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Silage quality control for animal feed and biogas production

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Content of the lecture

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- Live position tracking technologies
- Precision farming solutions in livestock farming: a case study on silage quality control

PART 1

Live position tracking on Earth surface with GNSS (GPS) systems

Global Navigation Satellite Systems (GNSS)

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GNSS is a widely used geolocalization technology for terrestrial, maritime and air navigation. It is used to provide real-time positions of vehicles using geographic coordinates (such as Latitude, Longitude and Altitude).

It is based on information received from satellite constellations, like:

- **GPS** (USA, 1993, 24 satellites)
- **Glonass** (Russia, 1995 , 24 satellites)
- **Galileo** (Europe, 2019 , 24 satellites)
- **Beidou** (China, 2018 , 24 satellites)

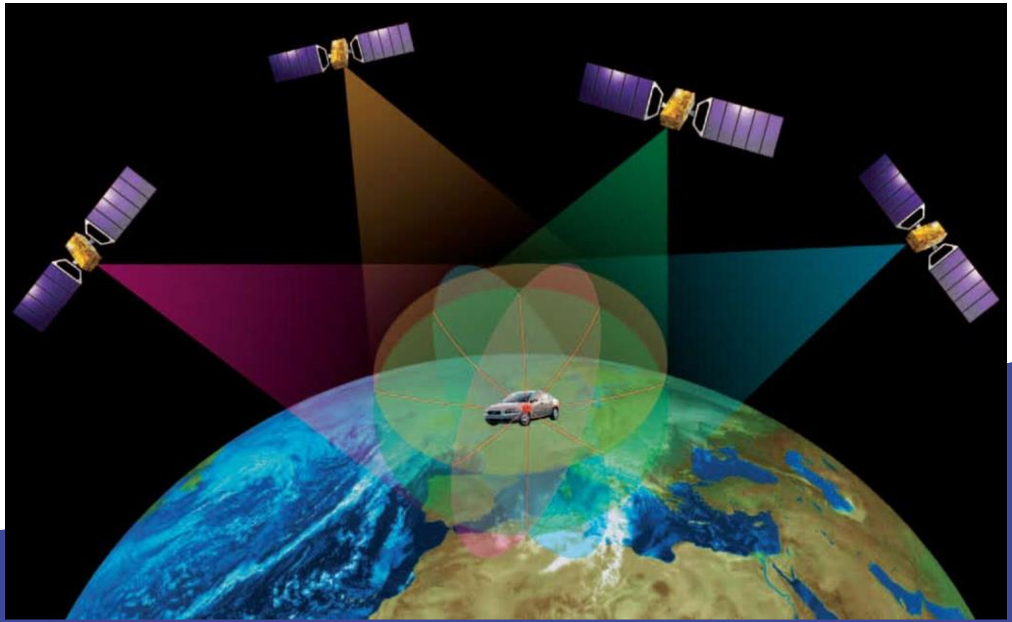

Image source: European Space Agency (ESA)

Global Navigation Satellite Systems (GNSS)

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In order to work, satellite transmit data over three bands of frequency:

- **L1 at 1575.42 MHz,** on which information on the position of satellites is provided;
- **L2 at 1227.60 MHz,** which is used to guess the reliability of satellite information due to clouds
- **L5 at 1176.45 MHz,** which can improve the accuracy of L1 satellites.

Not every GNSS device can work with every satellite constellation, and not every GNSS device (and antennas!) can receive data from every band. Cheapest devices work at L1 only, for instance.

Differential GNSS

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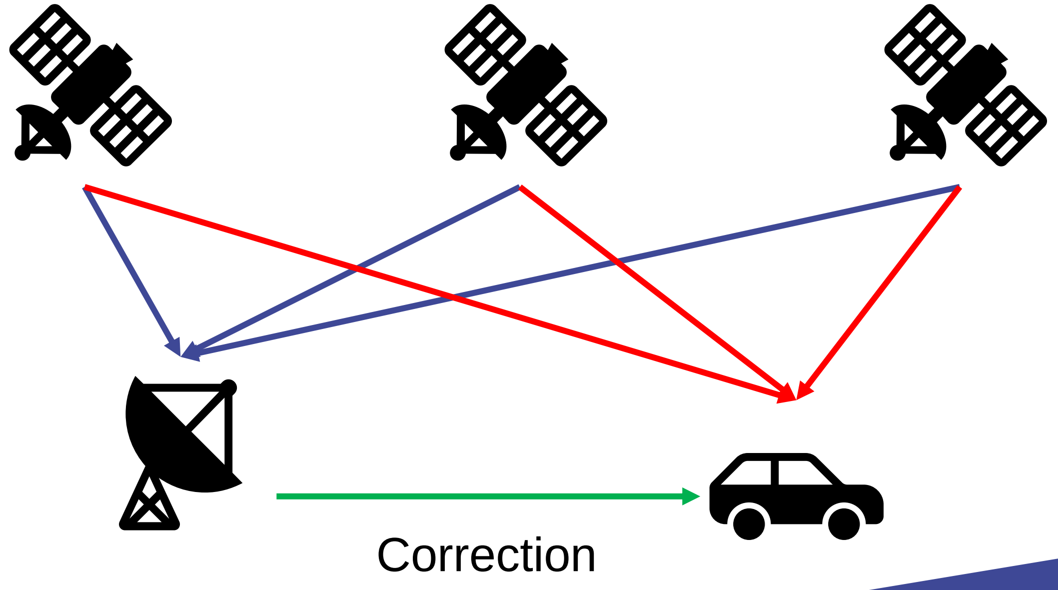
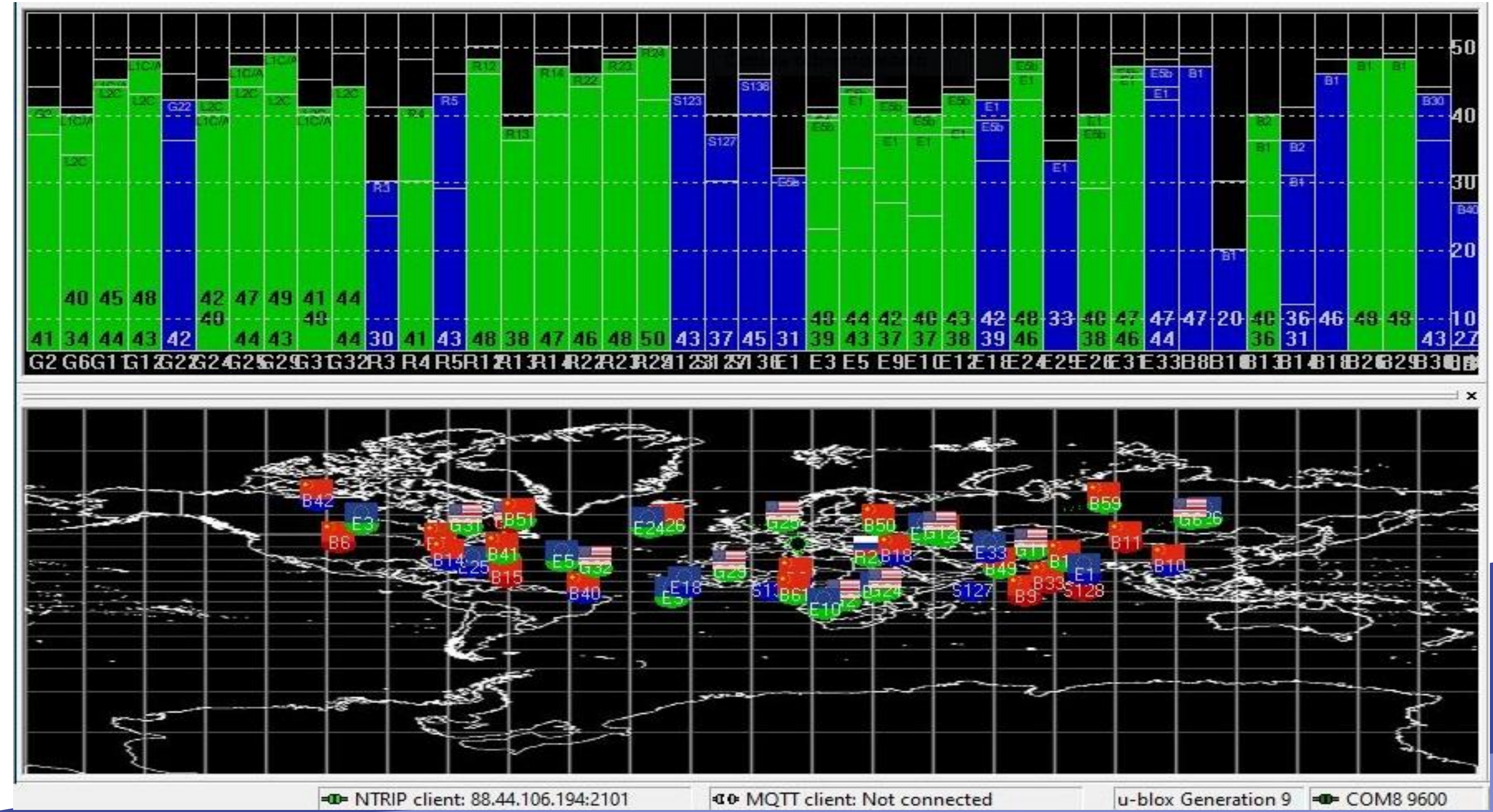
RTK stands for **Real Time Kinematics**, it is a differential GNSS technology (DGNSS) that provides exremely precise information by integrating data with corrections received by a fixed point on Earth. The object that is tracked is called «rover», while the fixed point is classed «base station».

Base stations provide **corrections** (called «fix» information) in RTCM format that allow rovers to solve uncertainties regarding their position. Information is usually provided over the internet by «**NTRIP**» servers (*Networked Transport of RTCM via Internet Protocol*).

Positioning errors of this method are in the range of few centimeters, but precision drops with increasing distances from the base station (approximately 1 cm per 10 km).



Example of GNSS satellite status on receiver



GNSS working modes

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GNSS (GPS) «3D» mode	RTK «float» mode	RTK «fix» mode
Navigation system «sees» enough satallites to estimate position (**lat,lon**) and elevation.	Navigation system receives «**corrections**» from a **base station** through NTRIP servers, but doesn't see enough satellites to resolve uncertainties.	Navigation system receives «**corrections**» from a base station through NTRIP servers. It sees enough satellites to solve uncertainties.
Positioning error: **± 1 m (many satellites)** ± 3 m (few satellites)	Positioning error: **± 0.5 m**	Positioning error: ± 0.1 m (base station at 100 km) **± 0.01 m (base within 10 km)**
Position is close to the exact point but uncertainty is high.	Position «floats» around a small area. Even if the receiver doesn't move, position sligthly changes with time.	Position doesn't changes with time and, if it does, variation is minimal.

GPS vs RTK

GPS paths of a tractor in a vineyard.
Positioning error (above 1 m) is almost as big as the spacing among rows.

RTK points of a tractor during field operations.
Positioning error (below 10 cm) allows to associate yield data to the coordinates.

Devices for (D)GNSS

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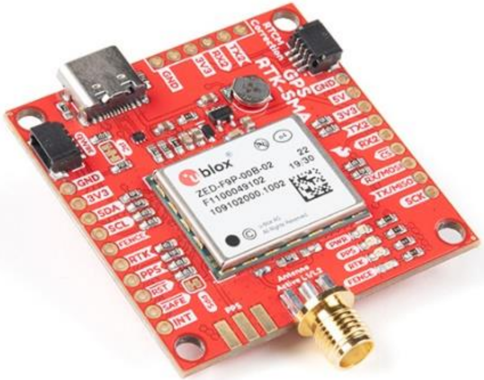
Antenna for L1 & L2 bands

GNSS board (no correction system)



DGNSS board (with RTK capabilities)

GNSS & GSM board

PART 2

Case-study: traceability and quality control of silage and rations

The case-study involves a large farm business that **integrates breeding, cultivation, and energy production.**

The production of silage and its storage at trench silos is the core activity for the production of:

- **ration** for animal feed
- biomass for energy production in **biogas reactors**

To fulfil its goals, most of the fields are devoted to cereals and fodder production.

In numbers, it could be measured in thousands of cattle and MegaWatts of instant energy production.

Due to the company’s dimension, its organization requires huge quantities of data and lots of information: that’s why **digital agriculture and precision livestock farming** are paramount to support any decision-making process.

Scenario description

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In for a pound, in for a penny

Given a daily production of high-quality milk that could meet the demand of a big town, it is not surprising that every detail counts in being able to stay on the market: profit aside, a small increase in production costs can become a major concern.

Silage production depends on crop yield, but what about its quality?

Biomass produced by fields, although, gets stored in large trench silos: this means that any punctual data collected on the field gets lost and when the silos will be reopened, it is impossible to know its quality and where it has been produced.



Silage

There are several biomass types that can be used in this preservation process for silage production:

- Maize;
- Triticosecale;
- Barley;
- Sorghum;
- Leguminous (less indicated).

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Silage characteristics

Foraggi Insilati	Sostanza Secca % TQ	NFC % SS	Amido % SS	Proteine grezza % SS	Proteine solubili % PG	NDF % SS	ADF % SS	ADL % SS	ceneri % SS
insilato di mais	33.7	40.8	29.6	7.3	60.1	45.1	24.2	2.5	4.3
insilato di cereali paglia	29.1	19.6	3.4	7.4	69.0	61.1	37.5	5.0	8.4
insilati di loietto	27.0	17.8	-	8.3	43.3	60.8	37.7	5.1	9.9
insilati di prato stabile	23.0	15.5	-	11.4	62.7	61.4	39.6	5.7	6.8
insilati di sorgo	22.3	15.7	3.2	8.5	52.6	64.8	39.2	4.8	8.6
insilati di medica	24.2	20.9	-	20.1	50.5	41.3	30.8	8.7	14.8

Maize silage characteritics

Chemical composition in %

SS (% t.q.)	**35,0**	**PG**	**8,2**
LG	**3,2**	**FG**	**18,5**
NDF	**48,0**	**ADF**	**21,0**
ADL	**3,8**	**EI**	**52,0**
Ca	**0,35**	**P**	**0,25**
Cen	**5,3**	**UFL**	**0,90**

SS	sostanza secca	PG	proteina grezza	FG	fibra grezza
LG	lipidi grezzi	EI	estrattivi inazotati	Cen.	ceneri
NDF	fibra neutro detersa	ADF	fibra acido detersa	ADL	lignina
ADL	lignina	Amido (pol.)	amido met. polarimetrico		
UFL	unità foraggere latte	EM	energia metabolizzabile		

Specific weight:

$\cong$ 500 – 600 kg m^{-3}

Trench-silo final covering

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- Multilayer plastic film
- Adhesion to silage mass
- Weighting > 150 kg/m^2
- In lateral areas, weight is increased with bags of gravel

Adding weights uniformly on the surface reduces the probability of damaging multilayer films, prevents additional air from getting inside and it can be done with any kind of material: it must be said, although, that pressure should be at least 150 kg/m^2 and lateral areas require particular solutions (usually gravel bags).

Scope of the experiment

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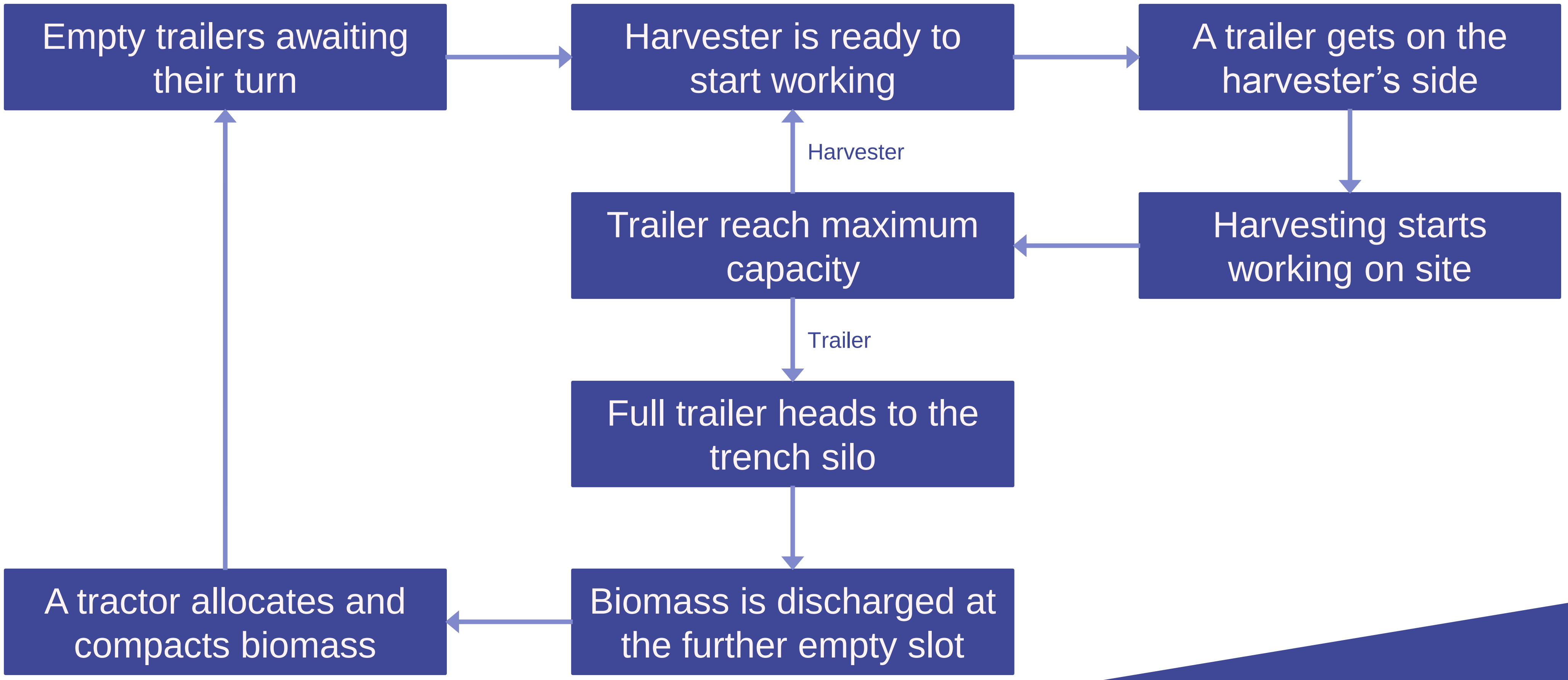
In order to answer questions regarding silage quality at utilisation, the experiment aims to:

- Gather data from harvesters regarding **biomass quality**
- Understand **what and where** it has been stored in trench silos
- Convert an information regarding biomass “horizontal layers” into information regarding silage quality at **“vertical layers”** at usage
- Adapt **rations according to silage quality** as it keeps being recovered from the trench silo

Harvesting and storage process of biomass



Scenario description

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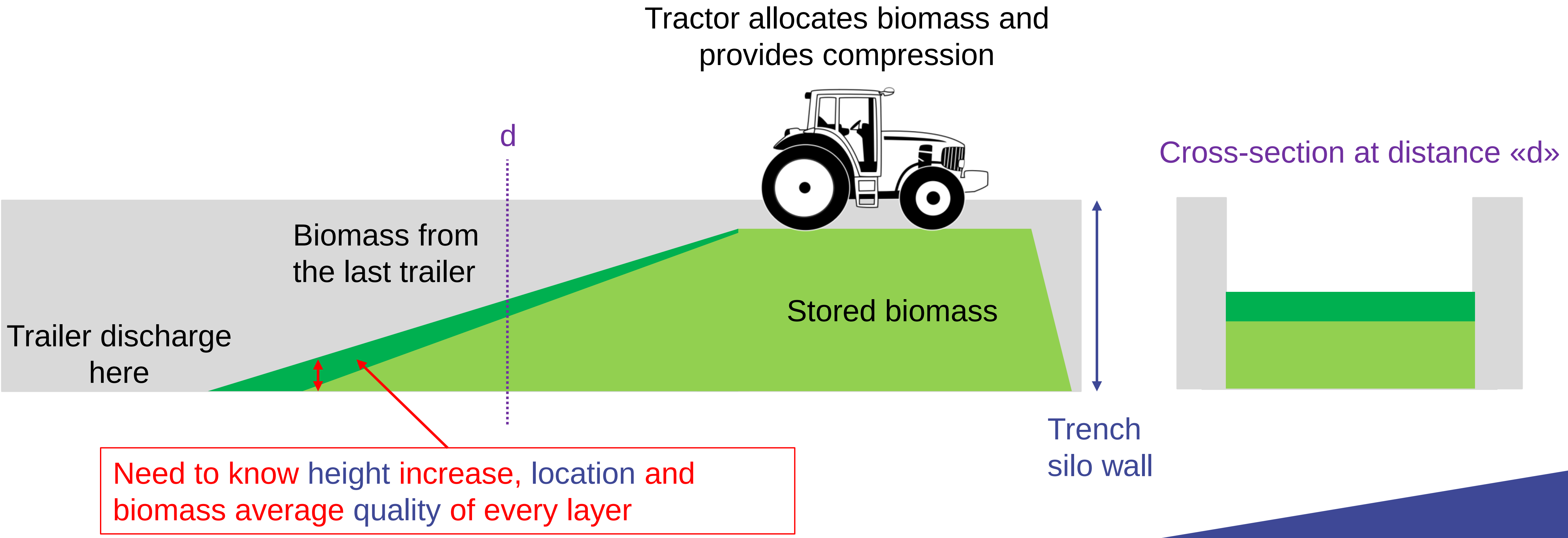
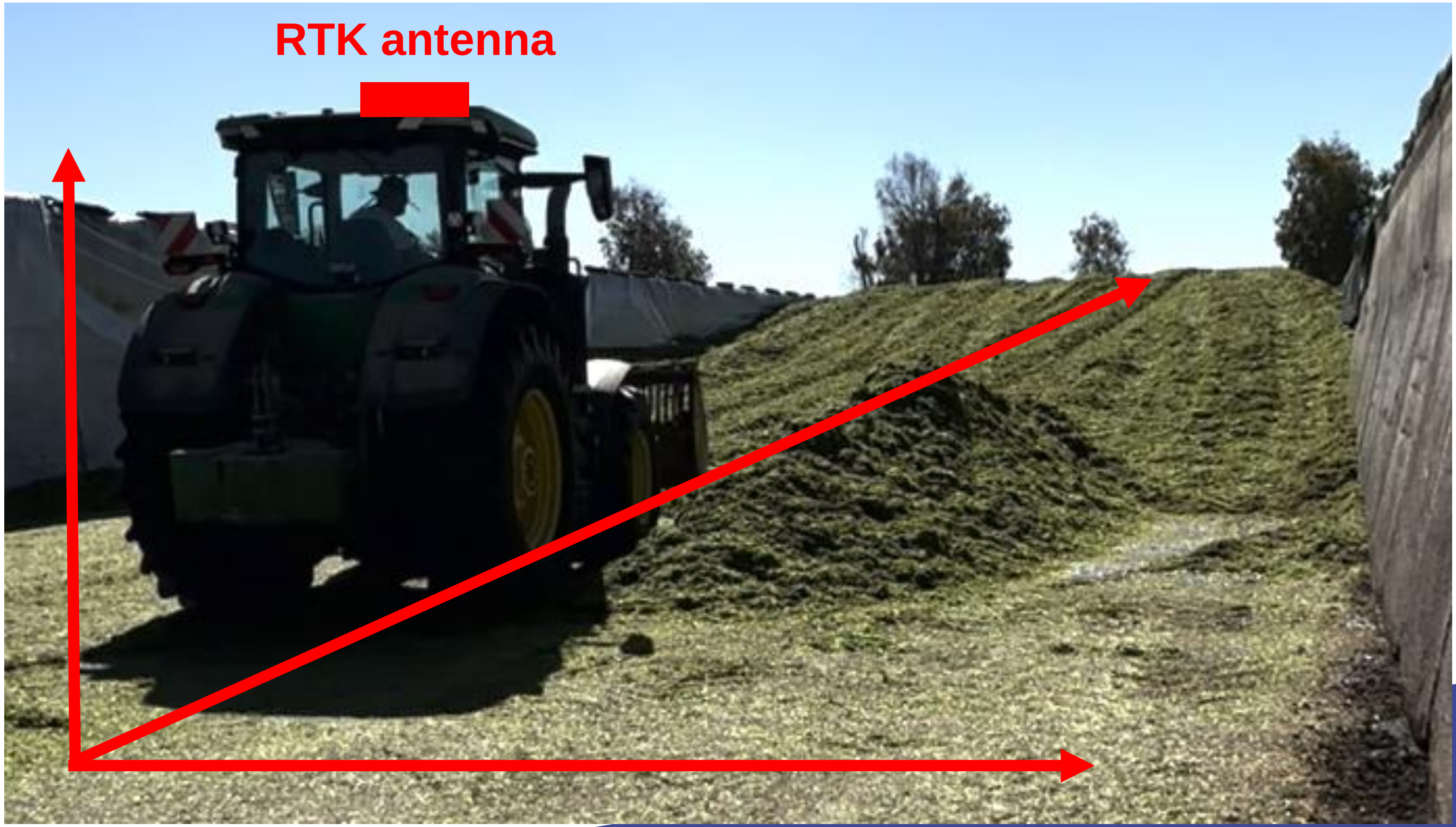


Storage at trench silos



Storage at trench silos

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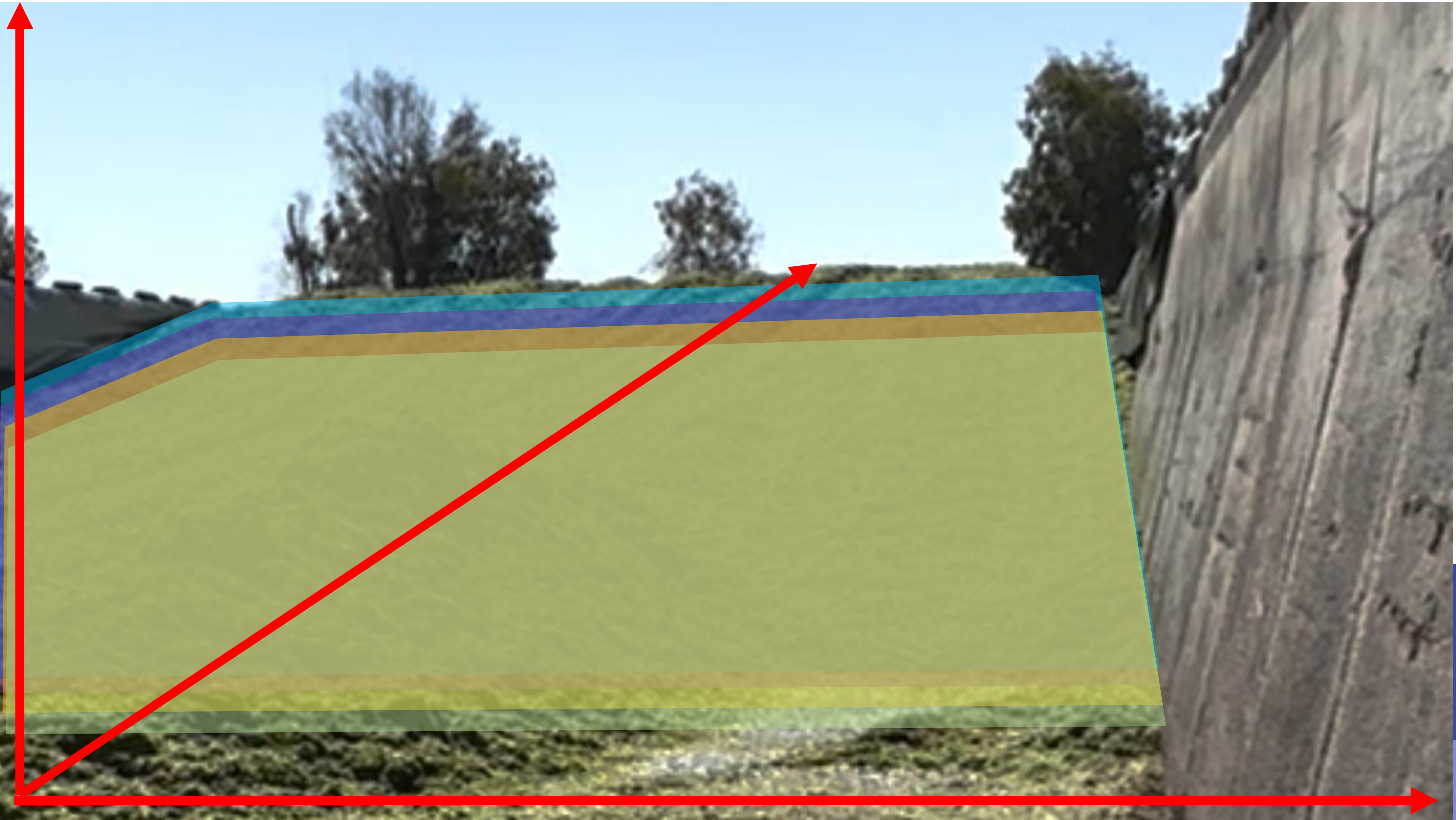
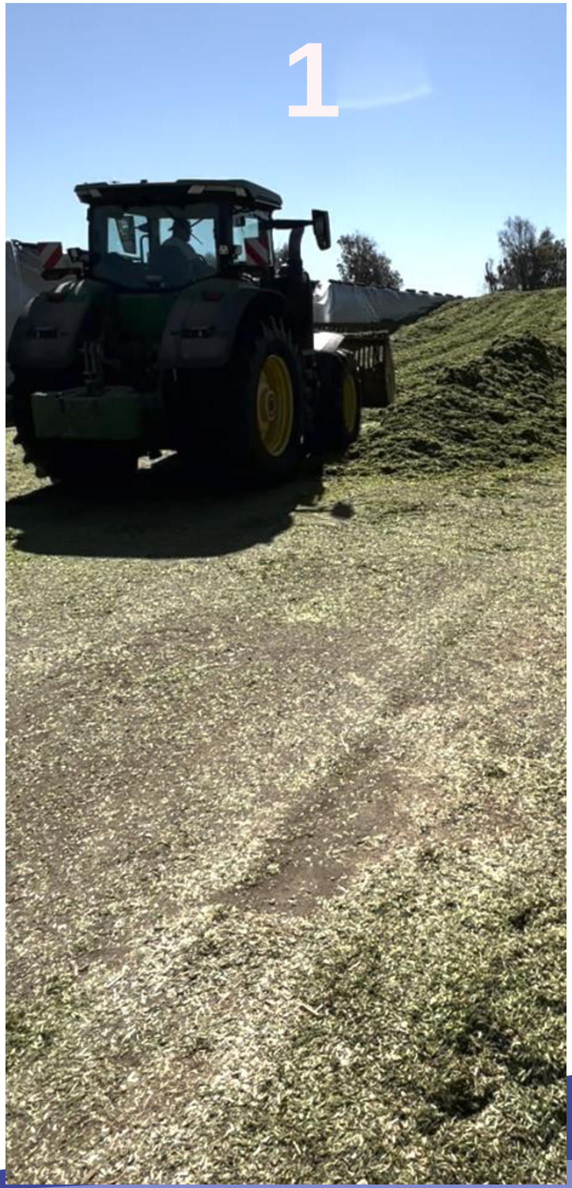
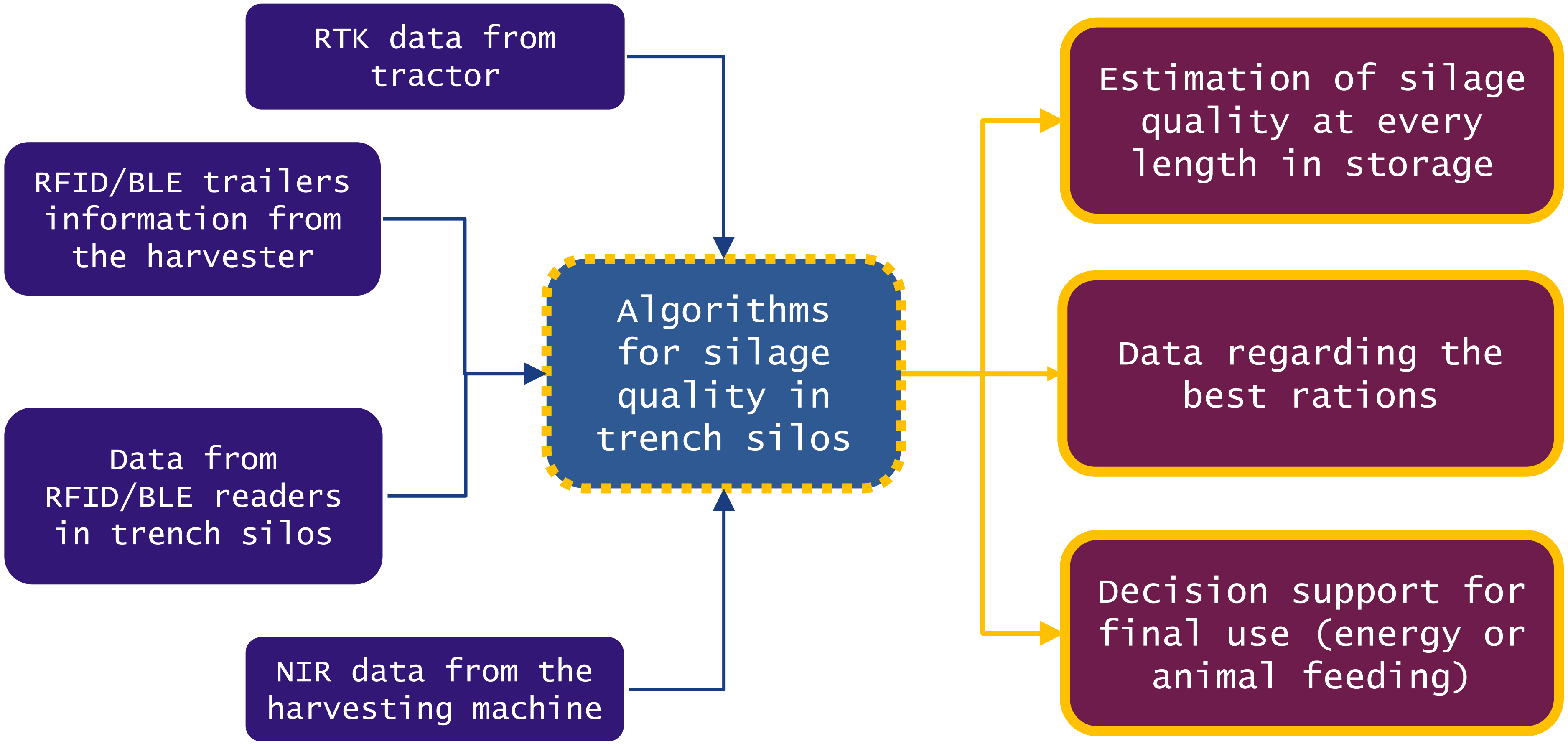


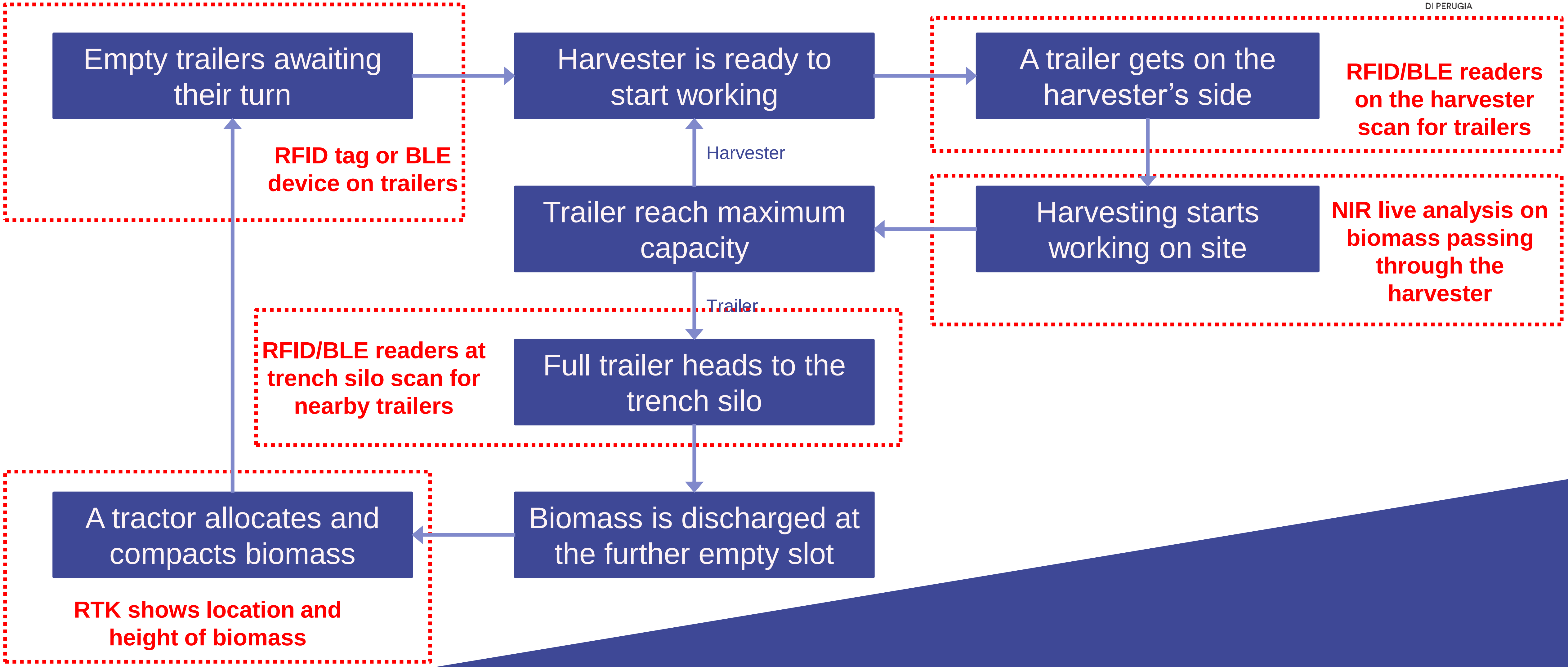
Storage at trench silos



Flowchart of the method



Devices for information control



Harvester & trailers

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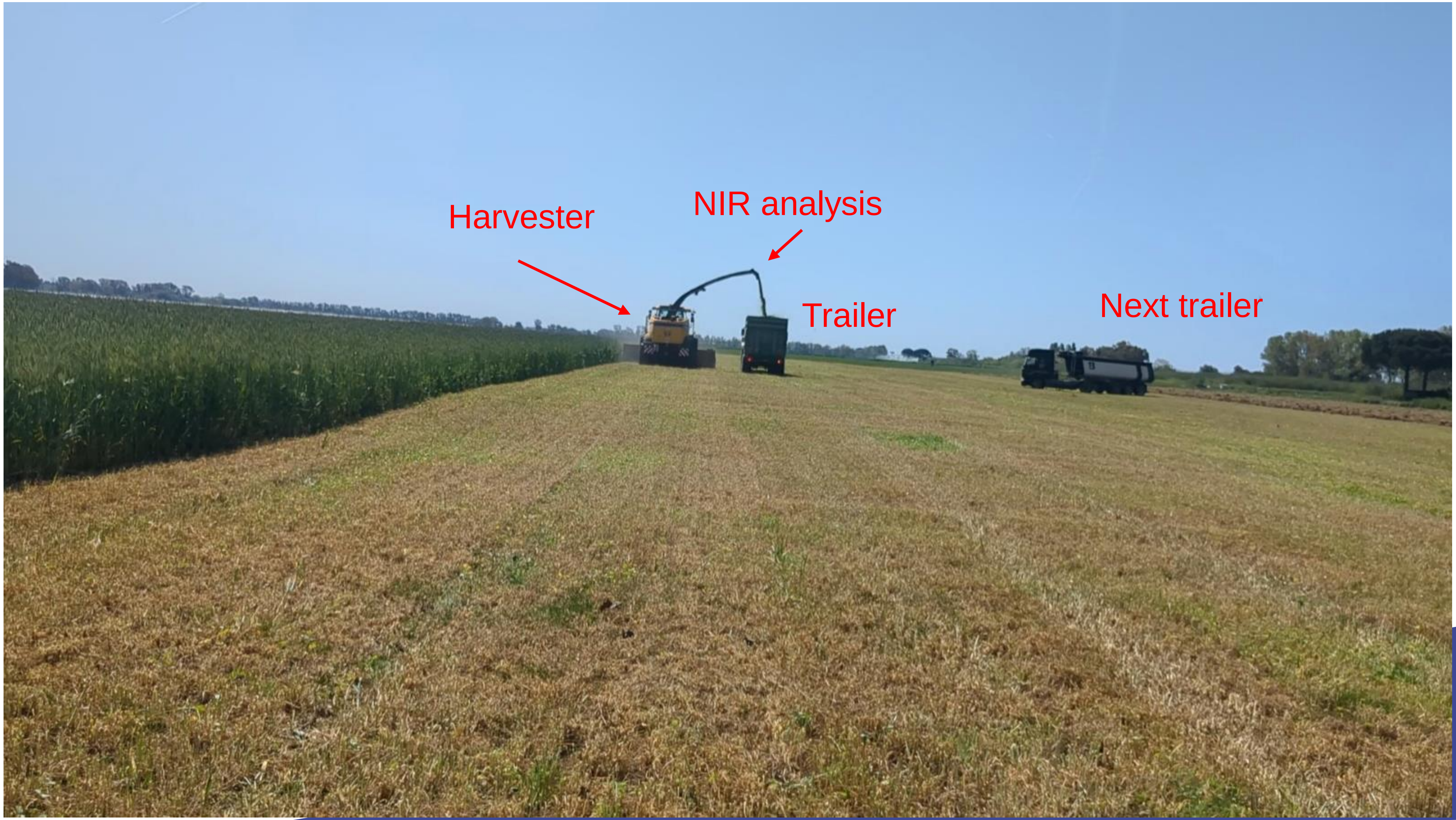

Harvesters

Wheel speed: 2,5 – 3,5 km h^{-1}

Field working capacity (at 65% humidity):
25 – 50 t h^{-1}

Harvester & trailer

Logistics

Results of on-board NIR analysis

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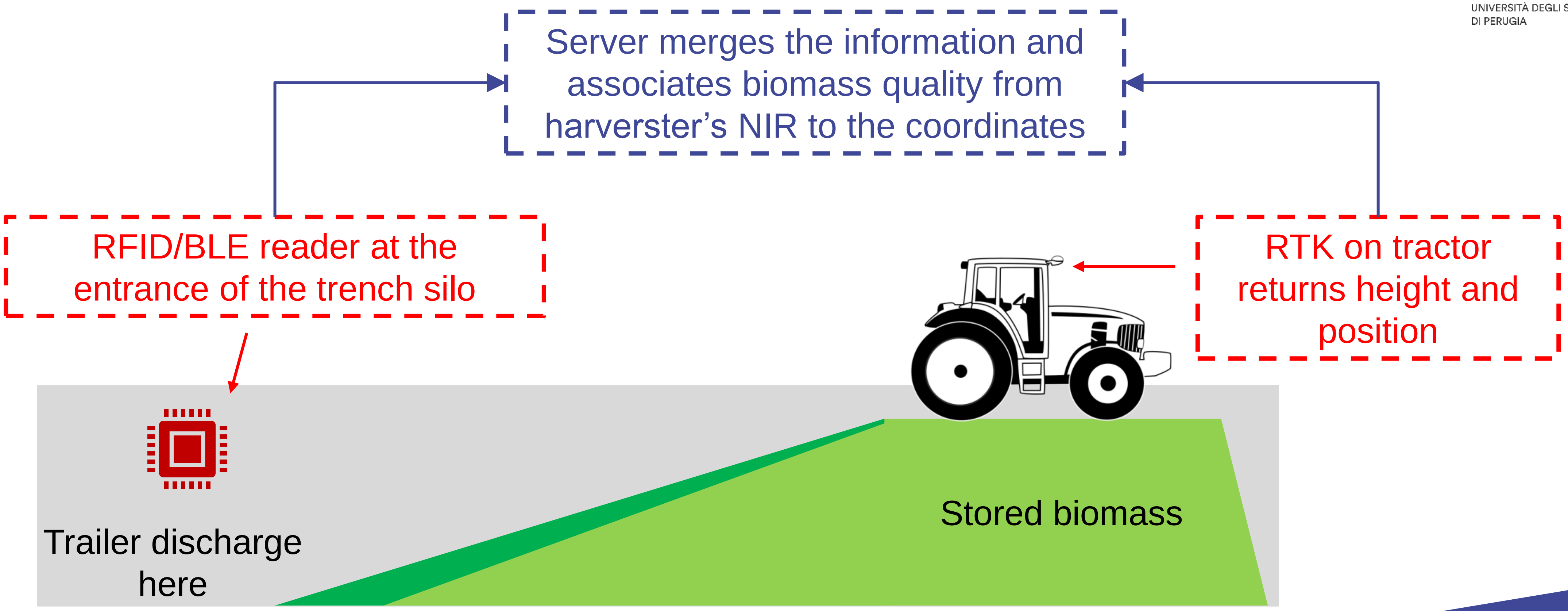
NIR analyzers can return data regardaing a wide range of variables (pH, nitrates, moisture, etc.)

Data regarding biomass collected by the trailer is the average of punctual measurements

The harvester uses RTK to track its position on the field

Data collection at the trench silo



Summary

Phase	Environment	Data availability	Technology
1. Harvest	Field	Position, yield, biomass quality, fuel consumption, time efficiency, operating costs, etc.	RTK, NIR
2. Trasportation	Road	Position, type, time efficiency, operating costs, quantity, etc.	RFID or BLE
3. Storage	Farm business center	Position, height on storage, fuel consumption, time efficiency, operating costs, etc.	RTK

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Thank you for your attention

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