PRECISION TURFGRASS MANAGEMENT

PRECISION AGRICULTURE

A process (a high-tech management strategy) to apply:

- Right input
- Right source
- Right amount
- Right place
- Right time

Precision farming

Yield Quality **Turnover** Environment

Precision Turfgrass Mgt

Quality Cost **Environment**

In terms of widespread adoption, Precision Farming is **light years ahead** of Precision Turfgrass Management

WHY ??

Adoption factors of (“GO” / “NO GO”)
Precision Turfgrass Management

1. Data is available
   - YES it is: plenty of sensors and tools ! !
2. Data is good
   - YES it is: if you chose wisely ! !
3. ROI is clear
   - Things get tricky. No yield to measure…
4. Regulations
   - Privacy, confidentiality, laws…
5. Acceptance
   - “Will it replace me??”

Technical

1. DATA is available

AIR
- temperature
- humidity
- pressure(s)

PRECIPITATION
- intensity
- amount
- type

WIND
- speed
- direction

SUN & LIGHT
- solar radiation
- PAR (instant)
- DLI (cumulative)

SOIL
- temperature
- electric conductivity
- water content
- pH (?)
- nutrients (?)
- infiltrometry

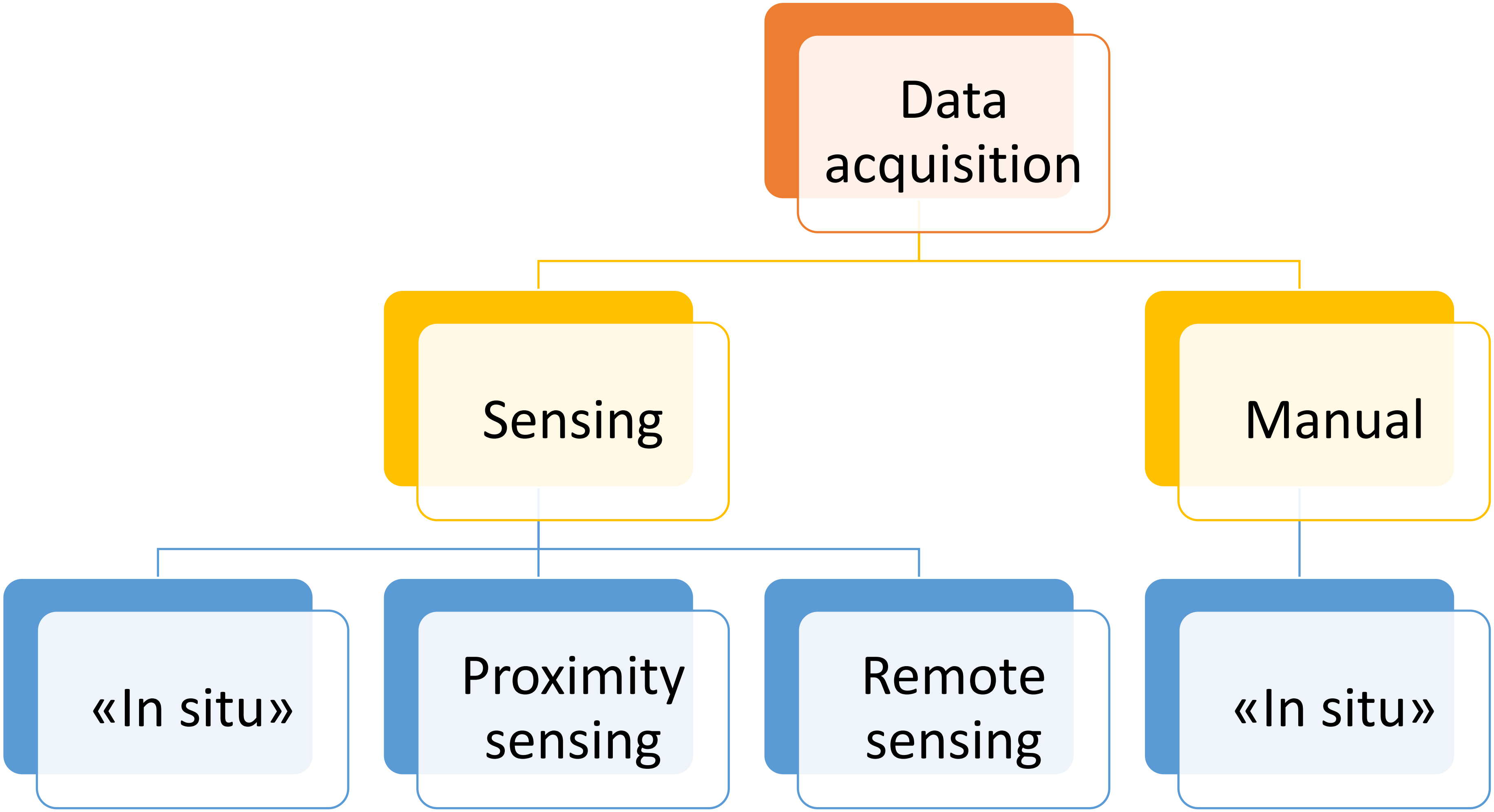
PLANT
- leaf wetness
- chlorophyll

CANOPY
- NDVI & other VI
- thermal IR
- evapotranspiration

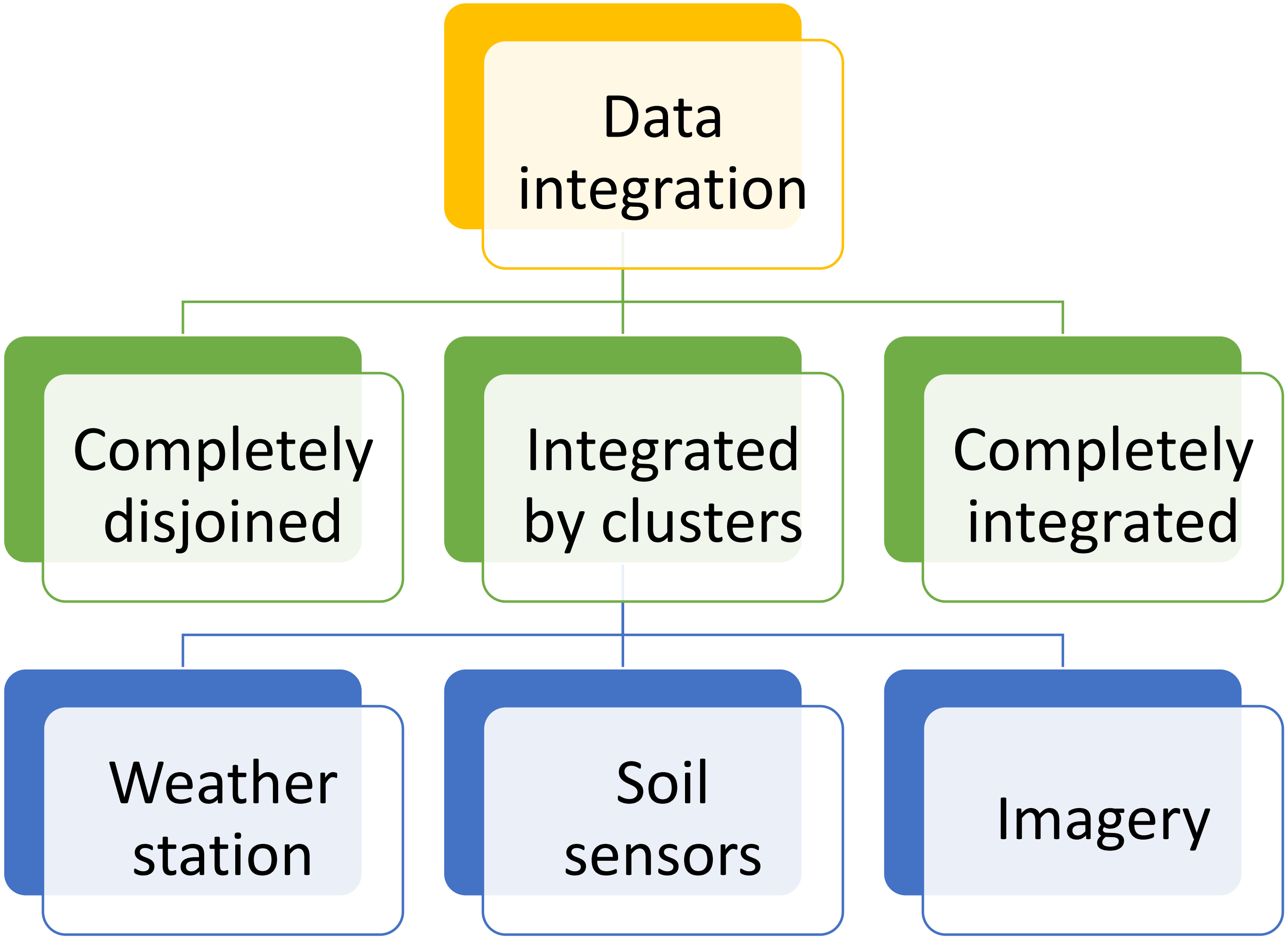
PERFORMANCE
- hardness
- penetrography
- ball/surface interaction
- athlete/surface interaction

SOFTWARE
- annotation / planning
- monitoring / management

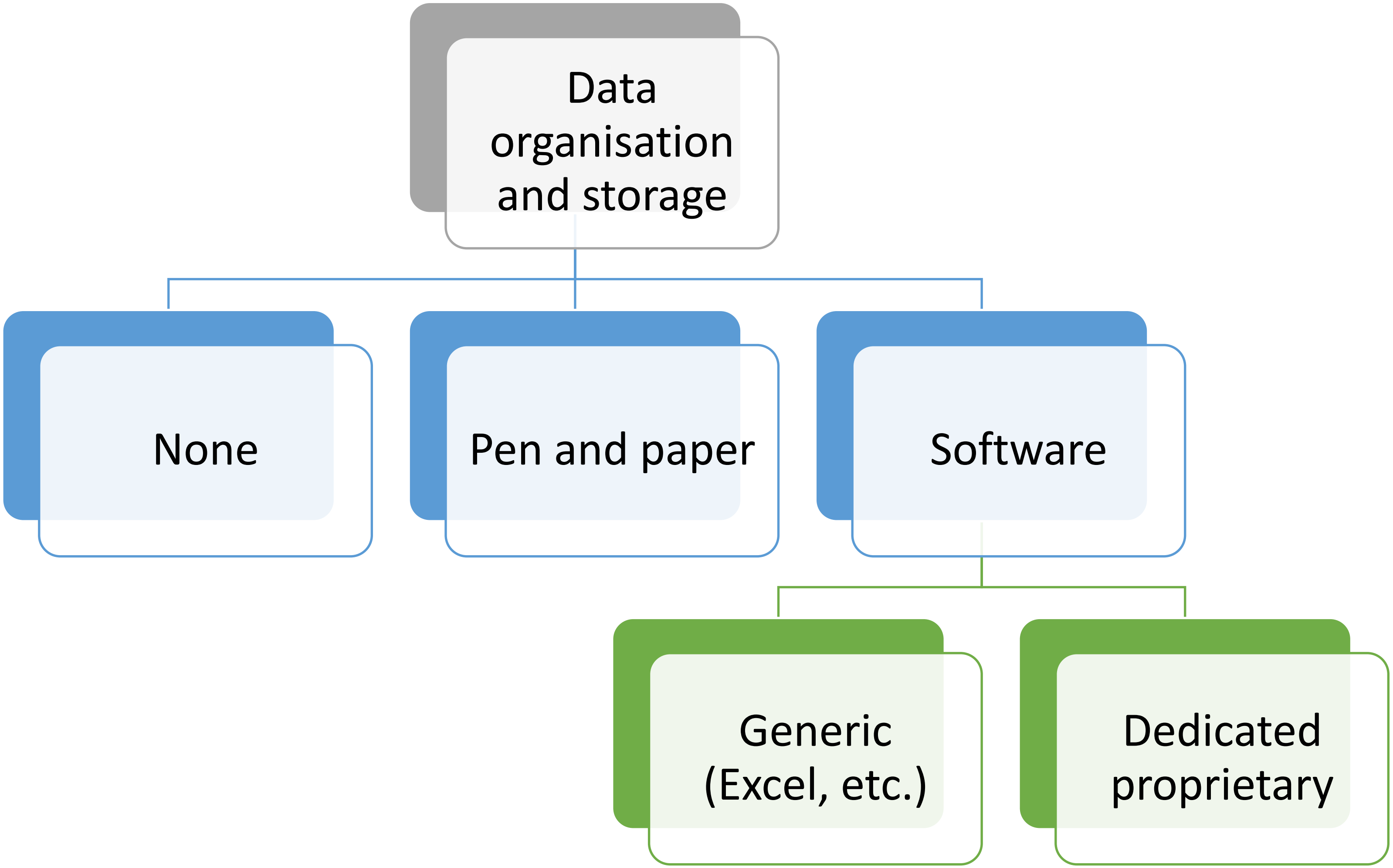
1. DATA is available



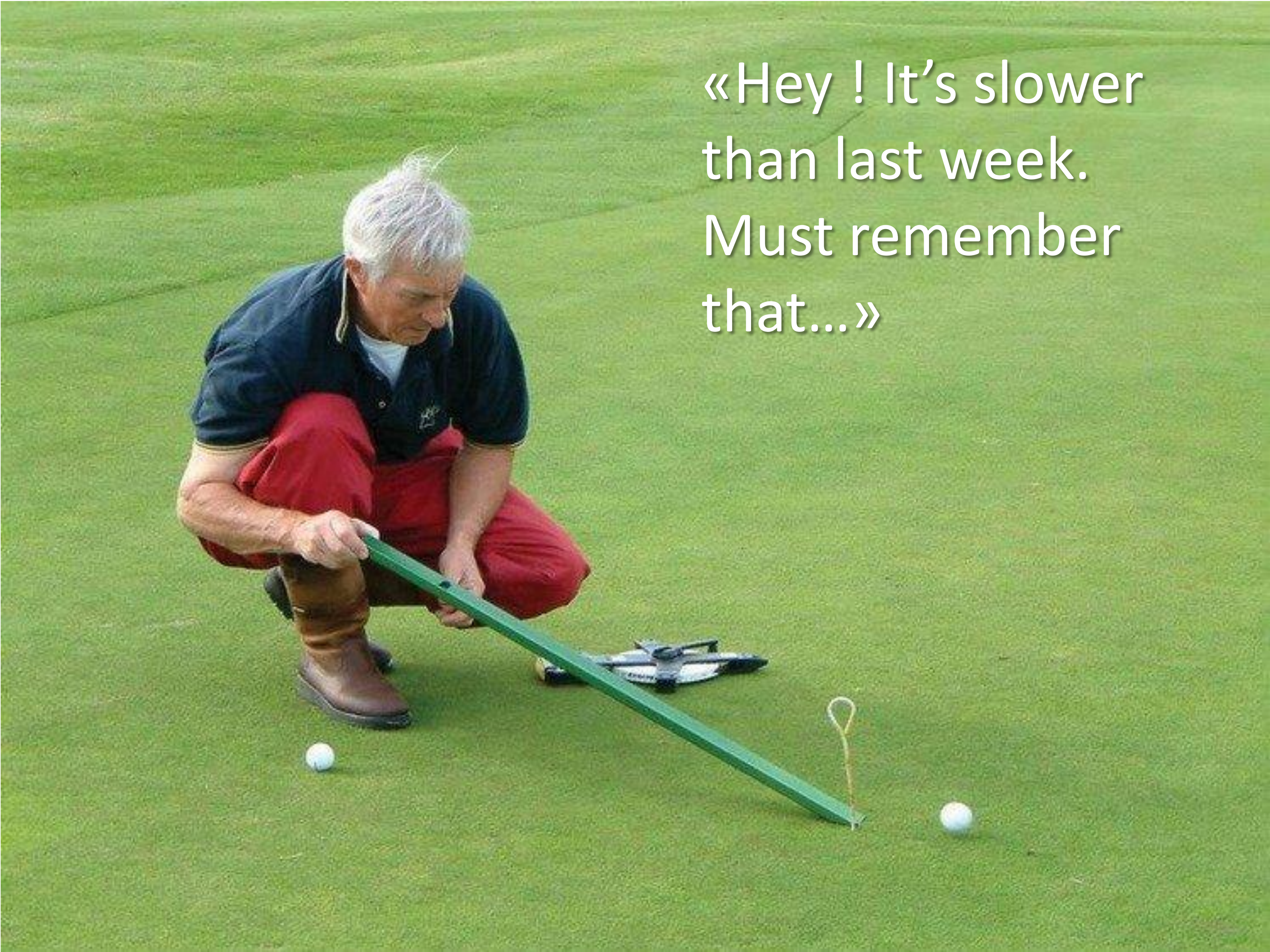
1. DATA is available

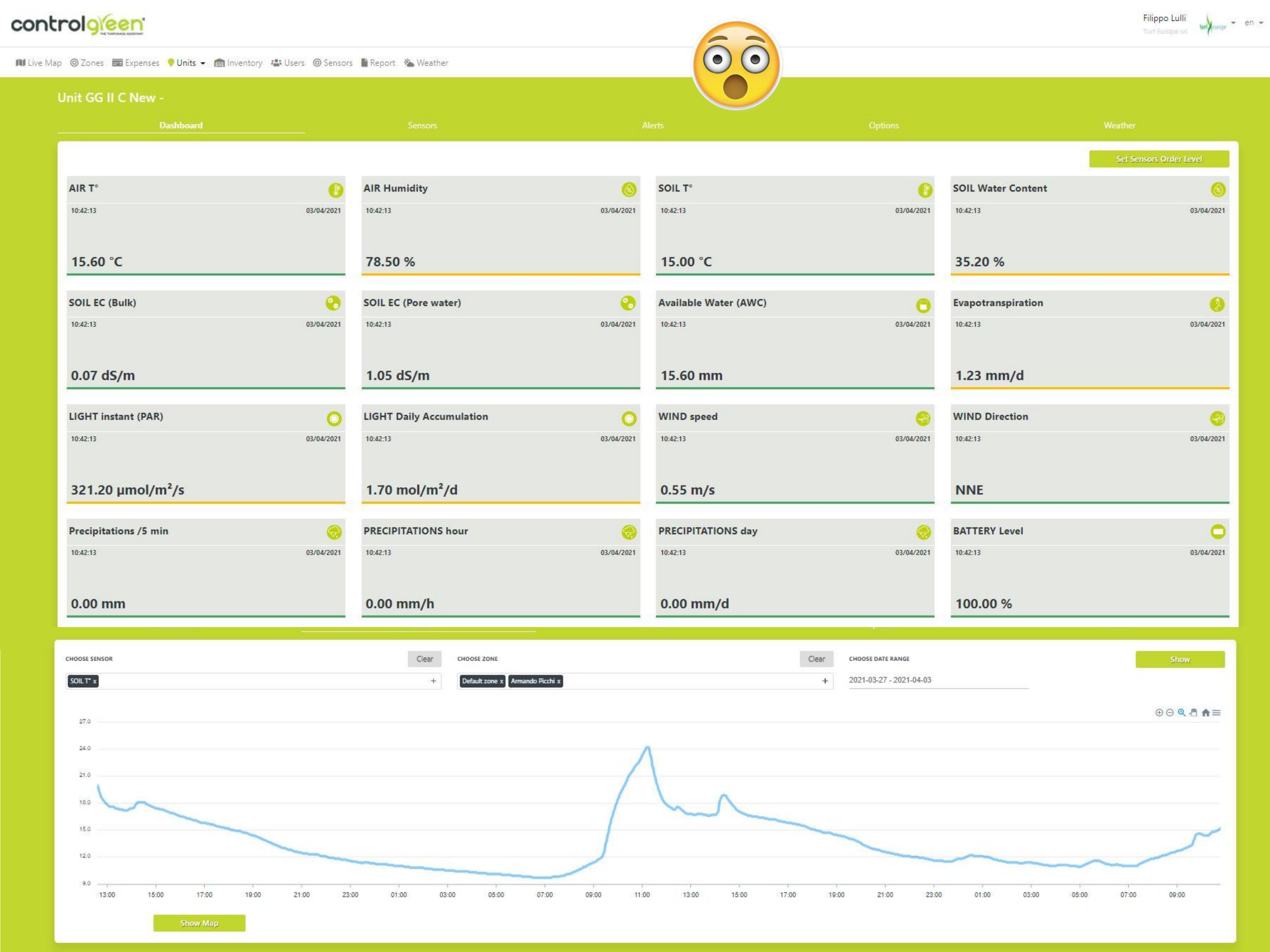


1. DATA is available



Local / Cloud / Exclusive / Shared


«Hey ! It’s slower
than last week.
Must remember
that…»


controlgreen
Filippo Lulli
Turf Europe srl
en
Live Map
Zones
Expenses
Units
Inventory
Users
Sensors
Report
Weather
Unit GG II C New -
Dashboard
Sensors
Alerts
Options
Weather
Set Sensors Order Level
AIR T°
10:42:13 03/04/2021
15.60 °C
AIR Humidity
10:42:13 03/04/2021
78.50 %
SOIL T°
10:42:13 03/04/2021
15.00 °C
SOIL Water Content
10:42:13 03/04/2021
35.20 %
SOIL EC (Bulk)
10:42:13 03/04/2021
0.07 dS/m
SOIL EC (Pore water)
10:42:13 03/04/2021
1.05 dS/m
Available Water (AWC)
10:42:13 03/04/2021
15.60 mm
Evapotranspiration
10:42:13 03/04/2021
1.23 mm/d
LIGHT instant (PAR)
10:42:13 03/04/2021
321.20 µmol/m²/s
LIGHT Daily Accumulation
10:42:13 03/04/2021
1.70 mol/m²/d
WIND speed
10:42:13 03/04/2021
0.55 m/s
WIND Direction
10:42:13 03/04/2021
NNE
Precipitations /5 min
10:42:13 03/04/2021
0.00 mm
PRECIPITATIONS hour
10:42:13 03/04/2021
0.00 mm/h
PRECIPITATIONS day
10:42:13 03/04/2021
0.00 mm/d
BATTERY Level
10:42:13 03/04/2021
100.00 %
CHOOSE SENSOR
Clear
SOIL T° x
CHOOSE ZONE
Clear
Default zone x
Armando Picchi x
CHOOSE DATE RANGE
2021-03-27 - 2021-04-03
Show
27.0
24.0
21.0
18.0
15.0
12.0
9.0
13:00 15:00 17:00 19:00 21:00 23:00 01:00 03:00 05:00 07:00 09:00 11:00 13:00 15:00 17:00 19:00 21:00 23:00 01:00 03:00 05:00 07:00 09:00
Show Map

2. DATA is good

STORE

understandable timely

affordable RELIABLE share

"junk in / junk out" relevant

useable SPATIAL VARIABILITY

retrieve

VARIABILITY IN TIME EASY

2. DATA is good

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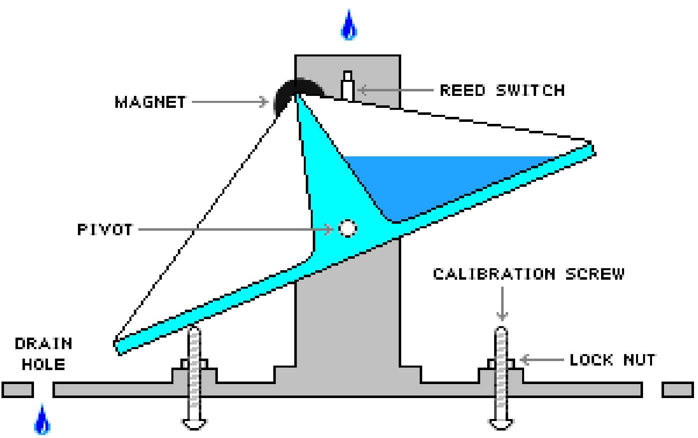
PRECIPITATION



“Tipping bucket”
traditional

“Gold leaf”

Doppler / radar

“Optical”
infrared drop count

“**How much rain**” per time unit: mm/5 min – mm/hour – mm/d

→ is it “useful” rain ?

→ adjust irrigation schedule dose and time

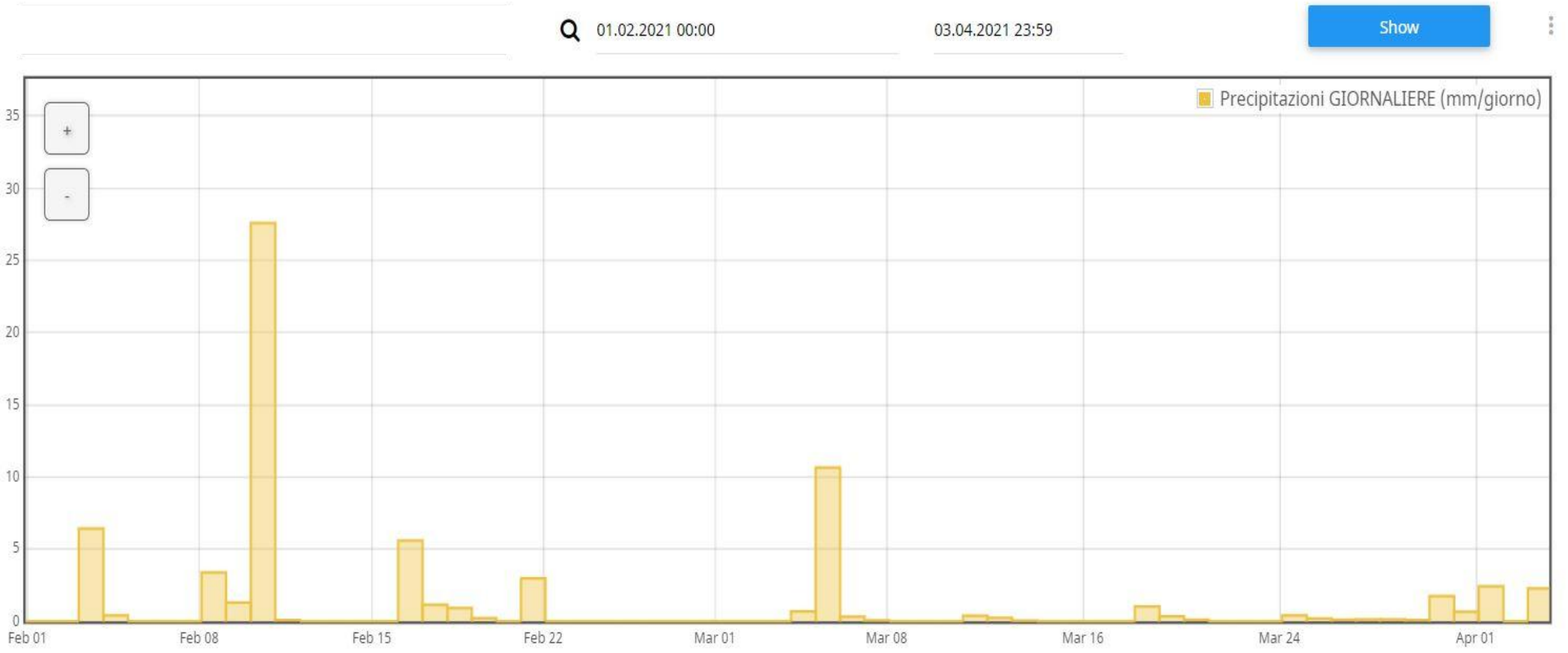
→ is my irrigation system working properly ?

“**What intensity**”: mm/h

→ can my soil store it or will most of it runoff ? (Infiltrometry)

2. DATA is good

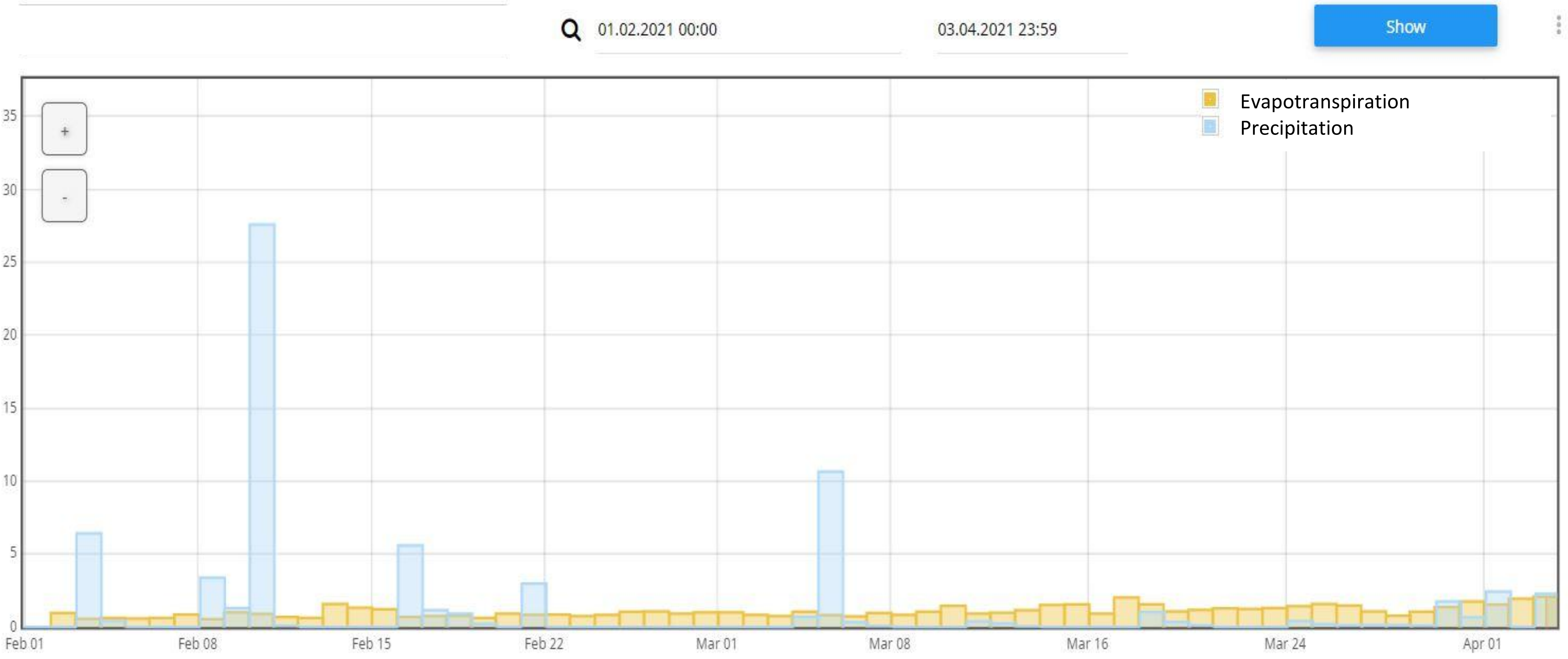
PRECIPITATION



Who cannot use a graph like this in their lives…??

2. DATA is good

PRECIPITATION



Who cannot use a graph like this in their lives…??

2. DATA is good

WIND

Traditional

Ultrasounds
no moving parts

Why spray if the wind is more than 3 m/s ?

NO WIND? Very low ET_0, watch out for fungi…

STRONG WIND? Very high ET_0

turf europe

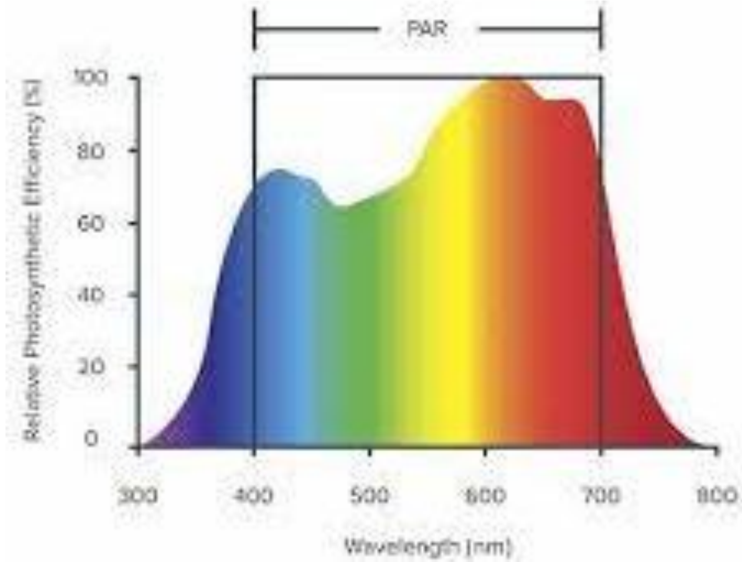
2. DATA is good

ETS

PAR LIGHT

PAR sensor
for integration

PAR sensor
Handheld stand alone



Plants need a minimum daily amount of PAR light to carry out their **metabolism,** measured in **moles/m²/day**.

C3 species: 7-20 moles/m²/day

C4 species: 10[1]-28[2] moles/m²/day

Huge issue in closed-in stadium turfgrass management:

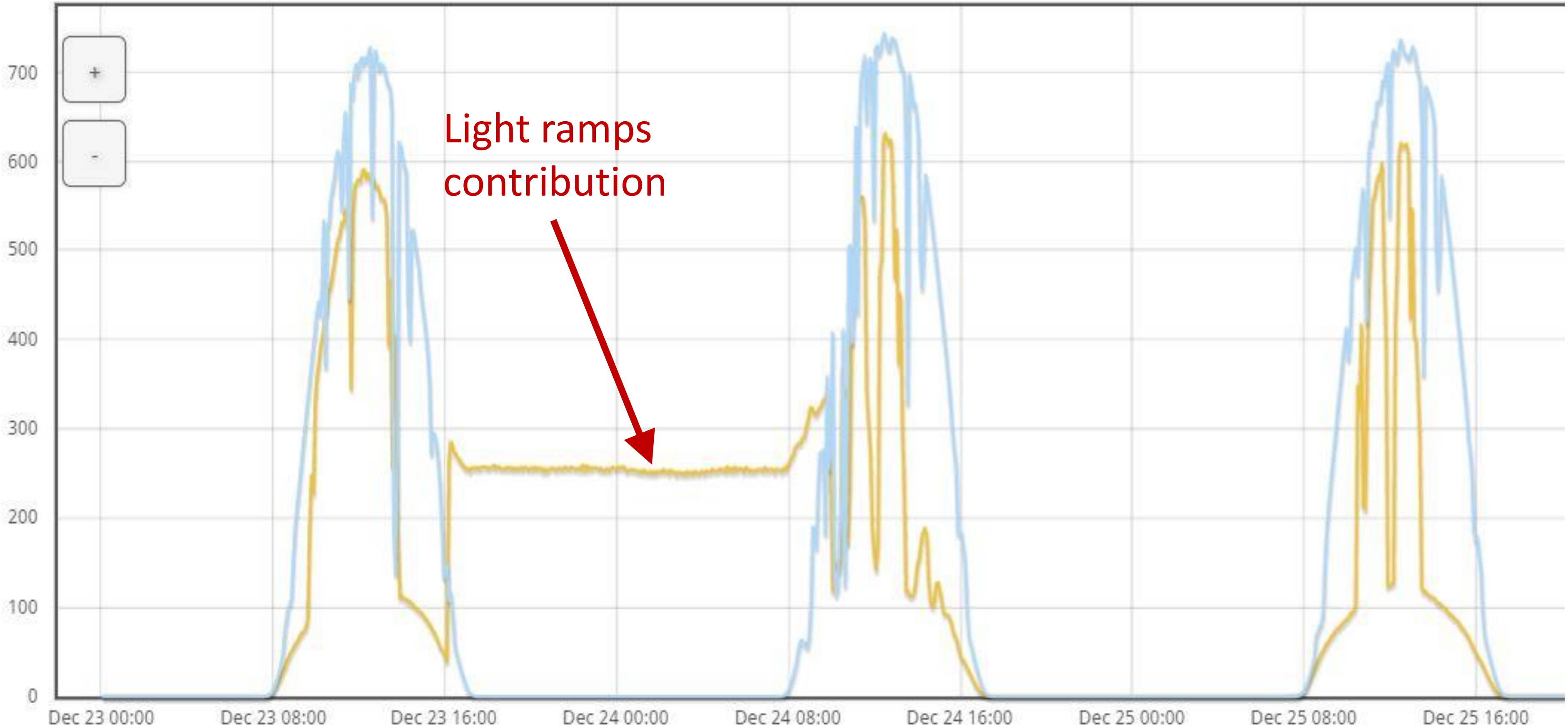
- electricity cost[3]: up to **100+ K €/year**
- CO_2 footprint: 1 kWh = **275 g CO_2**[4]
- moving the ramps

OPTIMIZE ! !

9 ramps on for 1 day = 9 x 60 bulbs x 1 kW x 24 h = **12.960** kWh = **1.620** € = **3,56** t CO_2

2. DATA is good

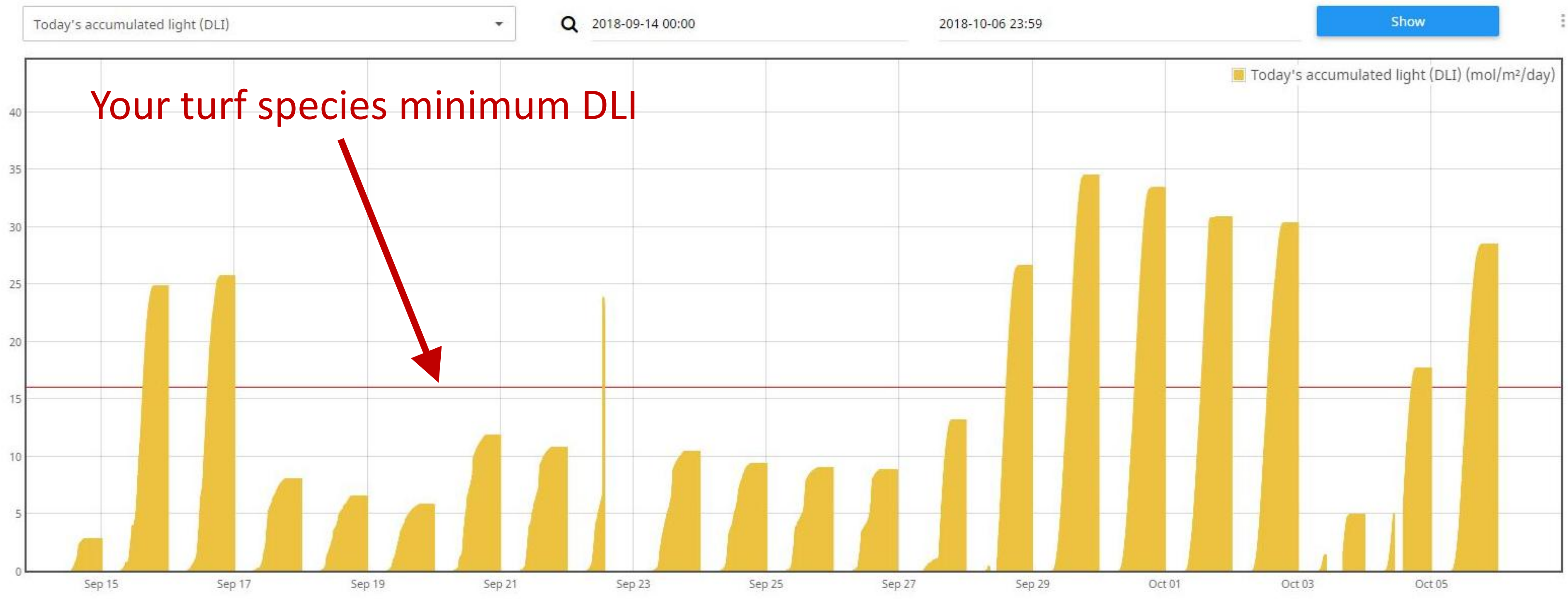
PAR LIGHT



Measuring light ramps contribution

2. DATA is good

PAR LIGHT



Baselining DLI in stadiums, or golf

2. DATA is good

PAR LIGHT

Then what…? A practical example[5]

1. Measure the DLI supplied by direct sunlight: do that by placing a Quantum PAR sensor in the area of the pitch you want to monitor. A couple of days readings should give you a good indication of the DLI.

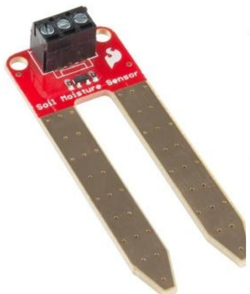
2. Measure the PAR intensity of your lighting rig(s) in the dark (10 minutes will do). Do so in the centre of the rig's layout, under a central bulb (this will give you the maximum intensity). And then apply the following empirical formulae:

PAR 100 mmol/m2/s = 0,36 mol/m^2/h	PAR 150 mmol/m2/s = 0,54 mol/m^2/h
PAR 200 mmol/m2/s = 0,72 mol/m^2/h	PAR 250 mmol/m2/s = 0,90 mol/m^2/h
PAR 300 mmol/m2/s = 1,08 mol/m^2/h	PAR 350 mmol/m2/s = 1,26 mol/m^2/h
PAR 400 mmol/m2/s = 1,44 mol/m^2/h	PAR 450 mmol/m2/s = 1,62 mol/m^2/h

3. For example, you have a DLI of 7 mol/m^2/d **(A)** in a certain given area of the pitch, you are growing perennial ryegrass mowed at 25 mm, which needs a minimum of 16 mol/m^2/d **(B)** and your lighting rig's maximum intensity is 250 mmol/m^2/s, thus supplying 0,9 mol/m^2/h **(C)**. You will need to leave your lighting rigs on for a minimum of **(B - A) / (C) = 10 hours/day**

2. DATA is good

SOIL



On surface (static)
Stand alone

On surface or in soil (static)
For integration

On surface (portable)
With screen

On surface (portable)
With phone app

They measure 3 very important parameters:

- **Soil volumetric water content** (%) → exploit the soil property of **transmitting an electromagnetic impulse in a different way if it contains more or less water**.
- **Soil electric conductivity** (dS/m) → exploit a substance's property of **conducting an electrical current in a different way if it contains more or less salts**.
- **Soil temperature** (°C or °F) → exploit the property of bodies of **entering a mass-wheighted thermal equilibrium if put in contact for long enough.**

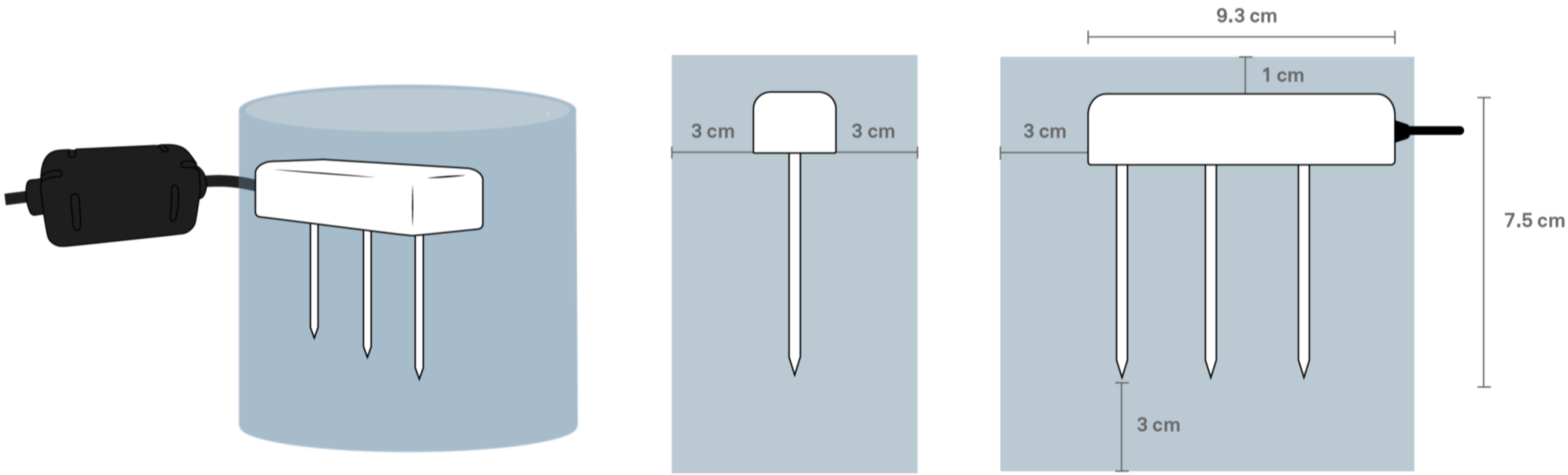
USEFUL ? SURE, but errors and misconceptions are always lurking...

2. DATA is good

SOIL

"Where am I measuring my soil water content? The tip of the spikes, right?"

Nope...! These sensors create a **"virtual cylinder"** of electromagnetic signal influence[6]



So, you're effectively measuring the **average volumetric water content in this "virtual cylinder" that's approximately 8 cm (depth) x 7 cm (radius) = 1.23 L**.

Don't worry, when the probe is planted into the soil (on the surface) **the air suppresses the signal above the probe**. Only if you fully bury it, then it will return the data including the area volume just above the probe.

Don't half bury the probe thinking that you only want to measure the humidity in the very first layer of soil, because then you will be measuring a lot of air and **your reading will be misleadingly low**…

2. DATA is good

SOIL

"Where am I measuring my soil temperature? The tip of the spike, right?"

Nope…! One of the probe's spikes is linked to a thermocouple which is drowned into the probe's plastic head. It works much like a thermometer

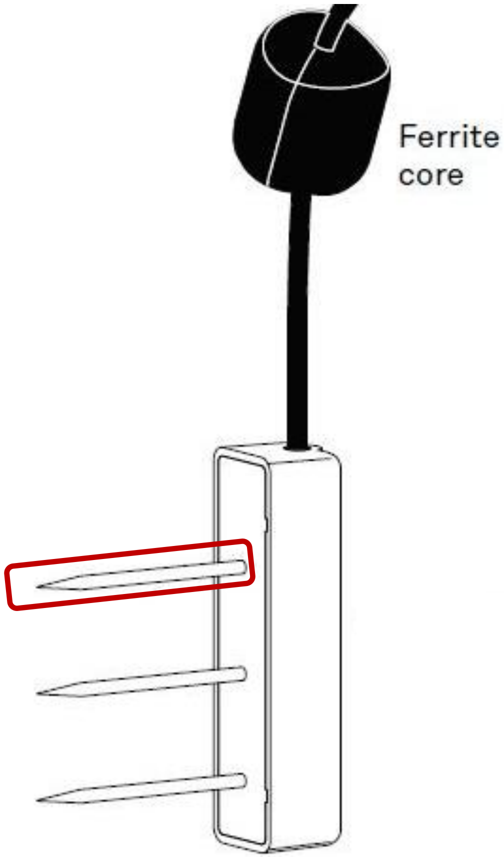
So **(1)** you insert the probe in the soil, **(2)** the steel spike and the soil enter a thermal equilibrium (basically the spike will reach the same temperature as the soil), **(3)** the thermocouple reads and transmits the T° data …

So, again, **you are measuring the average soil T° over the length of the spike.** Not at the tip. This has some interesting and important consequences:

Don't just bury the probe and expect to get a perfect reading after 1 second. **Give the spike time to reach the soil T°**.

If you don't fully bury the spike, you will get a misleading figure. Since air T° will influence the spike's T°…

Many surface probes have a reflective and specially conceived plastic cover to minimize sun heat . However, in the scorching heat of tropical summers, especially in the central hours of the day, **the plastic can overheat and slightly deviate the T° reading with excessively high readouts**. Take this into account.



2. DATA is good

SOIL

"The Dreaded Turkey Oven Thermometer" TM

So you've bought an oven thermometer, or an off-the-shelf water content probe at the local hardware store. Sure enough they will give different readings compared to the expensive professional probes.

Q: WHICH ONES ARE RIGHT ?
A: All of them / None of them
But please, compare apples with apples !

Different acquisition technologies, different influence zones, different sensitivities and ranges, different errors, etc.

The only undisputable test method for soil parameters is the **lab method** ! !
The rest can give a good (sometimes very good) approximation of the true value.
Sensing technology is in a **frenzy**, and we have not seen the ultimate definitive soil sensor yet.

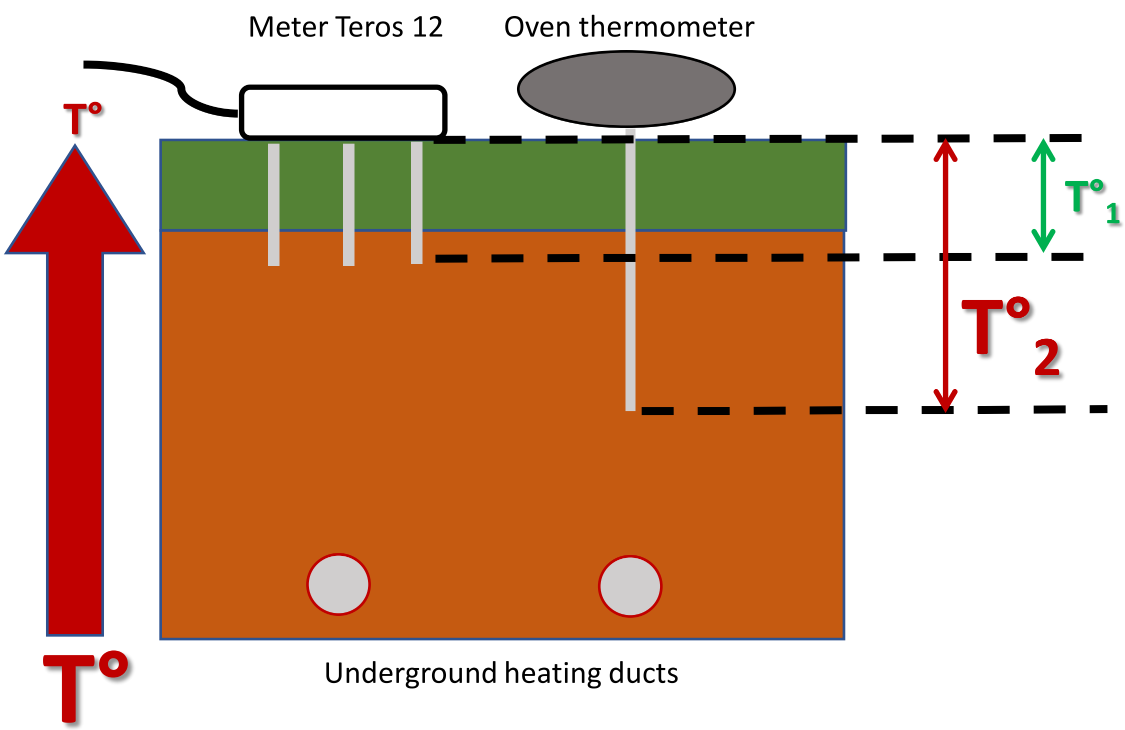
SO CHOSE ONE SENSOR and STICK TO IT !

Do not assume that all sensors should give the same reading...

2. DATA is good

SOIL

"The Dreaded Turkey Oven Thermometer" TM – EXAMPLE



A **head groundsman** of a top football stadium was v.v. unhappy about the data returned by a FDR soil probe because "**it did not reflect correctly the effect of the underground heating system**".
To be more precise, it was "**grossly underestimating soil temperature**"

Who is right?
Who is wrong?
Apples being compared with apples?

2. DATA is good

SOIL

"Is EC all the same ?"

Certainly not ! !

Most probes return something called "**Bulk EC**", just telling you how much salt is present in the substrate. This is why, in normal conditions, you often get an extremely low EC reading from your soil probe (often even zero).

A much more useful reading is "**Pore Water EC**", that is the amount of salt that is effectively dissolved in the water contained in your substrate. In order to do that an equation[7] was developed that takes into account EC, water content and temperature. "Pore Water" readings are available <u>only in some sensors</u>.

It is easy to see how **"Pore Water EC"** is much more relevant to the plants than "Bulk EC". If a given amount of salt is present in the substrate, **the plants will be more or less affected by it if this salt is dissolved in a lot of water or concentrated in very little water**. Temperature enters the equation because salts are more active and better dissolved at higher temperatures.

AGAIN, don't be surprised if you send a sample away to the lab and you get slightly different results from the ones you usually get from your probe…!

2. DATA is good

SOIL

Discover or apply the soil-specific FC and WP soil constants

Field capacity (FC): the amount of soil moisture or water content held in soil after excess water has drained away.

Wilting point (WP): the level of soil moisture at which water becomes unavailable to plants and permanent wilting ensues.

Available Water Content (AWC) = FC – WP

Keep soil moisture between the two lines ! !

2. DATA is good

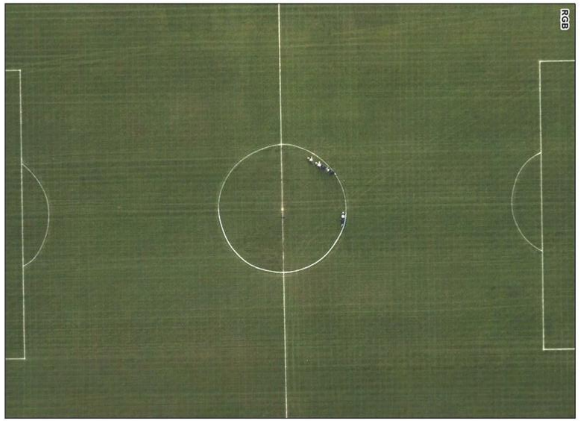
SOIL

Where ? Why ?

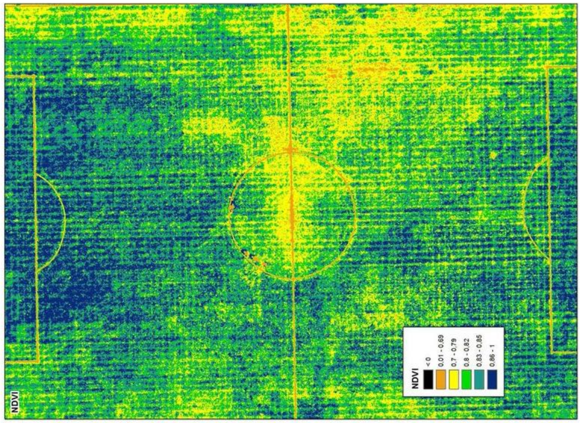
	On soil surface (static or semi-static)	On surface (portable)	Buried in soil (static)
Data variation in time (graph)	YES	Only if you put in the legwork	YES
Data variation in space (map)	Very difficult	YES	NO
Data transfer protocol	**GSM +++** **Radio ++** **Wi-Fi ++** **LoRa ++** **ZigBee ++**	**Not needed, or through phone app.**	**GSM ++** **Radio ++** **ZigBee +**
Preferred applications	Sports fields (semi-static) Private gardens	All	Sports fields Golf Parks and gardens
What depth?	Vertical influence cylinder 6-9 cm deep	Vertical influence cylinder 6-9 cm deep	You chose the depth
How many	Not too many (2-3) you have to move them...	1	As many as you like

2. DATA is good

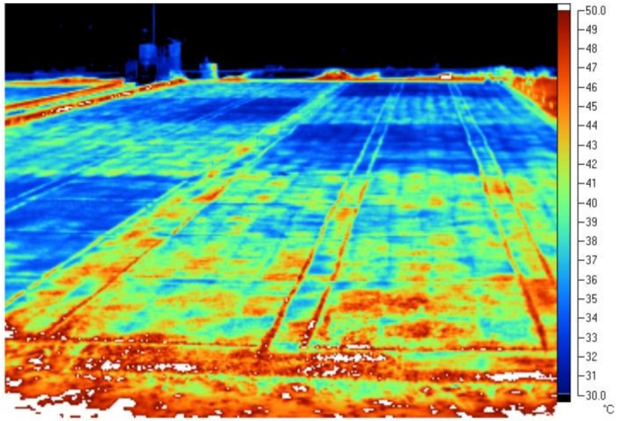
IMAGERY



RGB[8]



Multispectral (NDVI)[8]



Thermal IR[9]

A truly wonderful tool for Precision Turfgrass Management

RGB → general aerial monitoring

NDVI → general plant health

IR → water status

SOME CAVEATS ! !

2. DATA is good

IMAGERY

Satellite imagery will be extremely useful for turf.
One day...

“Refresh time” is in the weeks, not days.

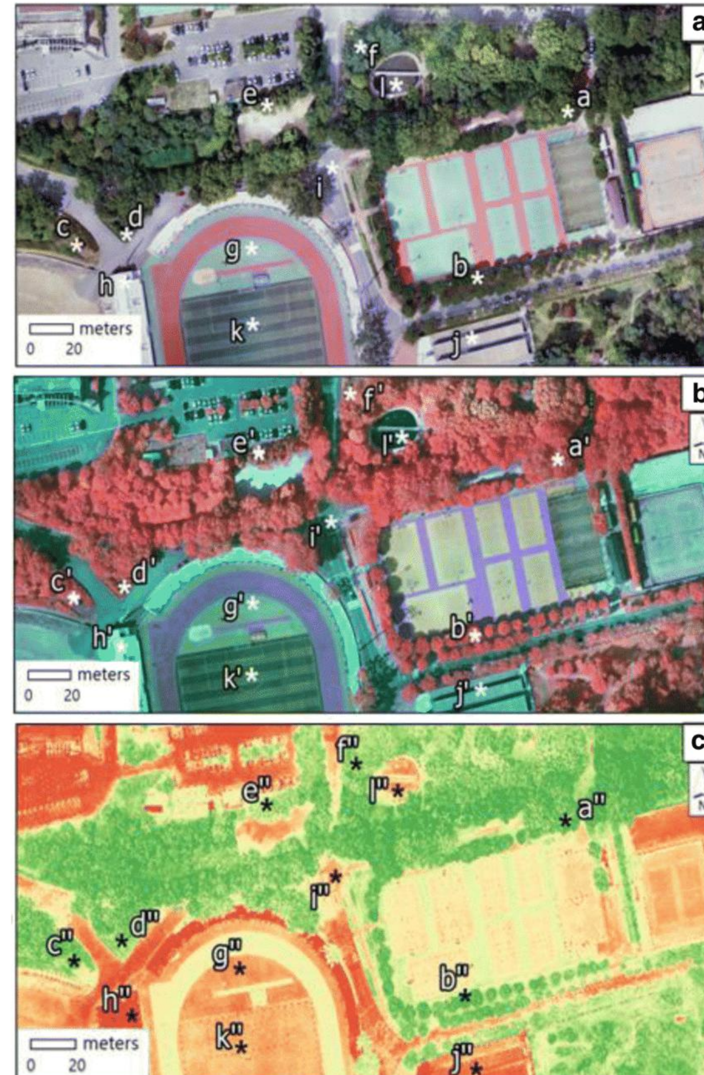
“On demand” images are astronomically expensive.

MS pixel size still too big for turf applications (>10 m).
Thermal pixel size still too big for turf applications (≈90 m).
Some exceptions (ie. WorldView-2, Aster, Sentinel-2)[10]

Soon (2-5 y) we will have **free, hi-res, frequently refreshed** satellite images in MS / IR in the sub 5 m pixel.

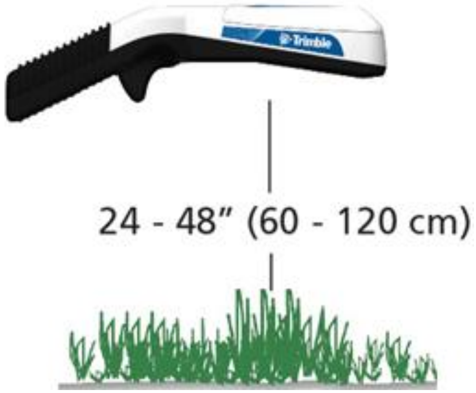
Until then **you cannot beat drone** (or fixed cameras) for :

- pixel resolution (as low as 5 cm)
- scheduling flexibility (if you have your own)
- cost (compared to paid satellite)

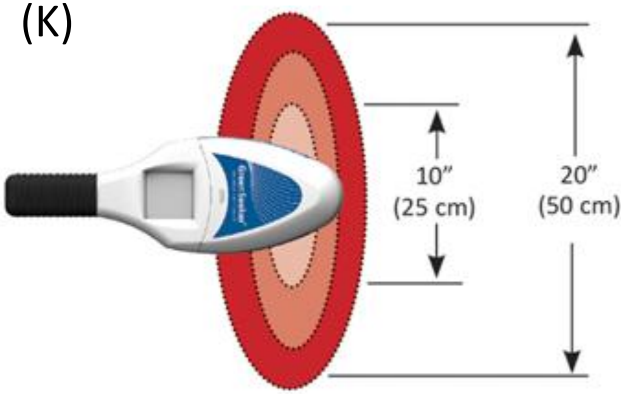


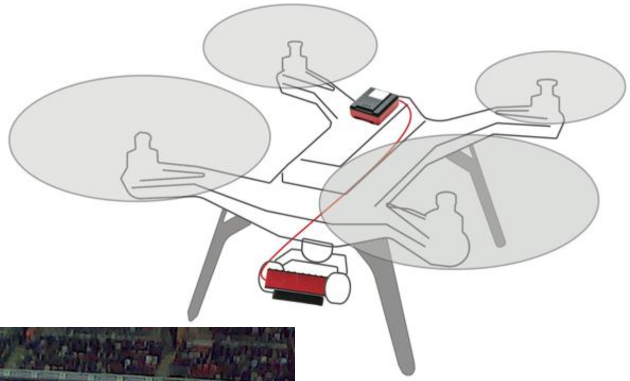
2. DATA is good

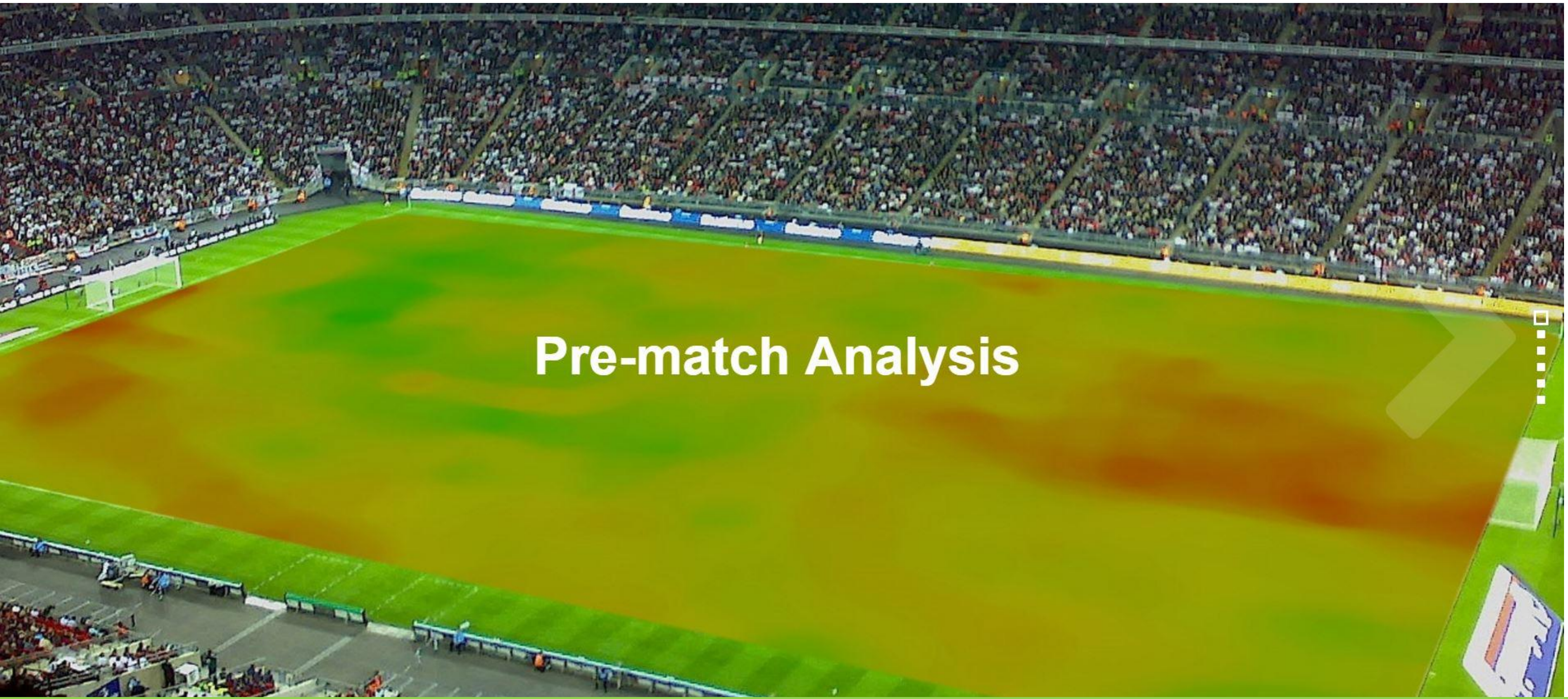
IMAGERY



(K)







turf europe

2. DATA is good

ETS

IMAGERY

NDVI is like a doctor asking you how you are

NDVI is linked to all and any of these:

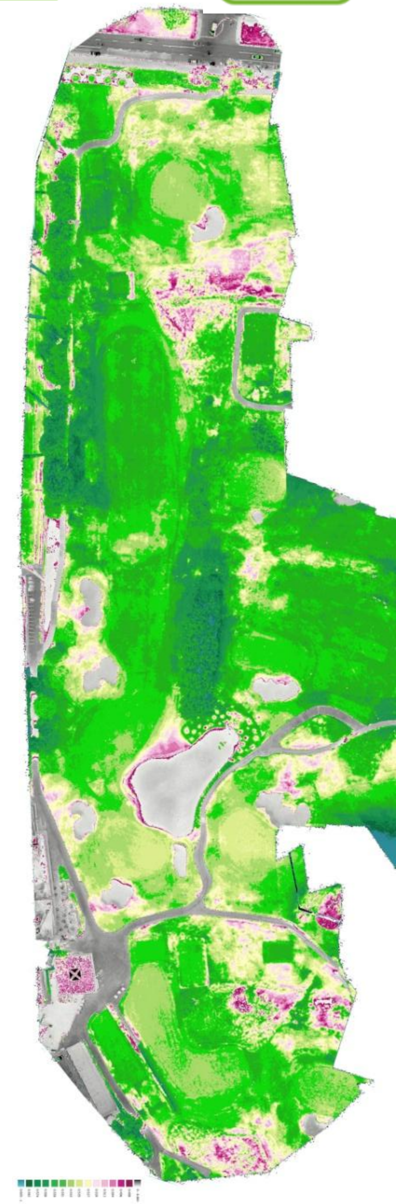
- density
- cover
- N nutrition
- water status
- color

So to have a **high NDVI** value (>80) turf must be OK for all of the above.
At the same time, if **NDVI is low** (<65) one or more of these must be not OK.
But you don't exactly know which one(s), at least from the picture.

"Hi turf, how are you?"

- Never been better (>90)
- Fine ! ! (80-90)
- Good (70-80)
- I'm OK (60-70)
- Meh… (<60)

OK, but why..?

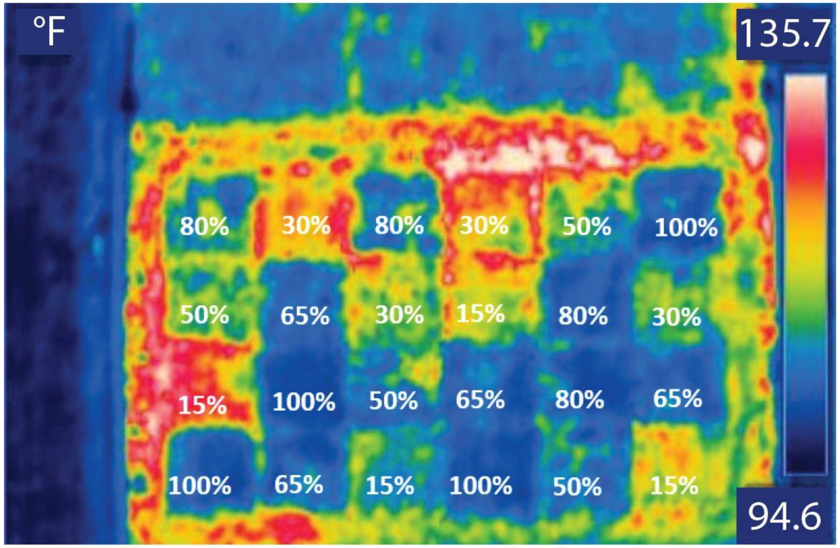


2. DATA is good

IMAGERY

Thermal Imaging Detects Early Drought Stress in Turfgrass[11]

Water needs to be preserved and turf is closely targeted[12] in water saving.
Mainly golf courses and residential turfed areas are in the spotlight.



…and it can spot pests too ! !

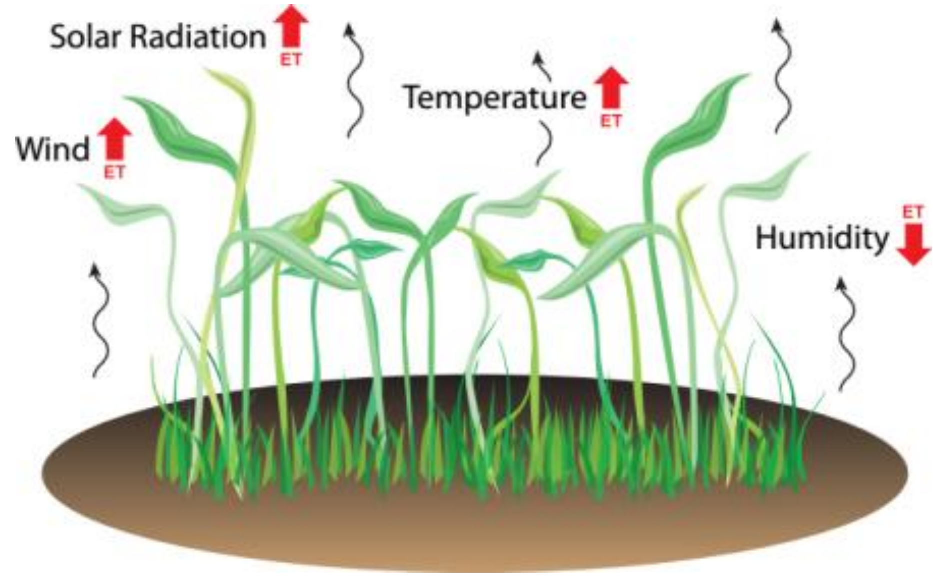
Thermal IR imagery allows you to spot which areas suffer from water stress (they heat up sooner than the others) well before they are visually discernible. This allows for:

- **differential irrigation**
- **investigate the causes and look for solutions**
- **save water !**

2. DATA is good

EVAPOTRANSPIRATION

"The amount of **water lost** by a canopy through the sum of evaporation (soil) and transpiration (plant stomata)"



Five variable inputs needed to carry out the calculation of ET_0 through **Penman-Monteith**[13]:

- Air T°
- Air humidity
- Air pressure
- Wind speed
- Solar radiation

Most weather stations have the sensors needed to accurately calculate ET_0 evapotranspiration.

EVAPOTRANSPIRATION CAN (should) BE USED to SCHEDULE and DOSE IRRIGATION ! !

But first a few things to point out...

2. DATA is good

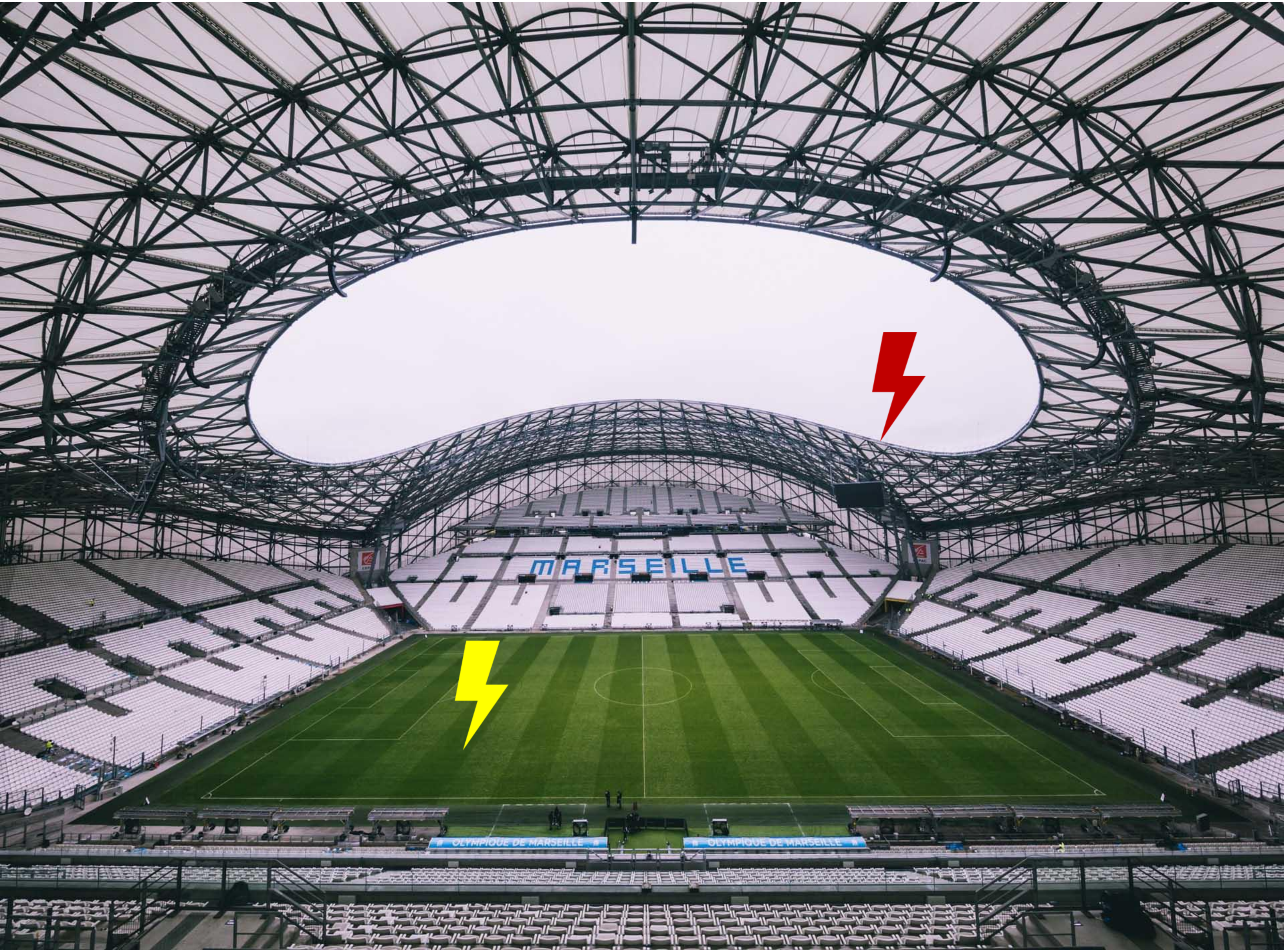
EVAPOTRANSPIRATION

Weather stations usually calculate "**potential**" evapotranspiration (ET_0), for a more accurate datum, this should be converted to "**effective**" (ET_C) according to **$ET_C = ET_0 \times Kc$**

Kc = crop coefficient that changes for each crop
Historically accepted turfgrass Kc
C3 = 0.8 **C4** = 0.6
Furthermore, Kc is actually **a value that changes throughout the year**...!

Therefore, do schedule and dose your irrigation using the ET_0 data generated by your weather station, knowing that:

1. If you take into account the ET_0 at face value you are probably over-irrigating
2. If you correct by a turfgrass Kc crop coefficient, do remember that this is slightly lower in winter and slightly higher in summer
3. Mind where your data is acquired and how...! !


MARSEILLE
OLYMPIQUE DE MARSEILLE
OLYMPIQUE DE MARSEILLE


? ?
HYUNDAI
nice-matin
Allianz Assurance
06
MÉTROPOLE NICE CÔTE D'AZUR
Allianz Famille

2. DATA is good

EVAPOTRANSPIRATION

A car-like use of data to schedule irrigation

- Species-specific average root depth (i.e. ryegrass rooted at **5 cm**)
- Total “fuel tank” = 1 m x 1 m x 0,05 m = 0,05 m3 = 50 L = **50 mm**
- Current soil WC = **18%** and soil wilting point (WP) (i.e. amended sand WP = **4%**)
- Total available “fuel” = 50 mm x (18% - 4%) = **7 mm**
- Current “fuel consumption” (ET_0) = **7 mm/day**
- Range = available fuel ÷ fuel consumption = 7 mm ÷ 7 mm/day = **1 day**

X

÷

=

Fuel tank =
Root depth (mm)
AWC (%)

Fuel gauge =
Soil WC sensors (%)

Fuel consumption =
Evapotranspiration (mm/d)

Range =
in days

turf europe

2. DATA is good

ETS

SOFTWARE

Annotation / Planning / Management

controlgreen®
THE GREENKEEPER ASSISTANT

Turfpal

turfhop

ONLINK

TurfKeeper.com
Measure Better, Manage Better

GREENKEEPER

TURF ASSISTANT

GRASPRO
– Pitch Management System

igK
Agronomy for sport

2. DATA is good

SOFTWARE

SELECT SUBSCRIPTION: OGC Plaine Nord

SELECT ZONE: OGC Plaine Nord

Activity log +

SELECT INVENTORY TYPE: Fertilizers

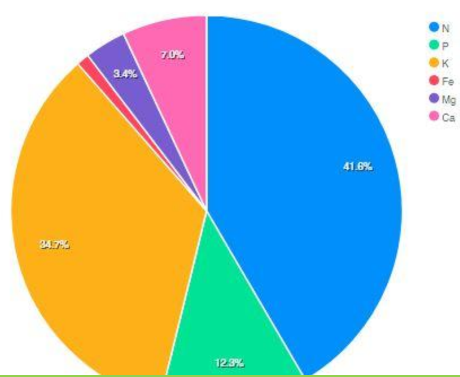
CHOOSE DATE RANGE: 2020-08-16 - 2020-10-15

Show

Search:

	Date	Name	Surface (m²)	Dose (kg - L)	N (kg)	P (kg)	K (kg)	Fe (kg)	Mg (kg)	Ca (kg)	Cost €		Notes	
●	2020-08-17	Sportsmaster CRF Mini Stress C...	8000.0	200.0	20.0	10.0	42.0	0.0	4.0	8.0	NaN	/	/	
●	2020-08-24	Greenmaster Liquid High K	8000.0	30.0	0.9	0.9	3.0	0.0	0.0	0.0	NaN	/	/	
●	2020-09-07	Super Turf	8000.0	200.0	50.0	10.0	10.0	1.8	0.0	0.0	NaN	/	/	
●	2020-09-14	Sportsmaster Base Cal K Mag	8000.0	30.0	0.0	0.0	4.2	0.0	1.8	3.9	NaN	/	/	
●	2020-09-28	Sierrablen Plus Active	8000.0	250.0	47.5	12.5	45.0	0.0	5.0	0.0	NaN	/	/	
●	2020-10-05	Greenmaster Liquid Effect Iron...	8000.0	20.0	0.0	0.0	0.0	1.3	0.0	0.0	NaN	/	/	
				Total	70.9	20.9	59.2	1.8	5.8	11.9	0.0			
				Total(kg/ha)	88.6	26.1	74.0	2.3	7.2	14.9				

Showing 1 to 6 of 6 entries



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THE GREENKEEPER ASSISTANT

turf europe

2. DATA is good

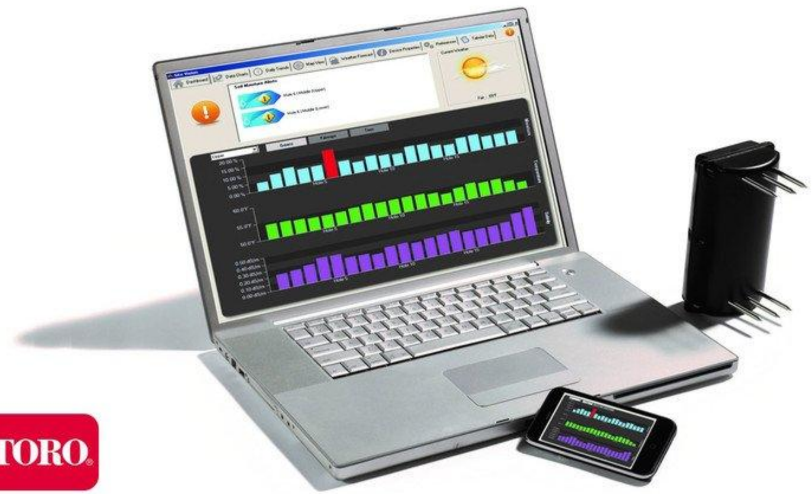
ETS

SOFTWARE

Monitoring

greengo®
YOUR TURFCARE UNIT

SGL for the love of grass



TORO

DAVIS®
Davis Instruments

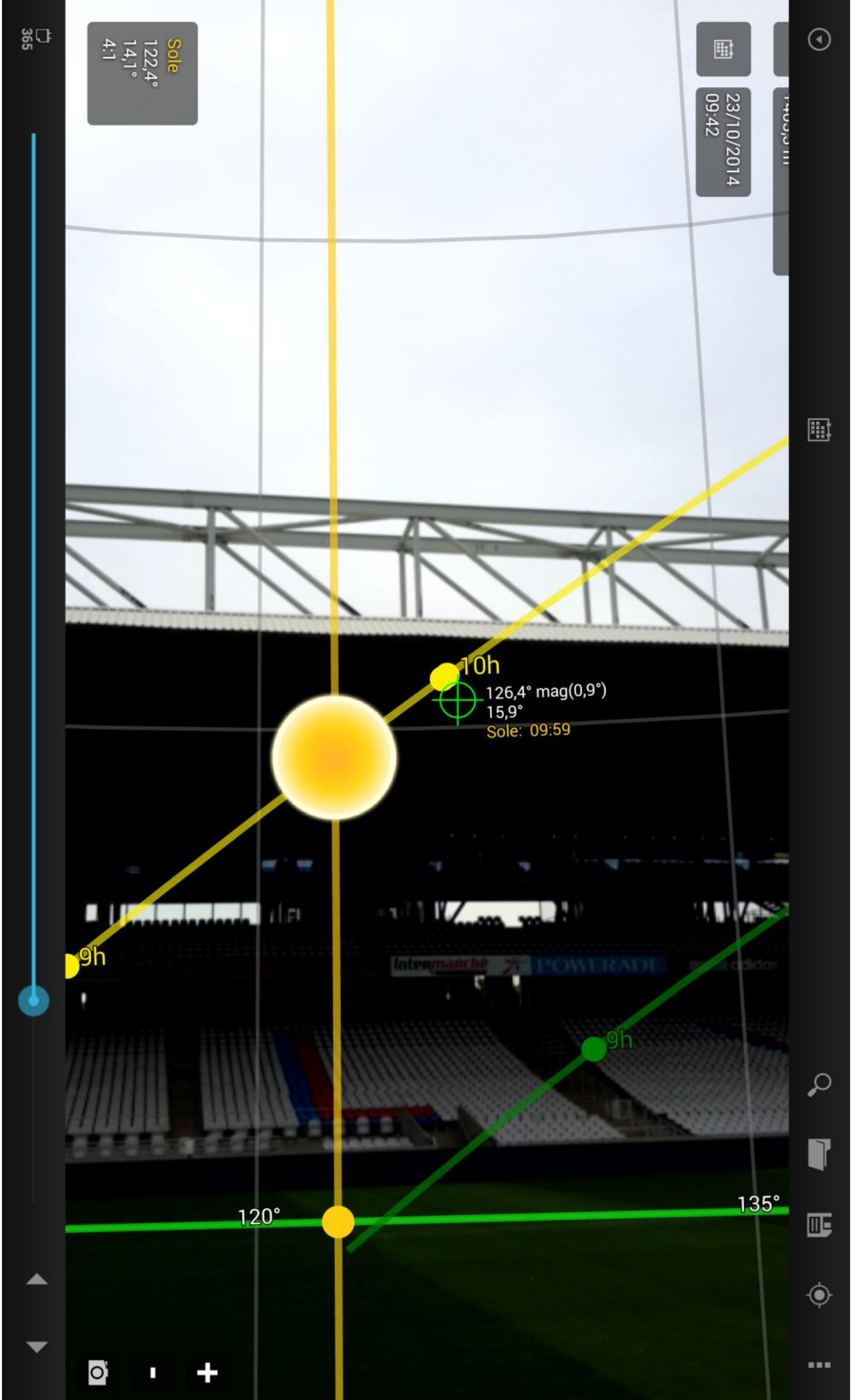
METER ENVIRONMENT

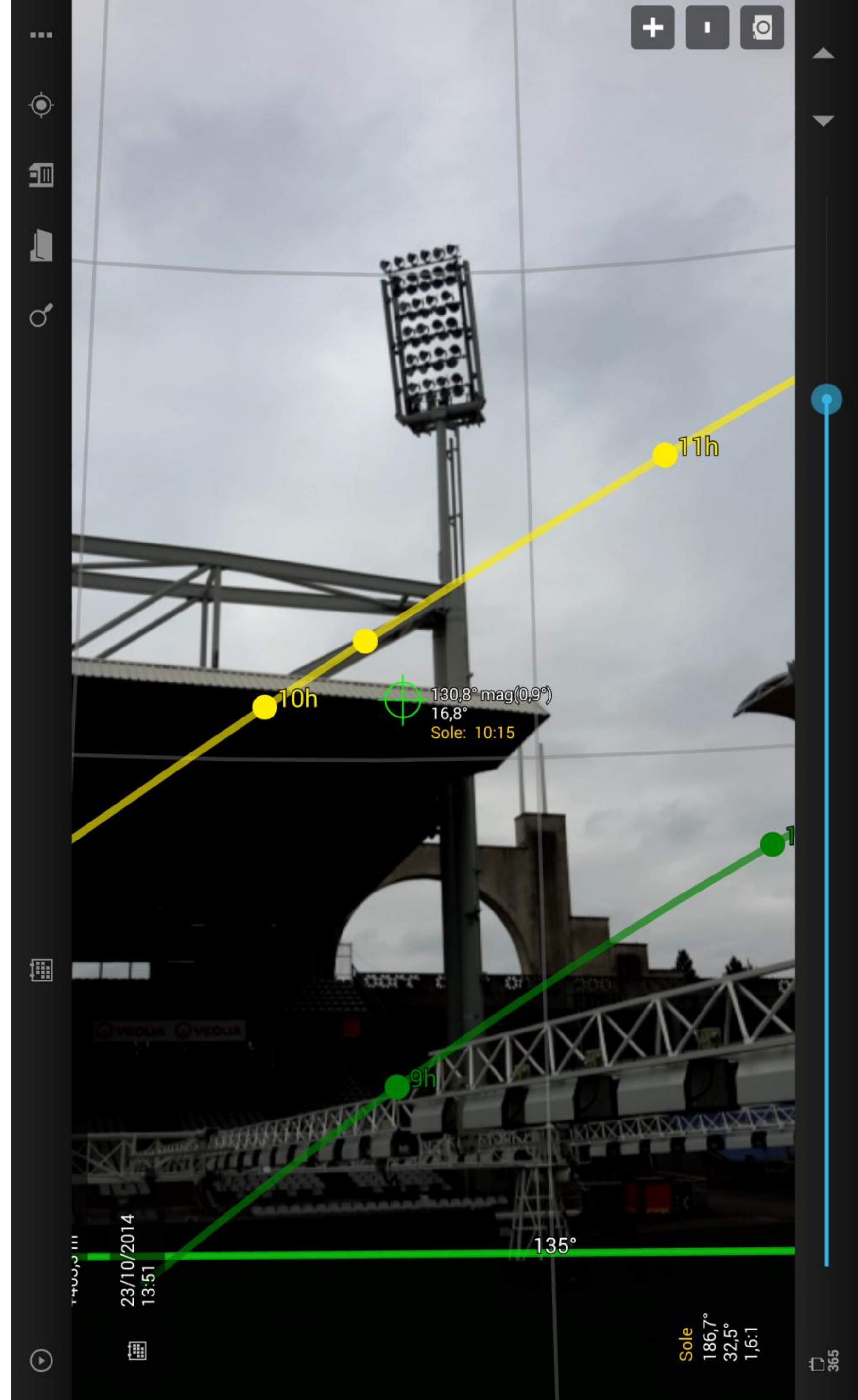
2. DATA is good

SOFTWARE

Monitoring

Sun Surveyor


Sole
122,4°
14,1°
4:1
23/10/2014
09:42
10h
126,4° mag(0,9°)
15,9°
Sole: 09:59
9h
9h
120°
135°
365


11h
10h
130,8° mag(0,9°)
16,8°
Sole: 10:15
9h
135°
23/10/2014
13:51
Sole
186,7°
32,5°
1,6:1
365

3. ROI is clear

THIS IS PROBABLY THE MOST SENSITIVE QUESTION REGARDING “PTM” ADOPTION

In **agriculture** ROI is <u>very</u> clear:

- Quality increases
- Yields increase
- Costs decrease

  } **My turnover and benefit increase !**

- Environmental impact decreases
- Food safety increases
- “Public image” improves

In **turfgrass** ROI is <u>not as clear</u>:

- Quality increases: yes, but this is not demonstrably linked to revenue increase…
- Yields increase: not applicable
- Costs decrease: yes, but enough to justify ?
- My environmental impact decreases: do I care?
- Surface safety increases for users: do they care?
- “Public image” improves: who cares?

3. ROI is clear

STEPS for FUTURE WIDESPREAD "PTM" ADOPTION

1. The governmental "**top down**" approach (this has worked before)
    - Mandatory minimum PTM equipment (i.e. rain irrigation on/off sensors)
    - Tax breaks for PTM equipment acquisition
2. Sports Governing Bodies "**top down**"
    - Accreditation
    - Certification (i.e. Golf Environment Organization[14])
    - Communication
3. Quantifying and accounting intangible **PTM-related benefits**
    - Ecosystem services / Environmental savings / Social benefits
    - Enter these in the corporate/regional/national balance sheet?[15]
4. Increase **know-how**
    - University courses
    - Greenkeeping schools

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Precision Turfgrass Management

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THANK YOU !