)	0.12	3.32	1.20	0.40	0.94	8%	4.18	
Quantitative screening	Milk C4 (g/dL)	0.01	0.23	0.10	0.03	0.93	8%	3.67	3
	Milk C6 (g/dL)	0.01	0.16	0.07	0.02	0.91	9%	3.32	
	Milk C8 (g/dL)	0.01	0.11	0.05	0.01	0.91	9%	3.29	
	Milk Citrates (mmol/L)	3.88	16.12	9.04	2.21	0.89	8%	3.04	
	Milk SCFA (g/dL)	0.05	0.80	0.35	0.10	0.93	7%	3.88	
	Milk C17 (g/dL)	0.00	0.09	0.03	0.01	0.80	13%	2.24	
	Milk C18 (g/dL)	0.05	1.32	0.40	0.15	0.84	14%	2.51	
	Milk Calcium (mg/kg)	593	1743	1149	135	0.82	5%	2.34	
Rough screening	Milk Odd fatty acids (g/dL)	0.03	0.50	0.16	0.04	0.83	10%	2.41	4
	Milk PUFA (g/dL)	0.02	0.53	0.16	0.05	0.77	13%	2.10	
	Milk Total_Trans (g/dL)	0.02	0.75	0.16	0.08	0.80	19%	2.26	
	Tot18_1trans (g/dL)	0.01	0.57	0.13	0.06	0.79	21%	2.17	

	Phenotype	Min	Max	Mean	SD	R^2cv	Relative RMSEcv	RPDcv	Cluster
	Cheese process r (s)	319	1653	906	231	0.58	16%	1.54	
	Dry matter intake (kg/d)	8.8	36.2	19.9	4.5	0.71	12%	1.83	
	Fresh cheese yield (g curd/100 g milk)	7.40	47.93	26.76	6.45	0.73	12%	1.91	
	Methane emitted (g/d)	180	786	413	102	0.68	14%	1.79	
	Milk C14_1 (g/dL)	0.00	0.15	0.04	0.02	0.68	21%	1.78	
	Milk C16_1c (g/dL)	0.01	0.24	0.07	0.03	0.73	20%	1.91	
	Milk C18_2c9c12 (g/dL)	0.00	0.17	0.06	0.02	0.72	19%	1.91	
	Milk C18_3c9c12c15 (g/dL)	0.00	0.09	0.02	0.01	0.68	22%	1.77	
	Milk isoanteiso FA (g/dL)	0.02	0.28	0.09	0.03	0.75	14%	2.00	
High and Low values	Milk Magnesium (mg/kg)	61	157	100	13	0.72	7%	1.88	5
	Milk omega3 (g/dL)	0.00	0.11	0.03	0.01	0.66	22%	1.73	
	Milk omega6 (g/dL)	0.01	0.33	0.10	0.03	0.72	14%	1.89	
	Milk Phosphorus (mg/kg)	509	1447	999	124	0.75	6%	1.99	
	Milk Potassium (mg/kg)	819	1985	1524	147	0.55	6%	1.48	
	Milk Tot18_2 (g/dL)	0.01	0.32	0.10	0.03	0.69	15%	1.79	
	N efficiency (%)	9.8	81.7	36.9	10.3	0.71	15%	1.87	
	N losses (kg/d)	0.04	0.81	0.31	0.11	0.65	20%	1.69	
	Weight of cows(kg)	448	832	617	73	0.70	6%	1.83	
	Blood BHB (mmol/L)	0.19	3.46	0.77	0.48	0.70	35%	1.81	
	Blood IGF-I (mg/L)	13	436	107	71	0.61	42%	1.59	
Extreme values	Lactoferrin (mg/L)	7	1248	299	222	0.66	44%	1.71	6
	Milk BHB (mmol/L)	0.05	1.60	0.22	0.17	0.75	46%	1.97	
	Milk C18_2c9t11 (g/dL)	0.00	0.14	0.03	0.02	0.74	37%	1.95	

Too bad

Phenotype	Min	Max	Mean	SD	R^2cv	Relative RMSEcv	RPDcv	Cluster
Blood Glucose (mmol/L)	1.93	4.51	3.47	0.47	0.44	10%	1.33	
Blood NEFA (μekv/L)	26	1956	672	440	0.39	51%	1.28	
Cheese process k20 (s)	160	386	225	39	0.34	13%	1.24	
Milk Glucose Free (mmol/L)	0.00	0.69	0.24	0.11	0.50	32%	1.41	
Milk Glucose6Phosphate (mmol/L)	0.00	0.93	0.16	0.08	0.49	36%	1.40	7
Milk IsoCitrate (mmol/L)	0.02	2.90	0.17	0.10	0.11	55%	1.06	
Milk Natrium (mg/kg)	234	1273	356	91	0.44	15%	1.34	
Milk Progesterone (ng/ml)	0.50	22.44	5.22	2.74	0.08	50%	1.05	
Milk Uric Acid (μmol/L)	2.4	348.5	158.8	54.6	0.32	28%	1.22	