Німецько-український фаховий діалог
DUALOG
зі сталого розвитку плодоовочевого сектору

German-Ukrainian Expert Dialogue on the Sustainable Development of the Fruit and Vegetable Sector

Gefördert durch:
Bundesministerium für Landwirtschaft, Ernährung und Heimat
aufgrund eines Beschlusses des Deutschen Bundestages

Educational modules
DUALOG
- Powerpoint -

MODUL OB04

Irrigation in fruit growing

Calculation of water requirements. Fertigation for apple trees

Author: Marcel de Jong, 2026

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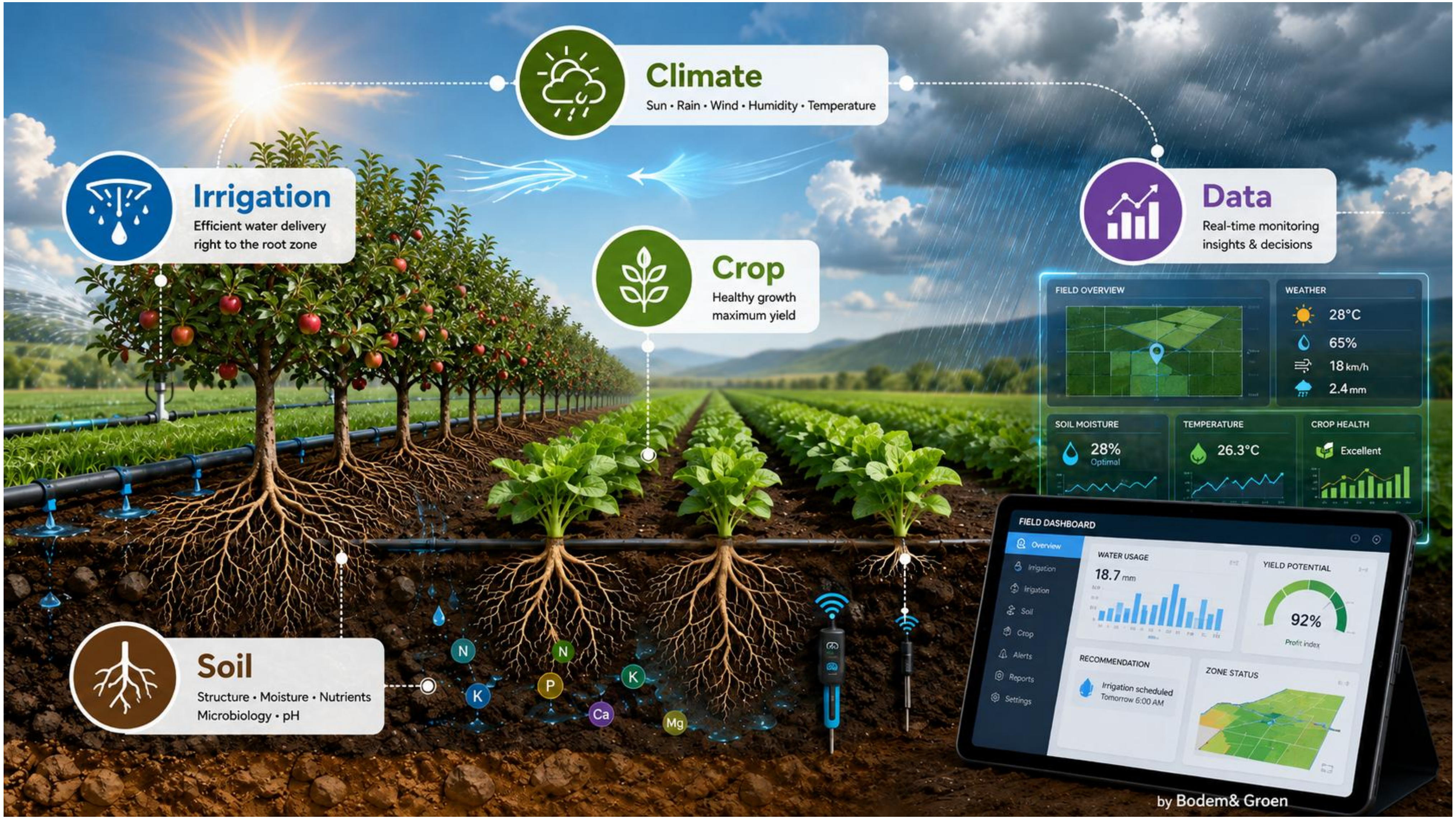
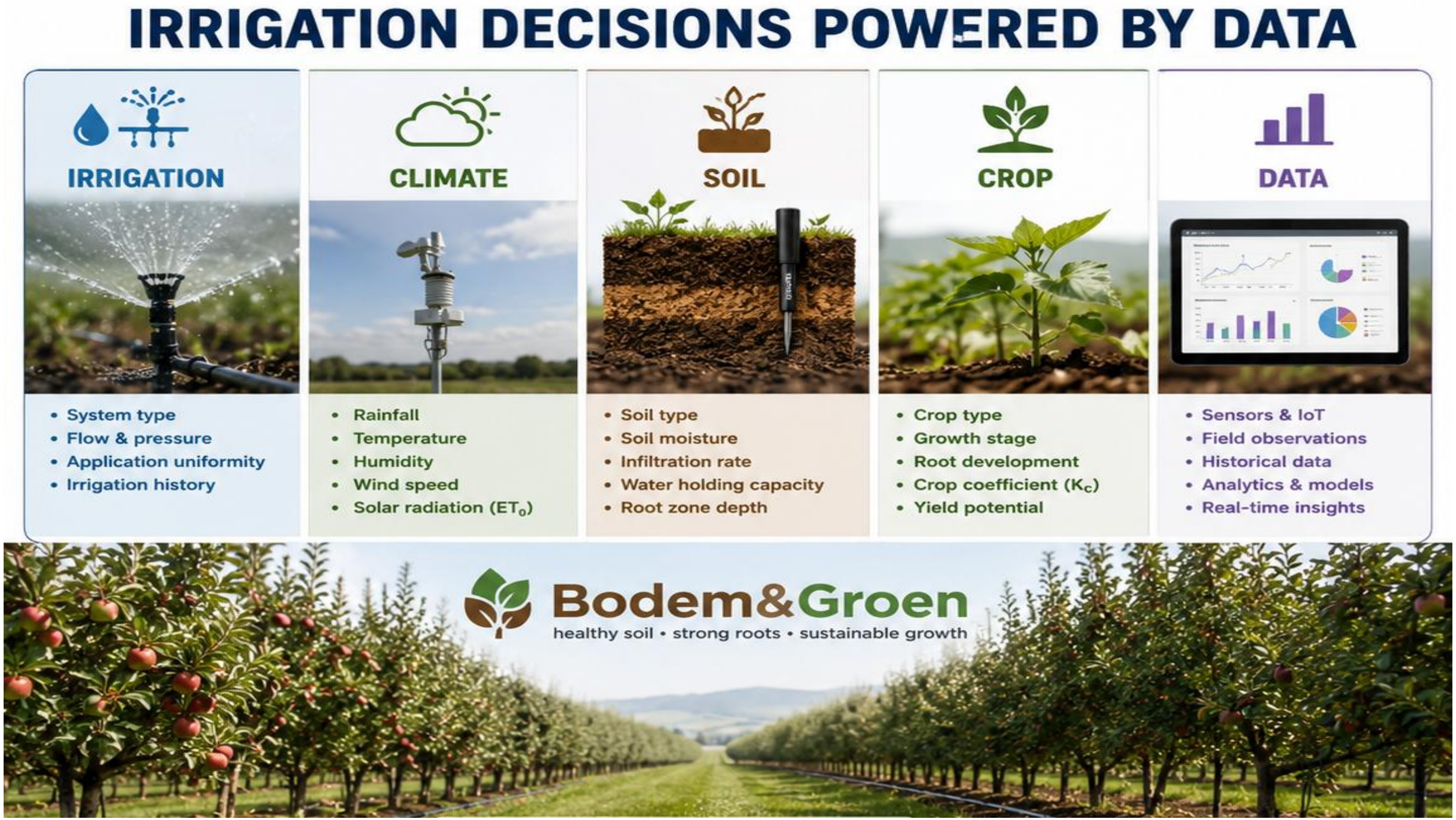
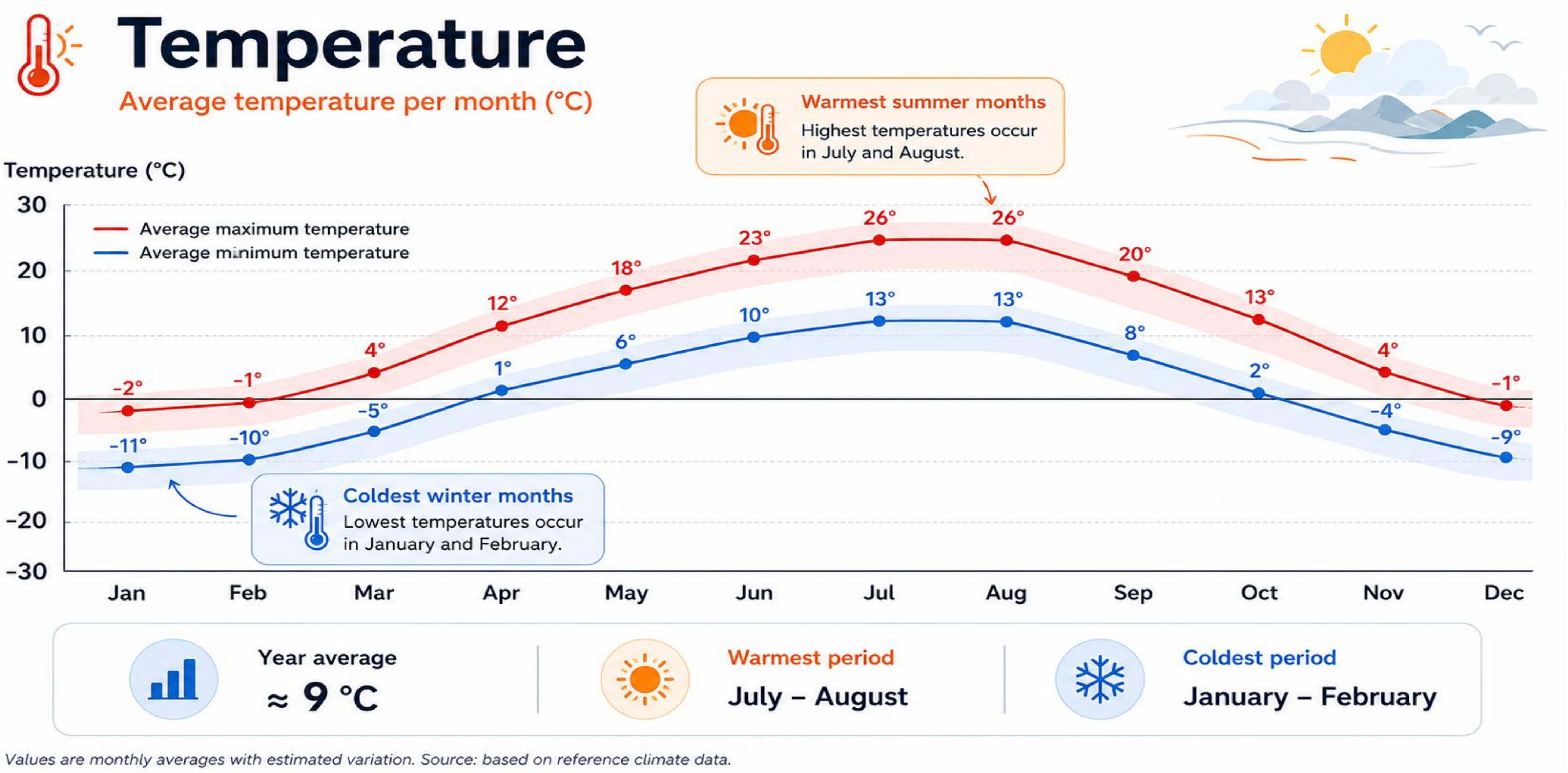
Content

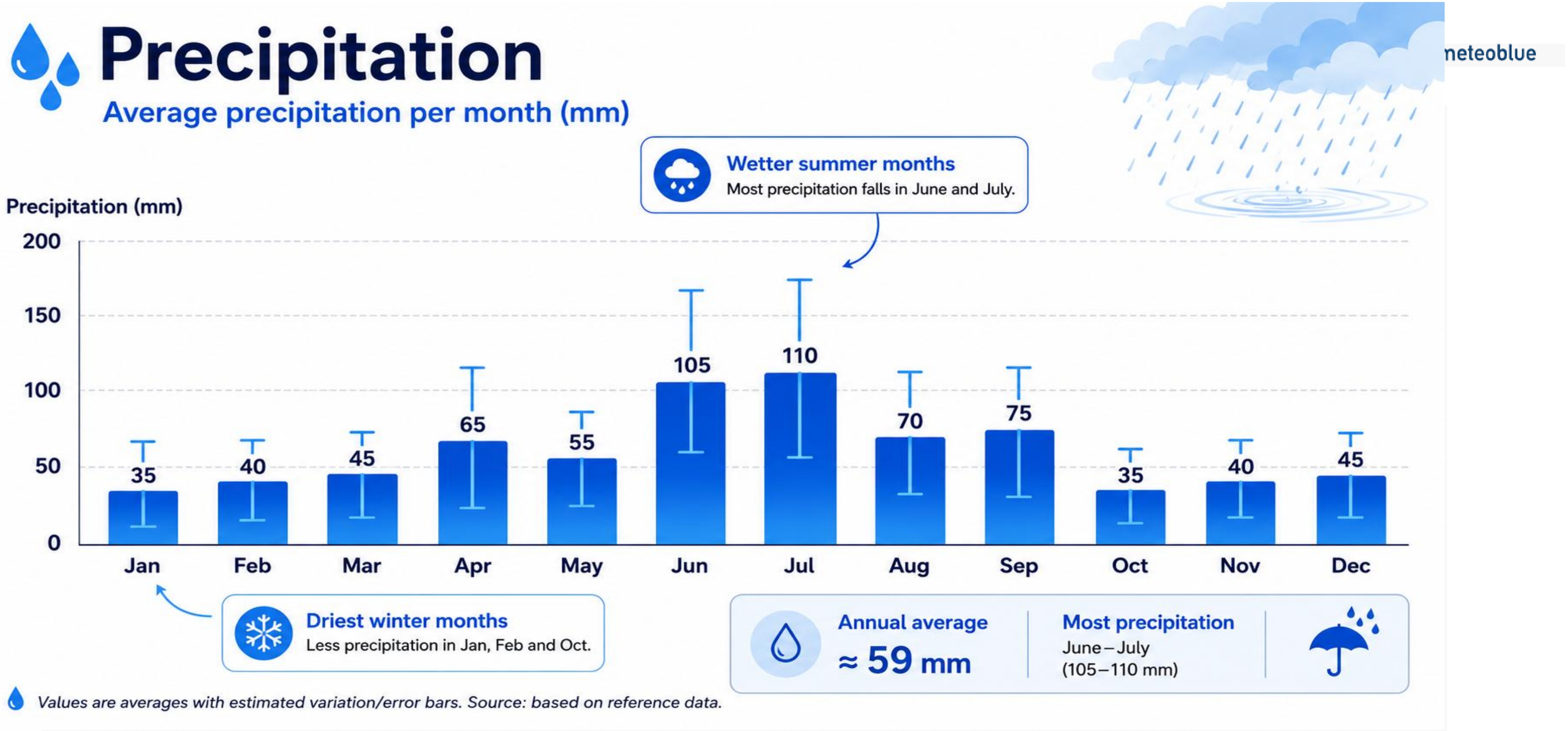

Climate
Sun • Rain • Wind • Humidity • Temperature
Irrigation
Efficient water delivery right to the root zone
Crop
Healthy growth maximum yield
Data
Real-time monitoring insights & decisions
FIELD OVERVIEW
WEATHER
28°C
65%
18 km/h
2.4 mm
SOIL MOISTURE
28%
Optimal
TEMPERATURE
26.3°C
CROP HEALTH
Excellent
FIELD DASHBOARD
Overview
Irrigation
Soil
Crop
Alerts
Reports
Settings
WATER USAGE
18.7 mm
YIELD POTENTIAL
92%
Profit index
RECOMMENDATION
Irrigation scheduled Tomorrow 6:00 AM
ZONE STATUS
Soil
Structure • Moisture • Nutrients
Microbiology • pH
N
K
P
Ca
Mg
by Bodem& Groen


IRRIGATION DECISIONS POWERED BY DATA
IRRIGATION
System type
Flow & pressure
Application uniformity
Irrigation history
CLIMATE
Rainfall
Temperature
Humidity
Wind speed
Solar radiation (ET0)
SOIL
Soil type
Soil moisture
Infiltration rate
Water holding capacity
Root zone depth
CROP
Crop type
Growth stage
Root development
Crop coefficient (Kc)
Yield potential
DATA
Sensors & IoT
Field observations
Historical data
Analytics & models
Real-time insights
Bodem&Groen
healthy soil • strong roots • sustainable growth

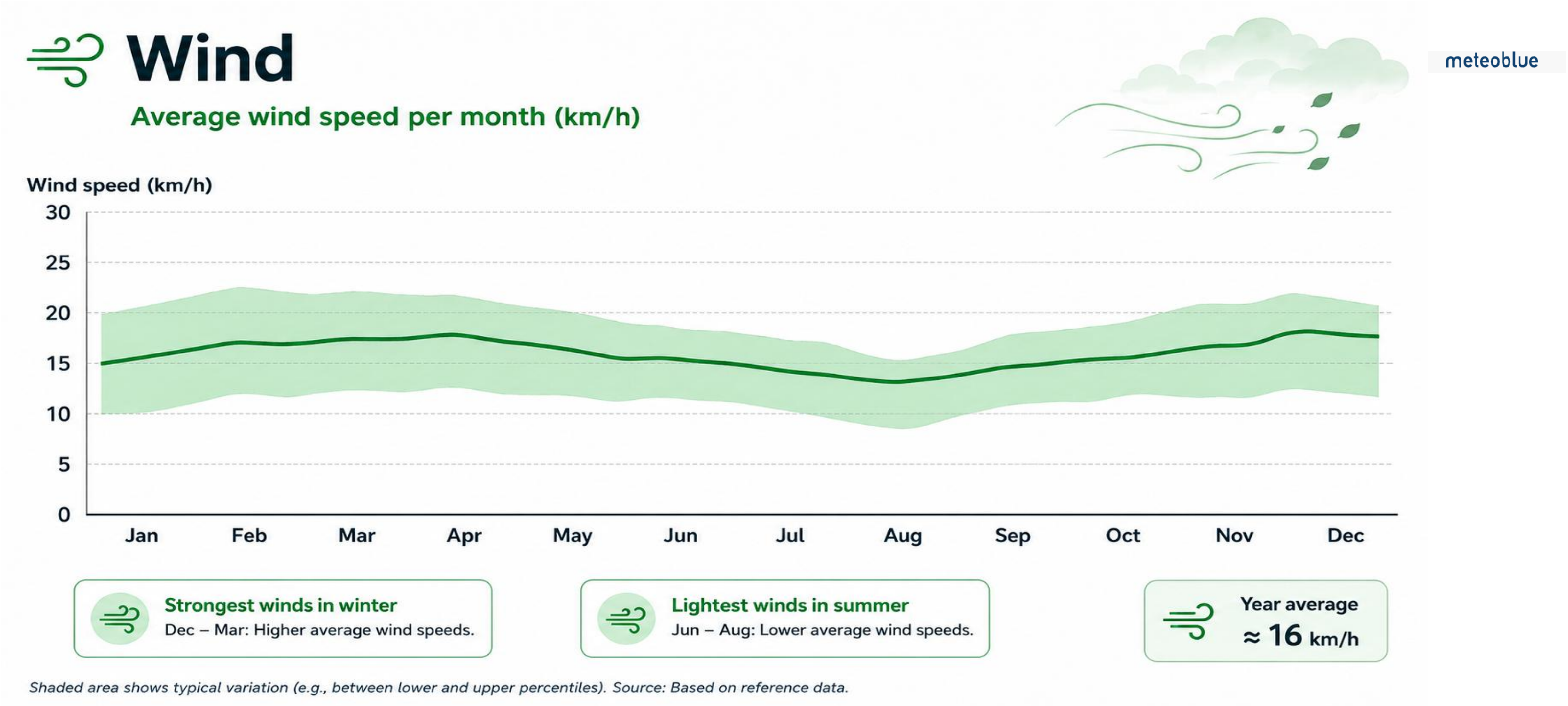
CLIMATE

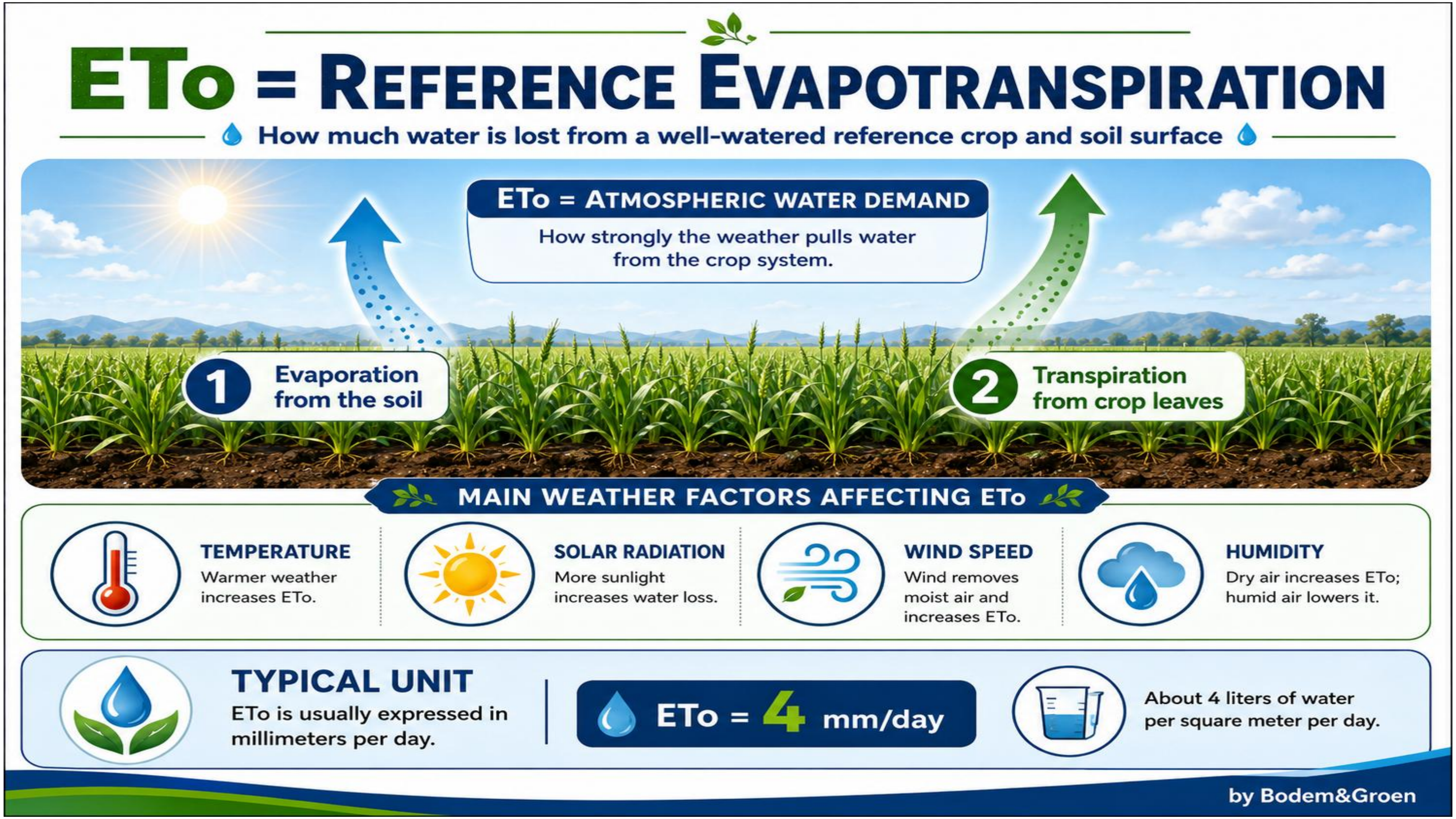

Temperature
Average temperature per month (°C)
Warmest summer months
Highest temperatures occur in July and August.
Temperature (°C)
30
20
10
0
-10
-20
-30
Average maximum temperature
Average minimum temperature
-2°
-1°
4°
12°
18°
23°
26°
26°
20°
13°
4°
-1°
-11°
-10°
-5°
1°
6°
10°
13°
13°
8°
2°
-4°
-9°
Coldest winter months
Lowest temperatures occur in January and February.
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Year average
≈ 9 °C
Warmest period
July – August
Coldest period
January – February
Values are monthly averages with estimated variation. Source: based on reference climate data.

CLIMATE


Precipitation
Average precipitation per month (mm)
meteoblue
Wetter summer months
Most precipitation falls in June and July.
Precipitation (mm)
200
150
100
50
0
35
40
45
65
55
105
110
70
75
35
40
45
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Driest winter months
Less precipitation in Jan, Feb and Oct.
Annual average
≈ 59 mm
Most precipitation
June – July
(105 – 110 mm)
Values are averages with estimated variation/error bars. Source: based on reference data.

CLIMATE

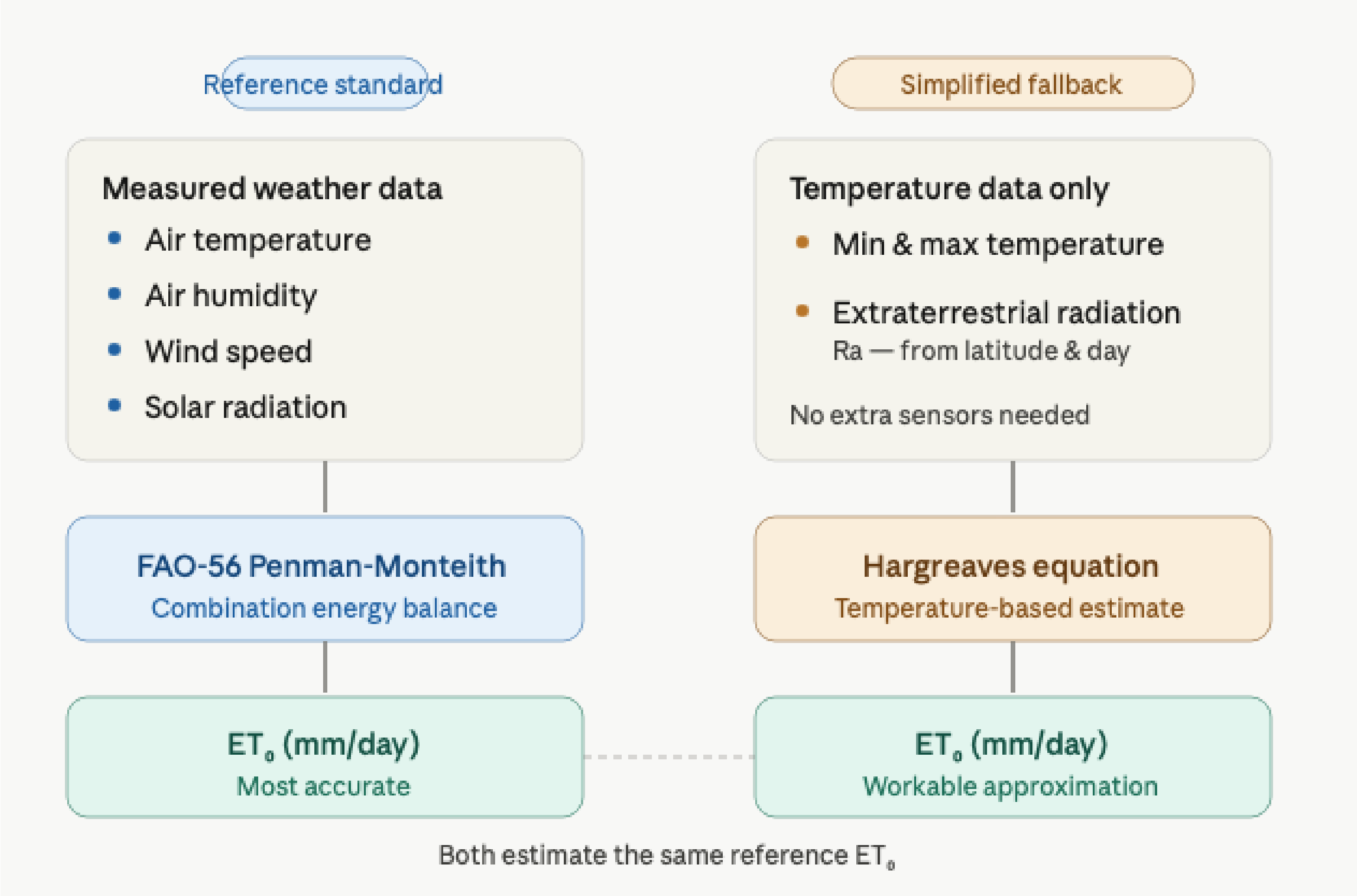

Wind
Average wind speed per month (km/h)
meteoblue
Wind speed (km/h)
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Strongest winds in winter
Dec – Mar: Higher average wind speeds.
Lightest winds in summer
Jun – Aug: Lower average wind speeds.
Year average
≈ 16 km/h
Shaded area shows typical variation (e.g., between lower and upper percentiles). Source: Based on reference data.


ETo = Reference Evapotranspiration
How much water is lost from a well-watered reference crop and soil surface
ETo = Atmospheric water demand
How strongly the weather pulls water from the crop system.
1 Evaporation from the soil
2 Transpiration from crop leaves
MAIN WEATHER FACTORS AFFECTING ETo
TEMPERATURE
Warmer weather increases ETo.
SOLAR RADIATION
More sunlight increases water loss.
WIND SPEED
Wind removes moist air and increases ETo.
HUMIDITY
Dry air increases ETo; humid air lowers it.
TYPICAL UNIT
ETo is usually expressed in millimeters per day.
ETo = 4 mm/day
About 4 liters of water per square meter per day.
by Bodem&Groen

CLIMATE

ETo from daily air temperature, humidity, wind speed, and solar radiation.

ET_0 is the climate-driven "demand" side of the irrigation equation, and how you calculate it depends on what your weather station actually measures.



CLIMATE

ETo from daily air temperature, humidity, wind speed, and solar radiation.

FAO-56 Penman-Monteith

$$ET_0 = [0.408 \cdot \Delta \cdot R_n + \gamma \cdot (900/(T+273)) \cdot u_2 \cdot (e_s - e_a)] / [\Delta + \gamma \cdot (1+0.34 \cdot u_2)]$$

Δ (vapour-pressure slope)	0.157 kPa/°C
γ (psychrometric)	0.065 kPa/°C
R_n (net radiation)	14.7 MJ/m²/d
$e_s - e_a$ (vapour deficit)	1.21 kPa
ET_0	5.3 mm/day

Hargreaves

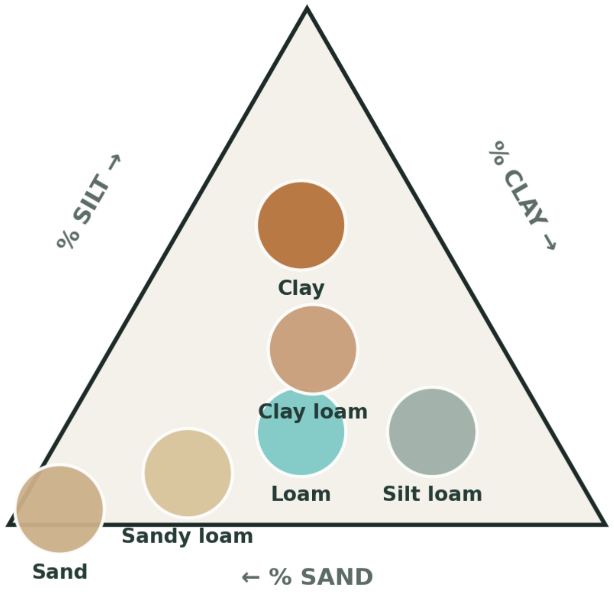
$$ET_0 = 0.0023 \cdot (T_{mean}+17.8) \cdot \sqrt{(T_{max}-T_{min})} \cdot R_a$$

$T_{mean} + 17.8$	39.3
$\sqrt{(T_{max} - T_{min})} = \sqrt{13}$	3.61
R_a (as evaporation)	16.4 mm/d
0.0023 × 39.3 × 3.61 × 16.4	—
ET_0	5.4 mm/day

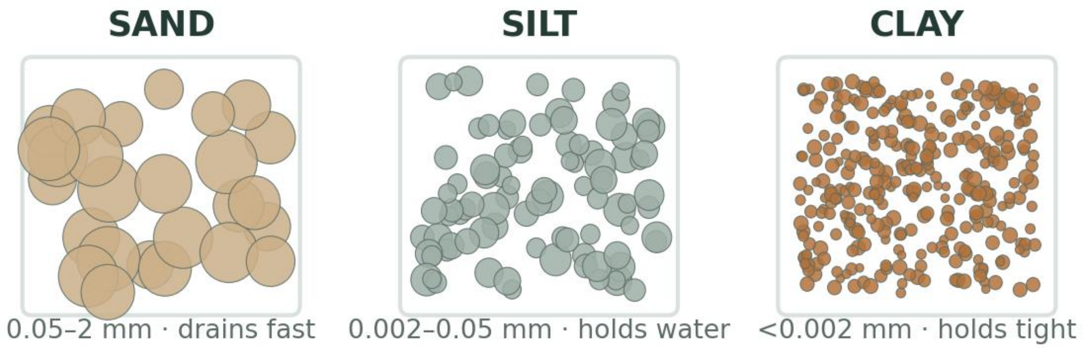
Scale 0–6 mm/day · difference ≈ 0.1 mm/day (~2%) on this calm, moderately humid day

SOIL

Soil water holding capacity



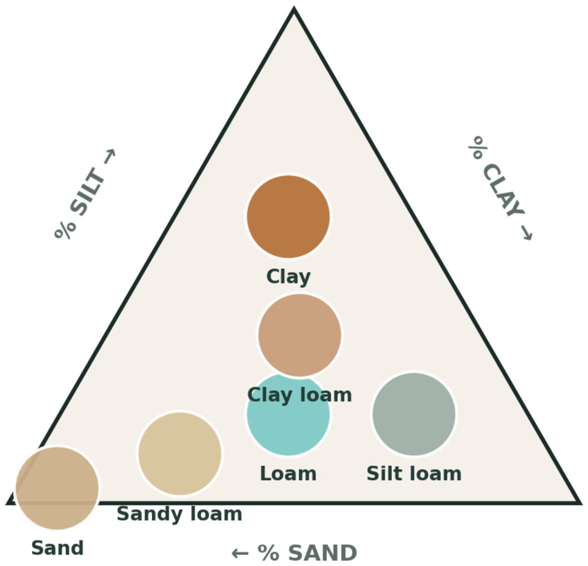
USDA texture classes



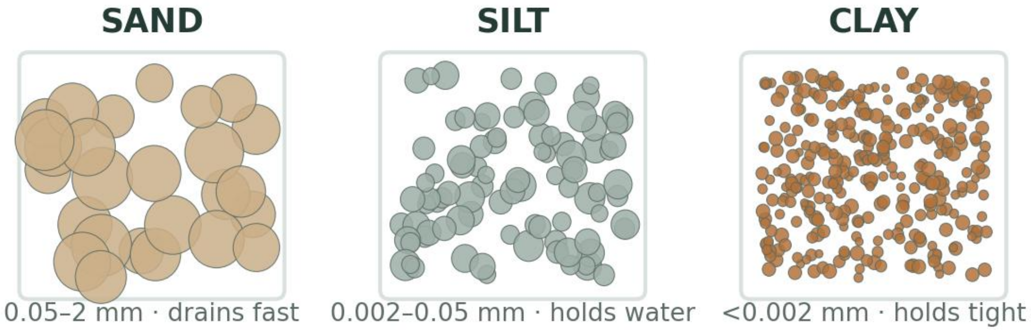
- Particle size decides pore size — and pore size decides how water moves and is held.
- Sand: large pores → drains fast, low storage, high infiltration.
- Clay: tiny pores → holds tightly, slow intake, much water locked from roots.
- Loam / silt loam: the balance — large usable reservoir.

SOIL

Texture sets the rules



USDA texture classes



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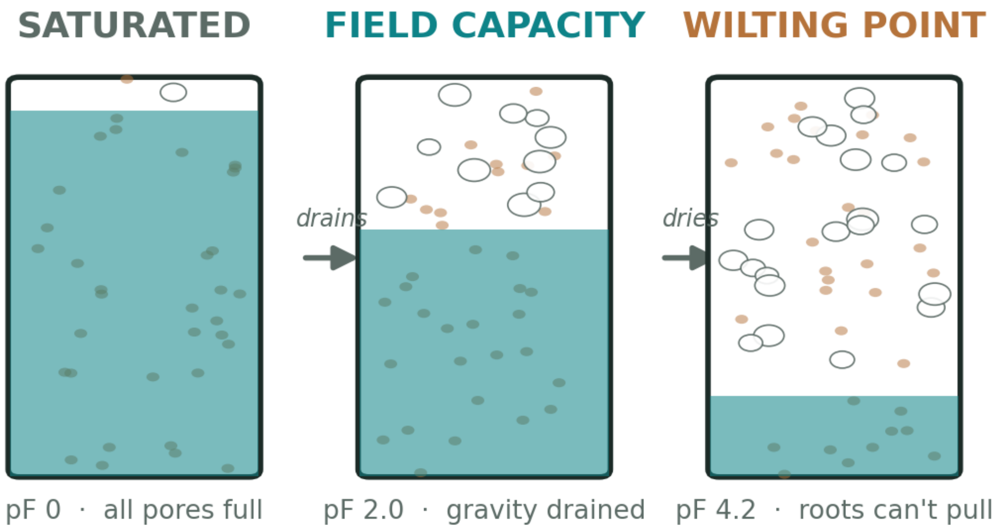
SOIL

How soil holds — and releases — water



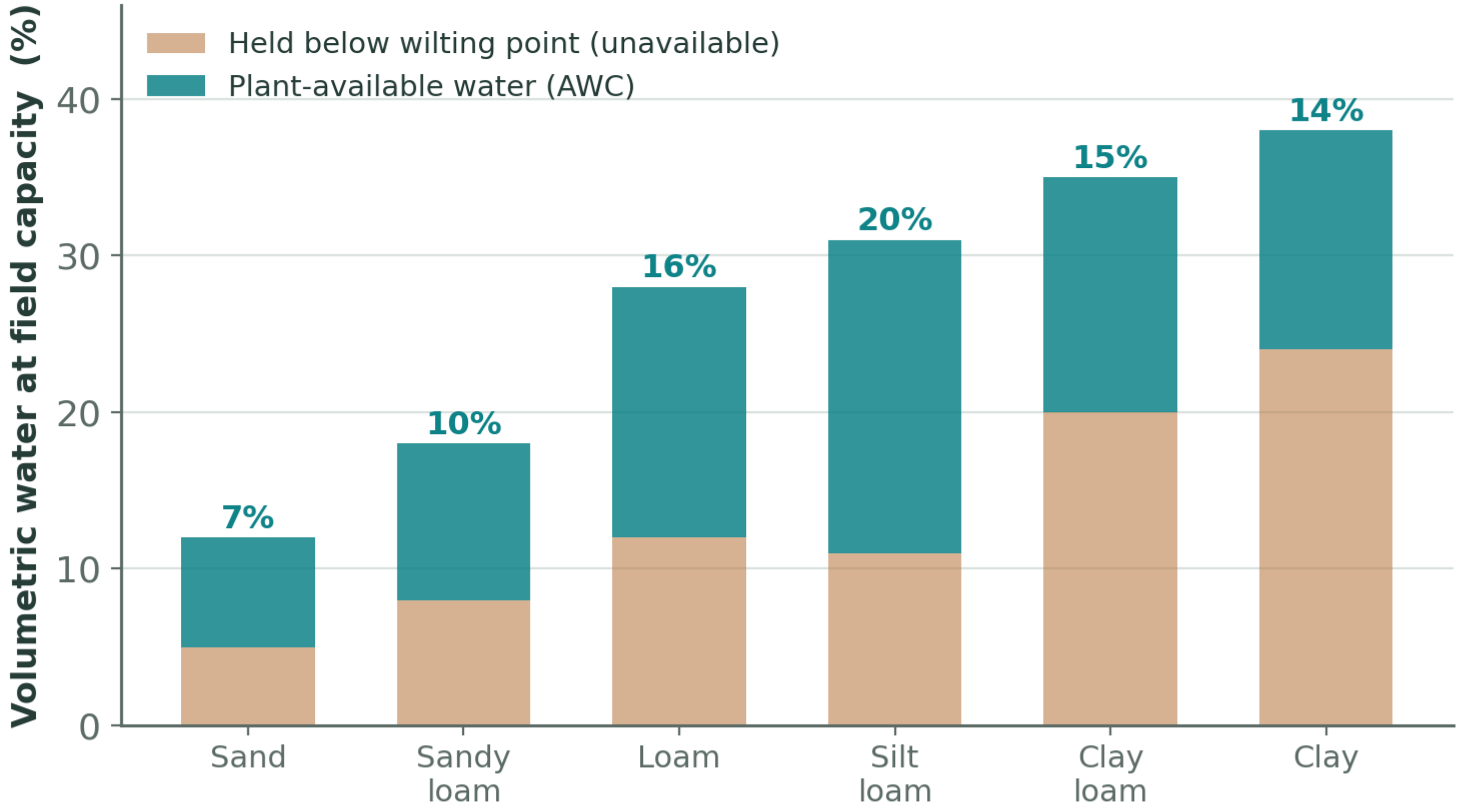
From saturated, to drained (field capacity), to wilting

Plant-available water
= θ(field capacity) − θ(wilting point)

- Above field capacity, gravity drains water away within a day or two.
- Below wilting point, water is held so tightly roots cannot extract it.
- The band between is the reservoir you manage with irrigation.

SOIL

Available water differs by soil type



Silt & loam win

- Largest plant-available reservoir per metre of soil.

Sand = small store

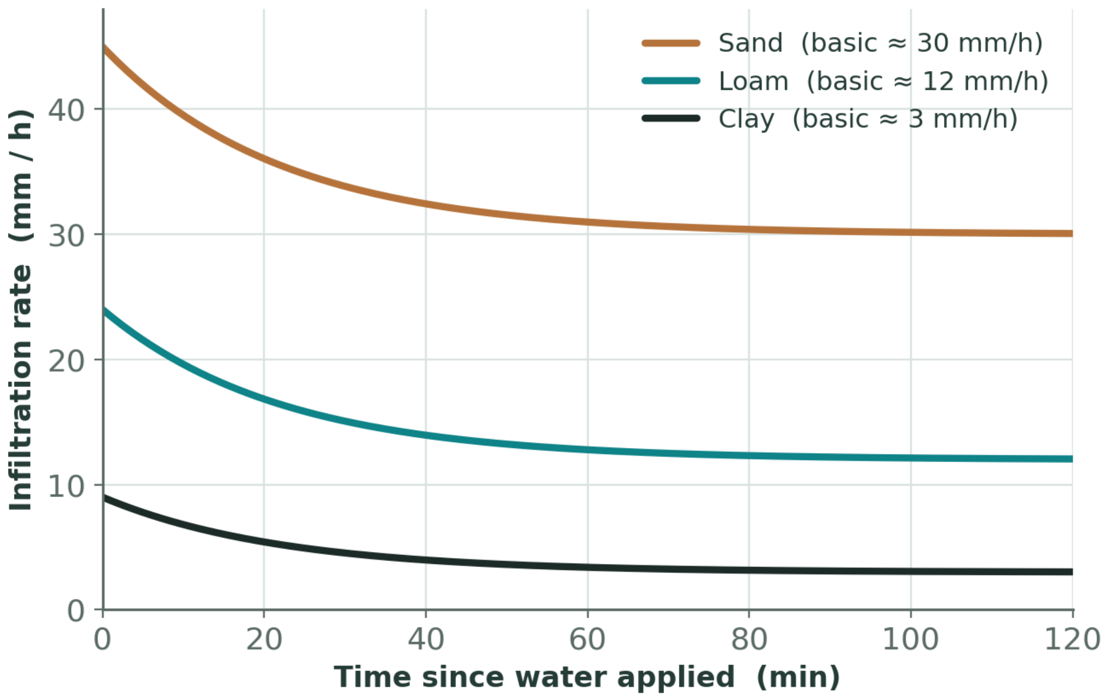
- Little & often: small doses, short intervals, watch leaching.

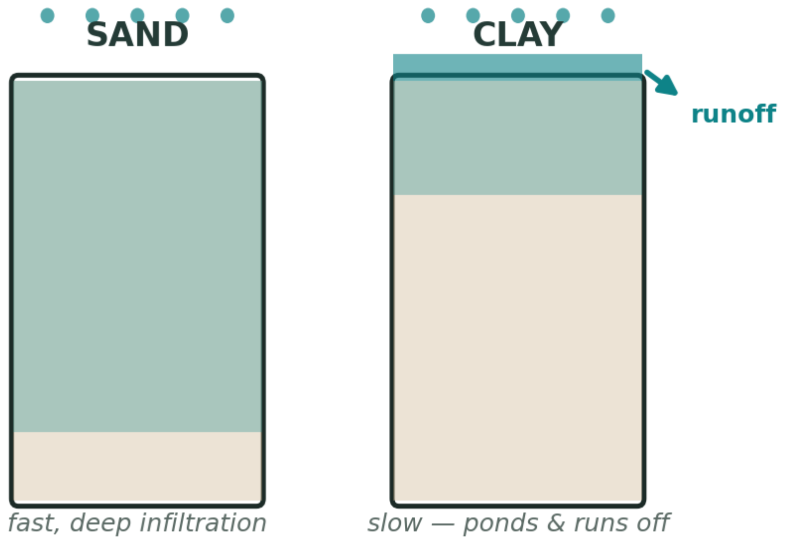
Clay can mislead

- High total water, but much is locked below wilting point.

SOIL

How fast water enters the soil





Soil Moisture & Irrigation

Match rate to intake. If you apply faster than the soil absorbs, water ponds and runs off — the clay trap. Keep application rate at or below the basic infiltration rate.

The pF Curve

SOIL

Soil & substrate water retention — and irrigation

$$pF = \log_{10} |h|$$

the suction — in cm water column — a root must beat to pull water out of the pores

FIELD CAPACITY pF 2.0 · 100 cm · ~10 kPa

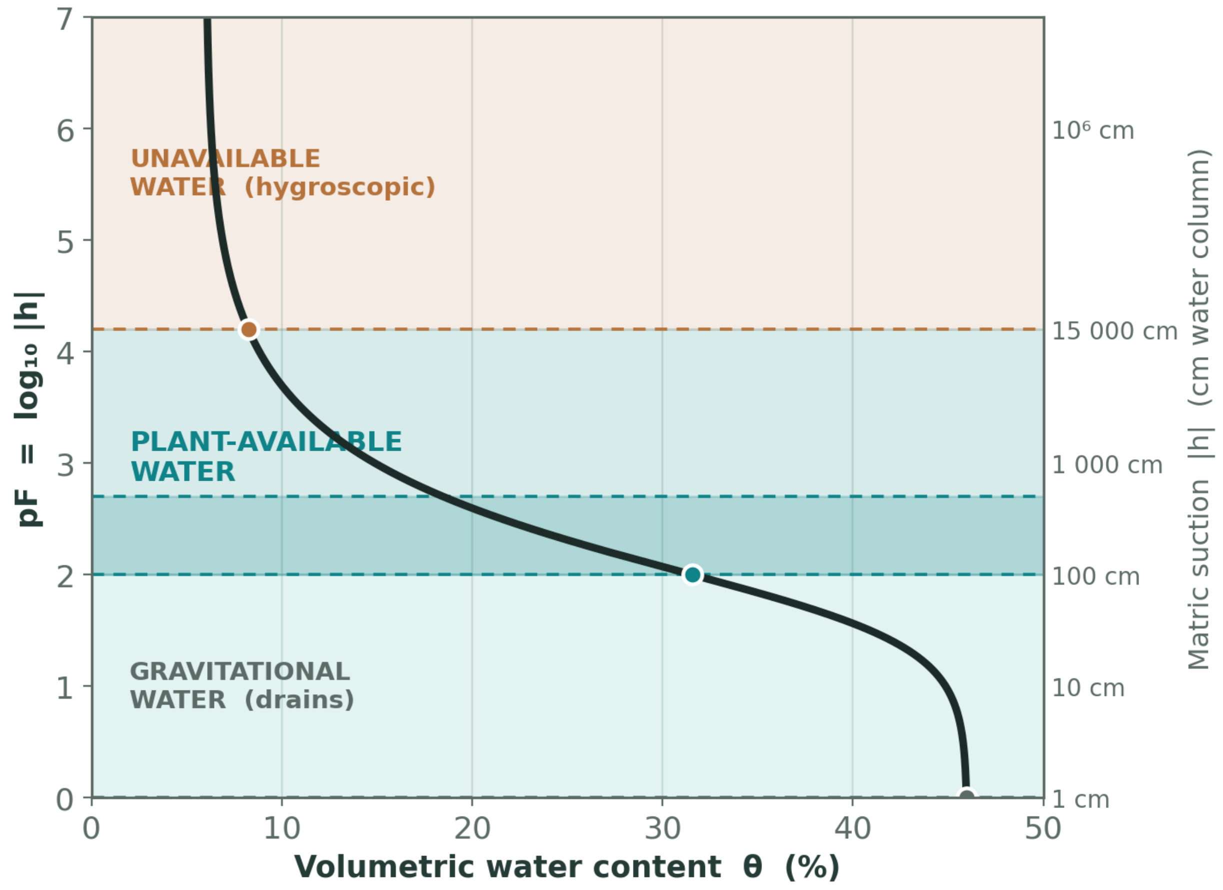
After gravity drainage — the wettest useful state

WILTING POINT pF 4.2 · 15 000 cm · 15 bar

Roots can no longer extract water — plant wilts

PLANT-AVAILABLE WATER θ(FC) – θ(PWP)

The reservoir you actually irrigate to refill



The characteristic curve: water content falls as suction (pF) rises

SOIL

The pF Curve

Soil & substrate water retention — and irrigation

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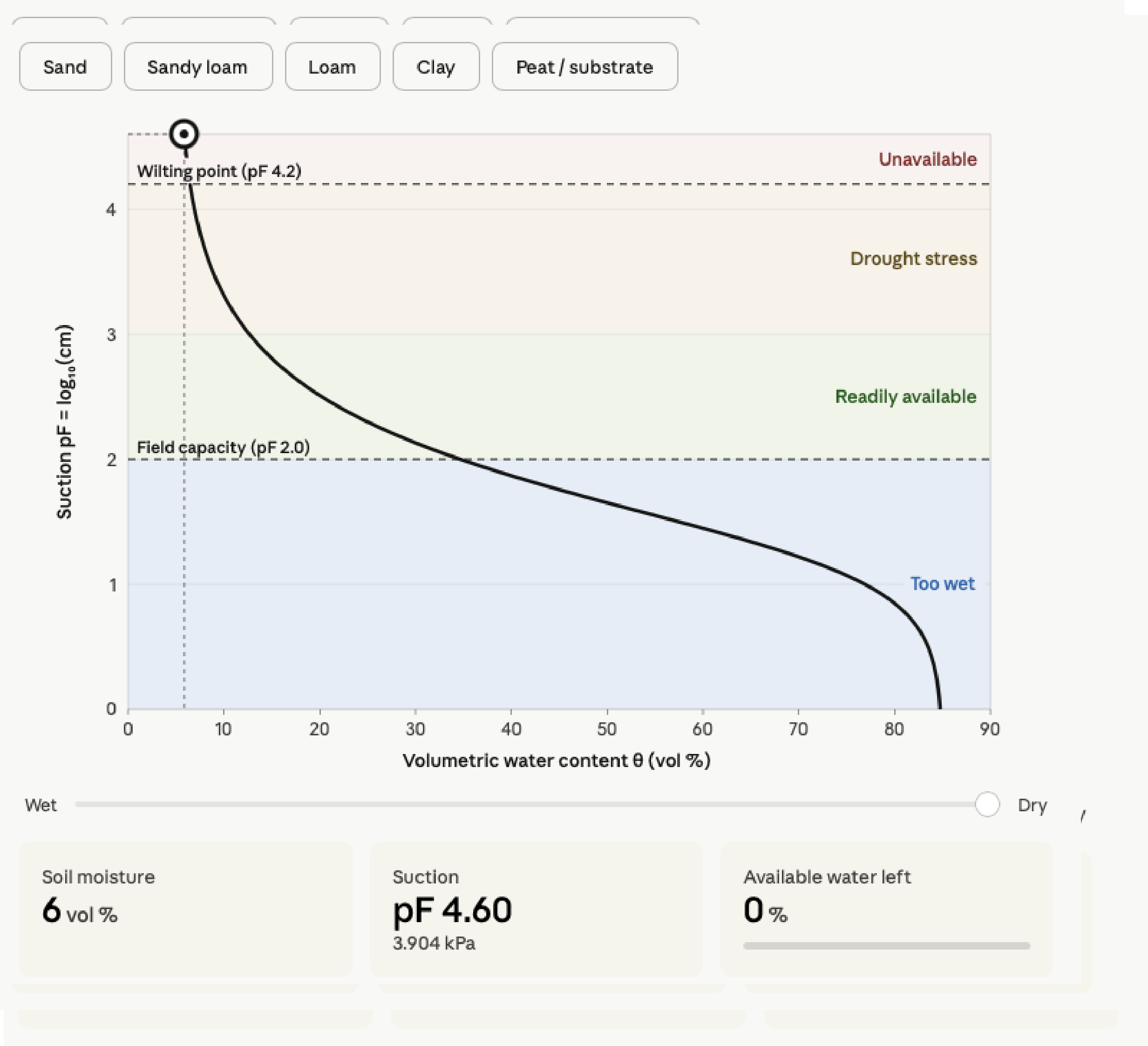
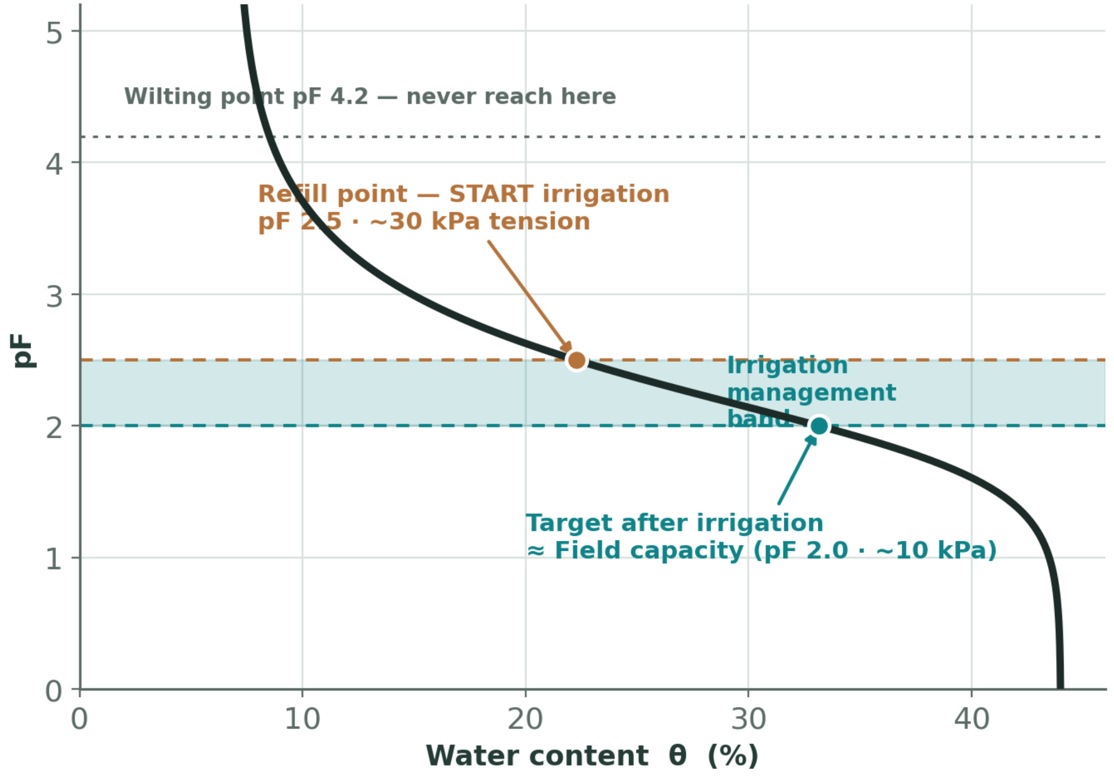


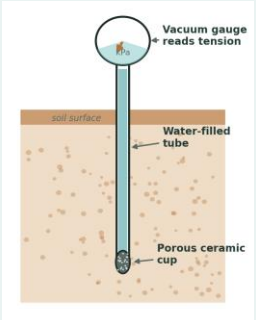
SOIL

Putting the pF curve to work in irrigation



Irrigate within a band: refill before stress, target field capacity

The pF Curve · soil & substrate water retention



Read it in the field

A tensiometer measures suction directly — the live pF of the rootzone.

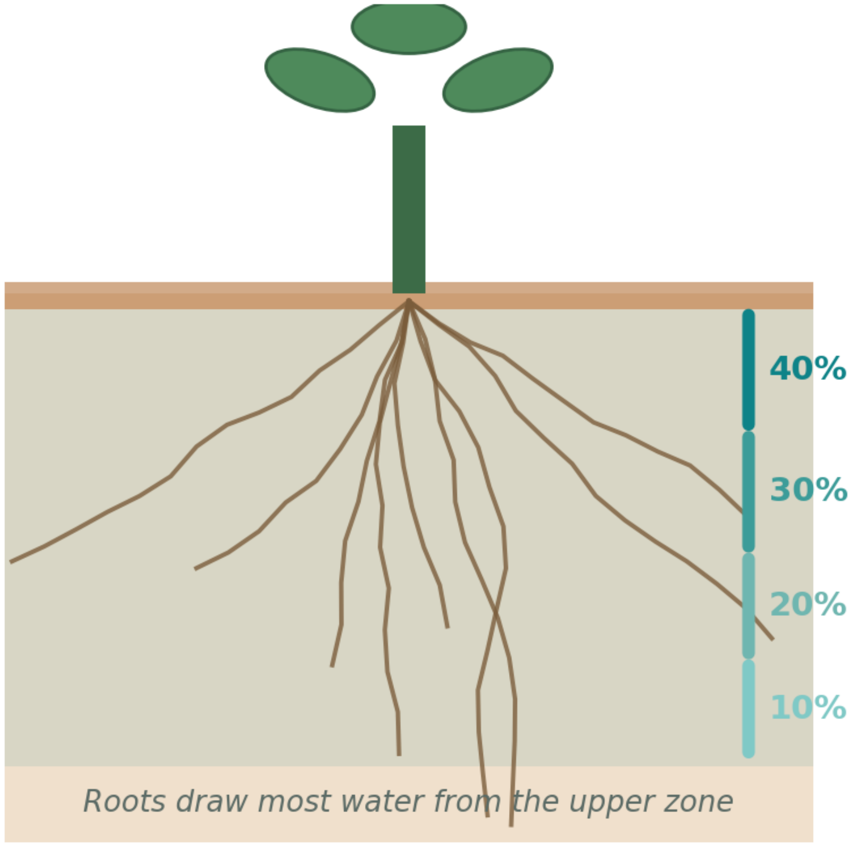
Trigger irrigation at a set tension; the curve converts it to a water deficit.

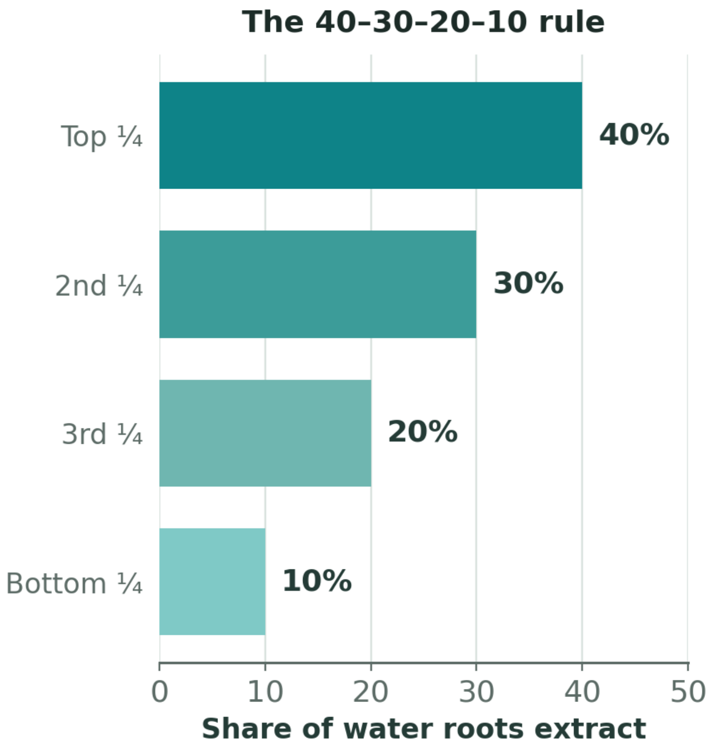
Typical start-irrigation thresholds

System / crop	Refill at
Sandy field soil	pF 2.3 · ~20 kPa
Loam / clay loam	pF 2.5–2.7 · 30–50 kPa
Blueberry in coco substrate	pF 1.7–2.0 · 5–10 kPa
Rose / pot crop (substrate)	pF 1.8–2.1 · 6–12 kPa

SOIL

How roots draw on the reservoir

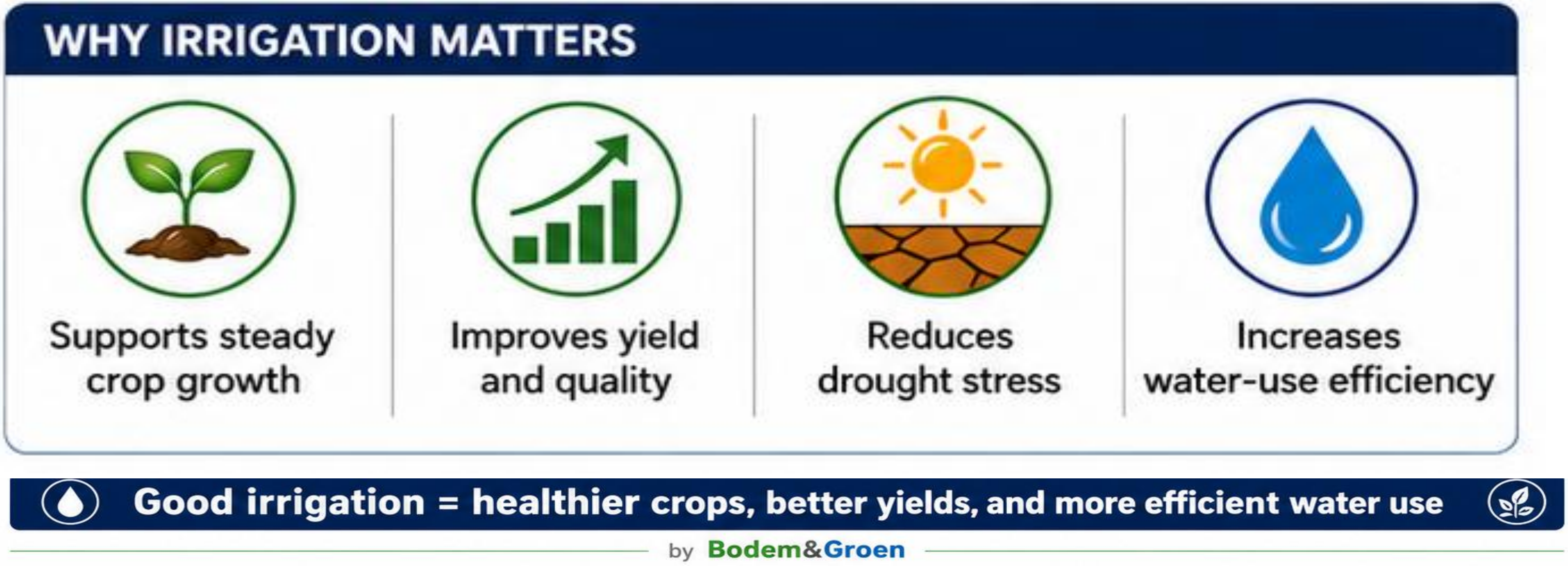




- Most water comes from the upper root zone.
- Rooting depth × available water = the usable store.
- Deeper roots = larger buffer between irrigations.
- Keep the active zone in the easy range — don't push to wilting.

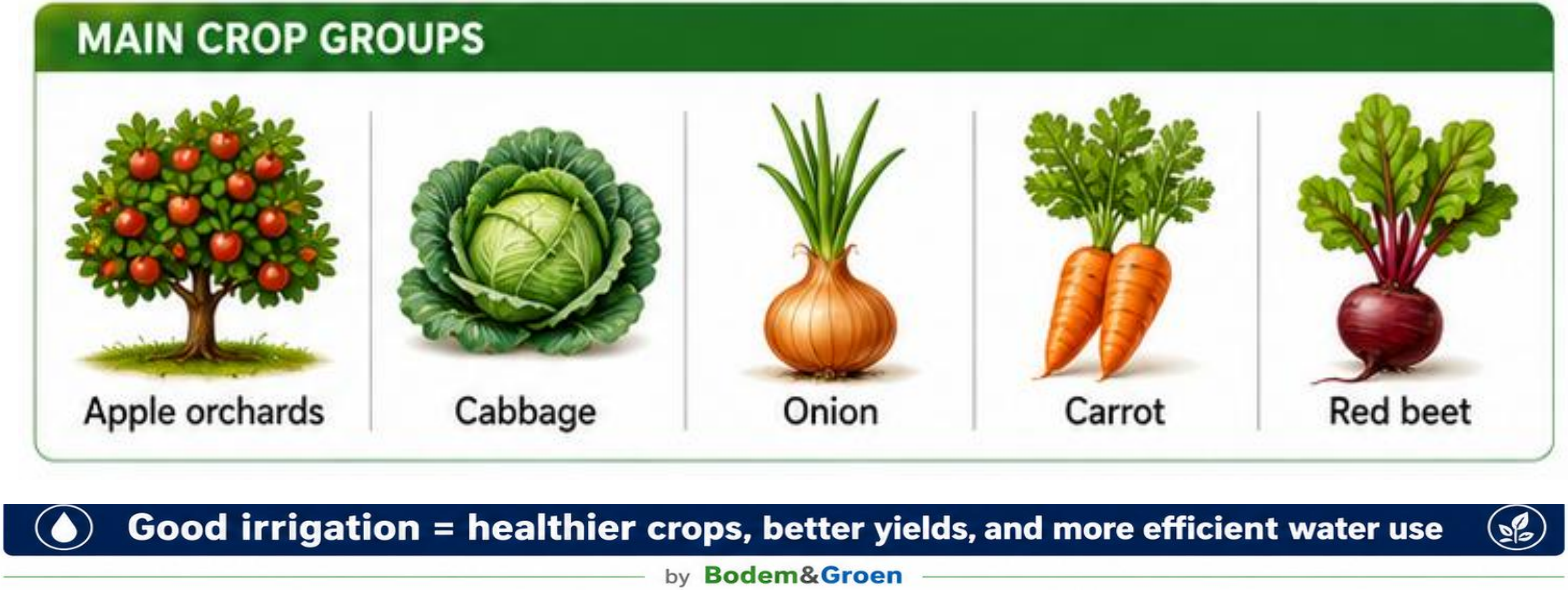
IRRIGATION

Importance of irrigation



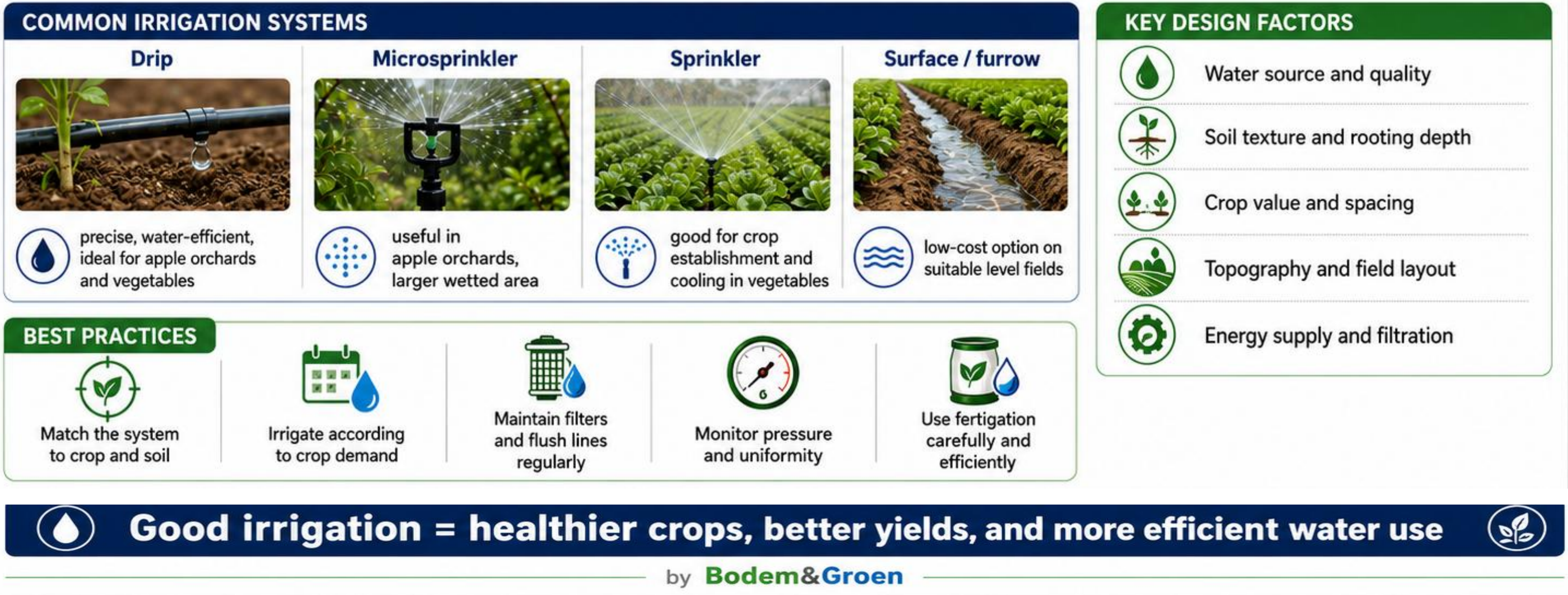
IRRIGATION

Importance of irrigation



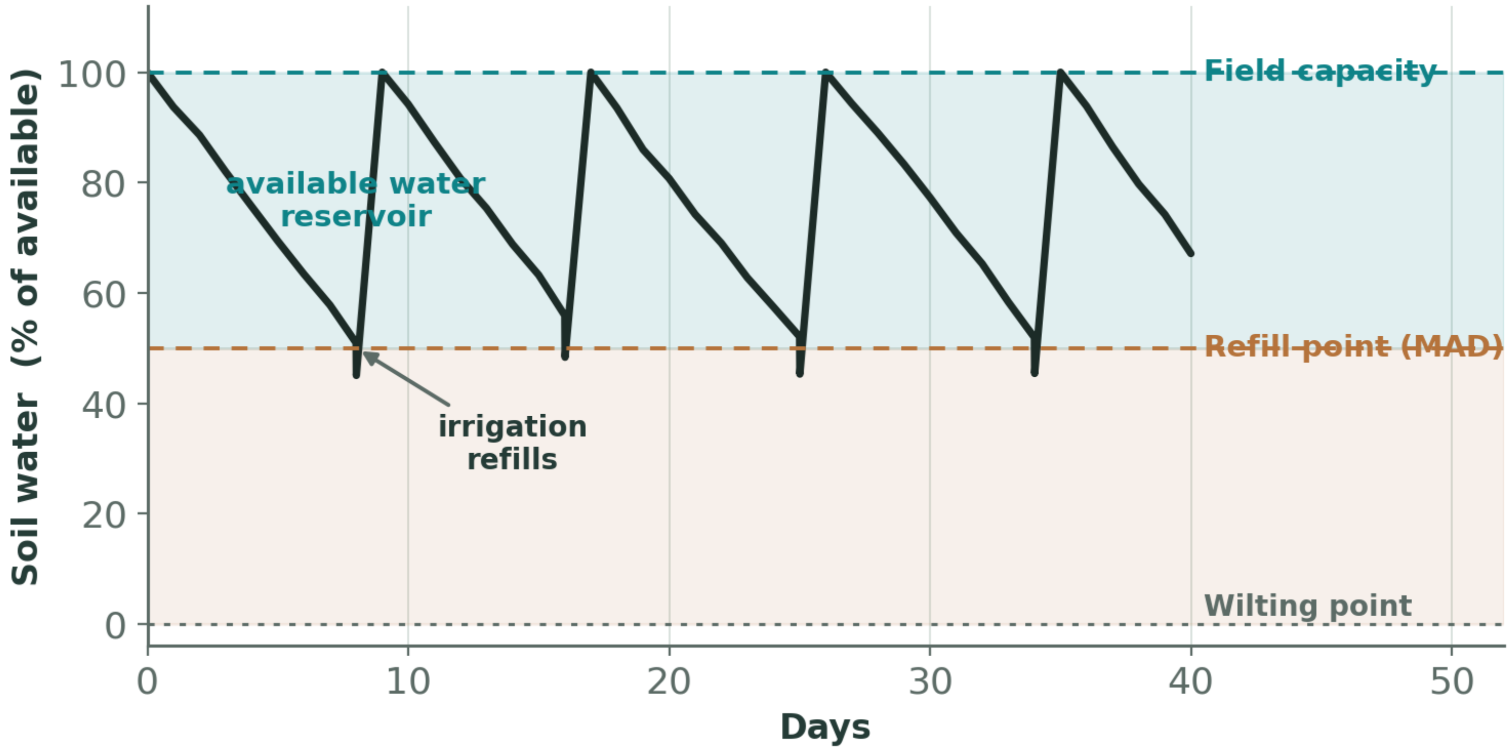
IRRIGATION

Importance of irrigation



IRRIGATION

When and how much to irrigate



Soil Moisture & Irrigation

WHEN

- At the refill point — the Management Allowed Depletion (often ~50% of available water).

HOW MUCH

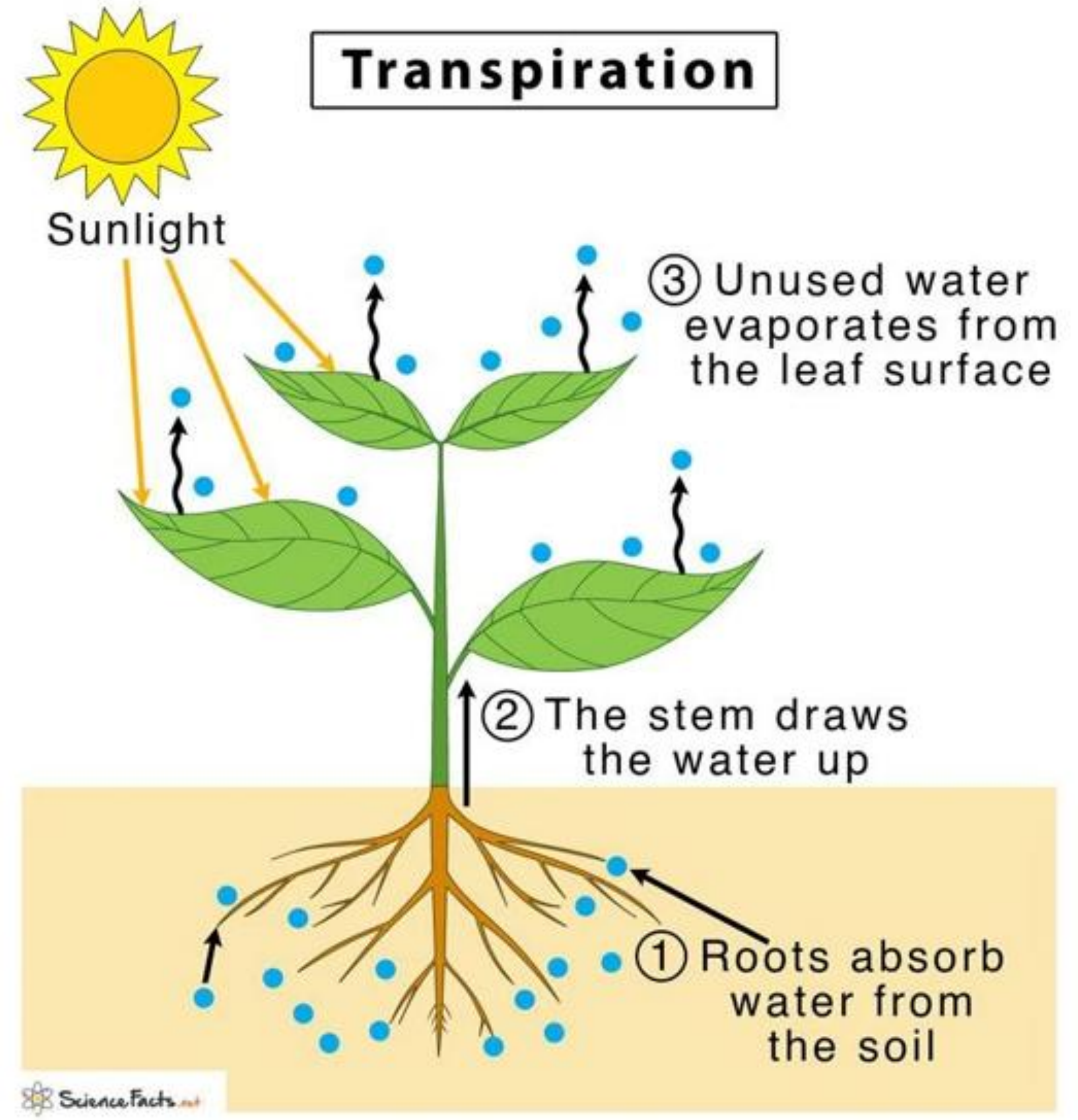
- Enough to refill the root zone back to field capacity.

NET DEPTH

- ≈ available water × MAD × root depth, adjusted for system efficiency.

EVAPORATION - TRANSPIRATION

Plant water uptake

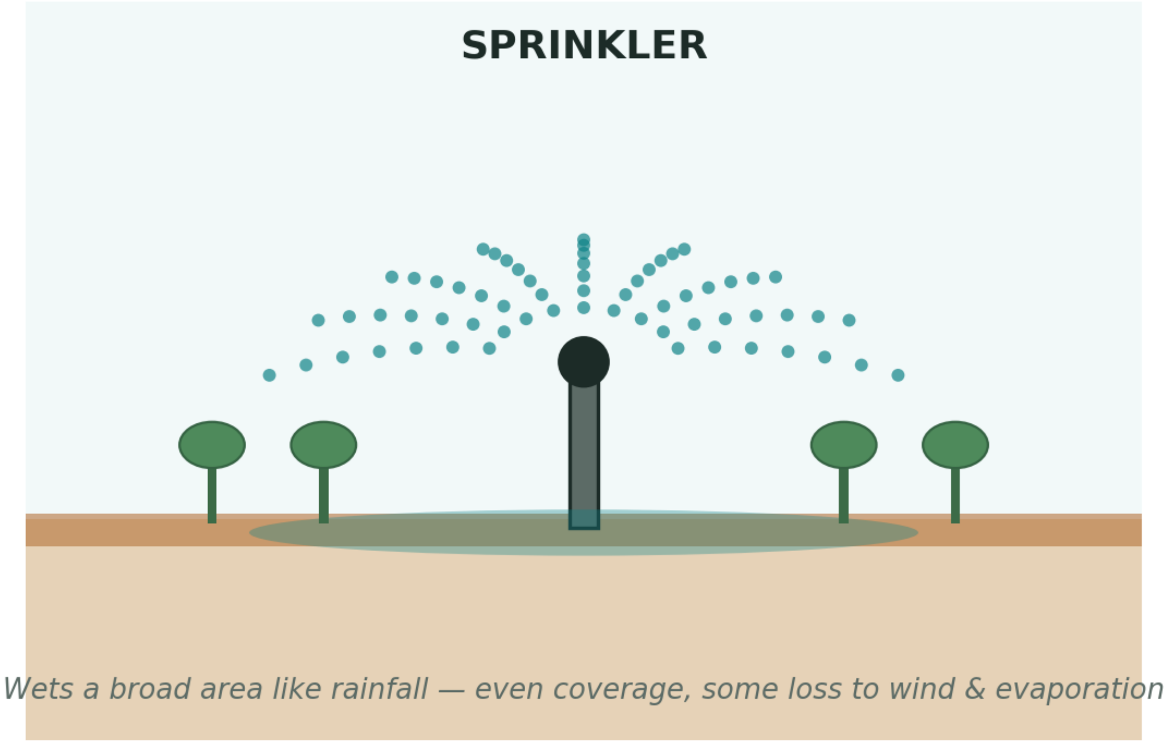


IRRIGATION

Sprinkler Overhead

IRRIGATION

Sprinkler irrigation



Wets a broad area like rainfall, from overhead nozzles under pressure.

Strengths

- Even coverage over whole field
- Good for closely-spaced crops
- Can cool / frost-protect

Watch-outs

- Wind & evaporation losses
- Wet foliage → disease risk
- Keep rate below clay's intake

IRRIGATION

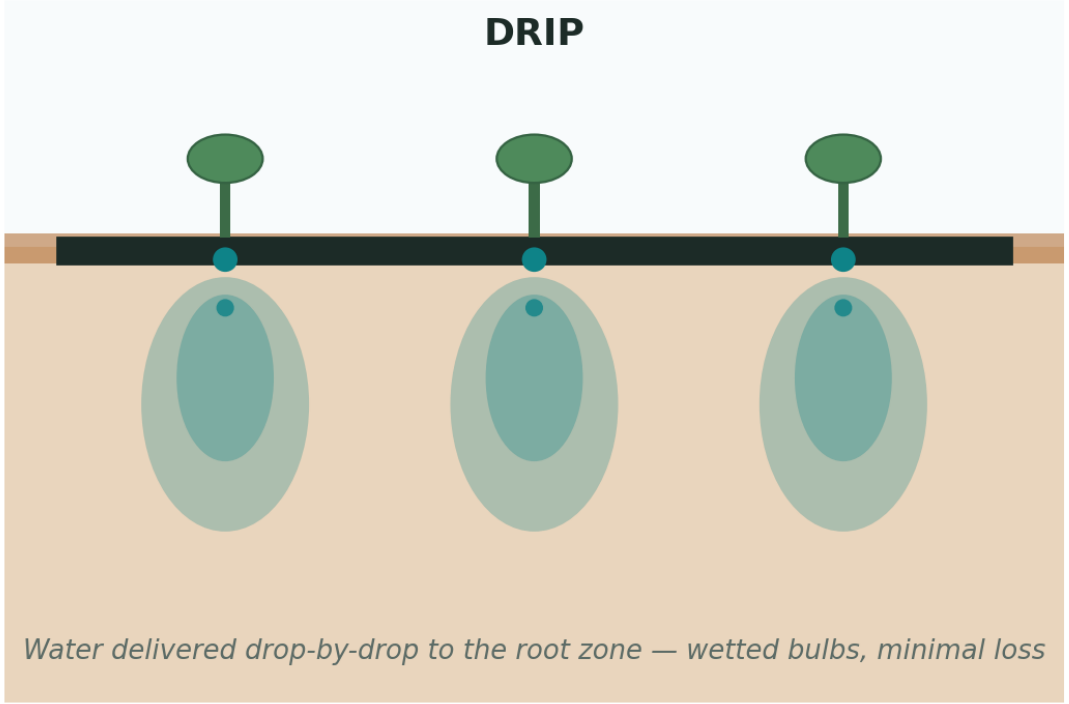
Under-tree Sprinkler

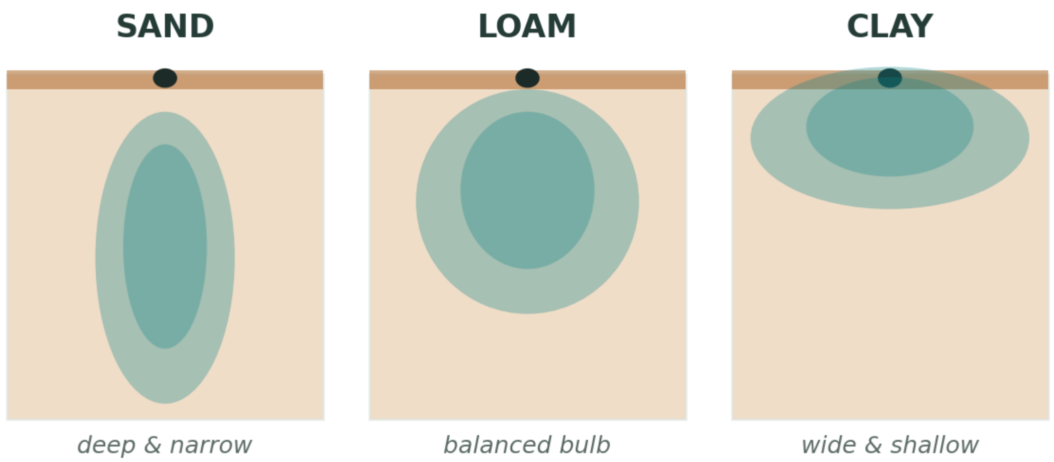
IRRIGATION

Micro-Sprinkler

IRRIGATION

Drip irrigation





Wetting bulb shape depends on soil type

- Sand: deep, narrow bulb → space emitters closer.
- Clay: wide, shallow bulb → emitters can sit farther apart.
- Pinpoint delivery → highest efficiency, dry inter-rows, less disease.

Best for high-value, row & substrate crops, saline water and uneven terrain.

Soil Moisture & Irrigation

IRRIGATION

Surface Drip

Surface drip lines are placed on the soil surface or suspended 10 to 30 cm above it along each tree row. Two configurations are common: a single lateral per tree row, sometimes with two emitters per tree, or a double lateral arrangement (one on each side of the trunk) used principally in young high-density plantings. Emitter spacing is typically 0.3 to 0.75 m along the lateral; pressure-compensating emitters are preferred to maintain uniform discharge over the length of the row and on sloping ground.

Surface drip systems are inexpensive to install (typically 2,500 to 4,000 USD/ha for materials in 2023 Ukrainian conditions), simple to inspect and maintain, and easy to retrofit. The disadvantages are exposure of laterals to mechanical damage (from cultivation, mowing, and wildlife — particularly hares in winter), exposure to UV degradation (rated working lives of modern surface drip lines are 7 to 12 years), and concentration of root systems near the surface, which can increase frost susceptibility.

IRRIGATION

Subsurface Drip

Subsurface drip irrigation (SDI) places drip laterals 15 to 30 cm below the soil surface. Modern SDI laterals incorporate emitters with anti-siphon membranes that prevent root intrusion and soil ingress. The advantages are reduced evaporation from the soil surface, complete protection from mechanical damage and UV, and the absence of any surface obstruction to cultivation and harvest operations. Some authors report water savings of 10 to 20 percent compared with surface drip in apple, though the evidence under Ukrainian conditions is limited.

The principal drawbacks of SDI in apple are difficulty of inspection (problems are detected only by their effects on the trees), the need for very careful filtration to prevent emitter clogging that cannot be cleared by surface flushing, and substantially higher installation cost. Specialised tools are required to install laterals at uniform depth, and root intrusion remains a long-term risk in some installations. SDI is increasingly used in new high-value Ukrainian apple plantings where soil cultivation continues throughout the orchard life, and where surface drip would be repeatedly damaged.

IRRIGATION

Selection criteria

The choice of irrigation system for an orchard should rest on a careful evaluation of the following factors, in approximate order of importance:

- Water source and water quality. Drip systems require well-filtered water (typically below 100 NTU turbidity and free of large suspended solids); microsprinklers can accept lower-quality water; surface systems are tolerant of nearly any quality.
- Capital availability and payback expectations. Drip systems have the highest capital cost (typically 3,500 to 6,000 USD/ha in Ukraine for fully installed systems including pump, filter, and fertigation), but the lowest operating cost per unit of fruit produced.
- Soil texture and depth. Sandy soils favour microsprinklers, which produce a larger wetted volume than drip; clay soils favour drip; shallow soils need frequent low-volume application that drip provides naturally.
- Topography and orchard layout. Steep or irregular sites favour pressure-compensating drip; large uniform blocks may permit surface systems.
- Crop value and management intensity. High-density, high-value plantings of premium varieties justify drip; lower-value orchards may be better served by less expensive systems.
- Energy supply and reliability. Pressurised systems require reliable electrical supply or robust diesel backup; surface systems do not.
- Frost protection requirement. Where late spring frosts are frequent and the variety is sensitive, an overhead sprinkler system may be justified — usually as a complement to a primary drip or microsprinkler installation.
- Available labour and technical skill. Drip and microsprinkler systems require trained operators able to monitor pressures, flush filters, and detect emitter problems; surface systems can be operated with less technical preparation.

IRRIGATION

Selection criteria

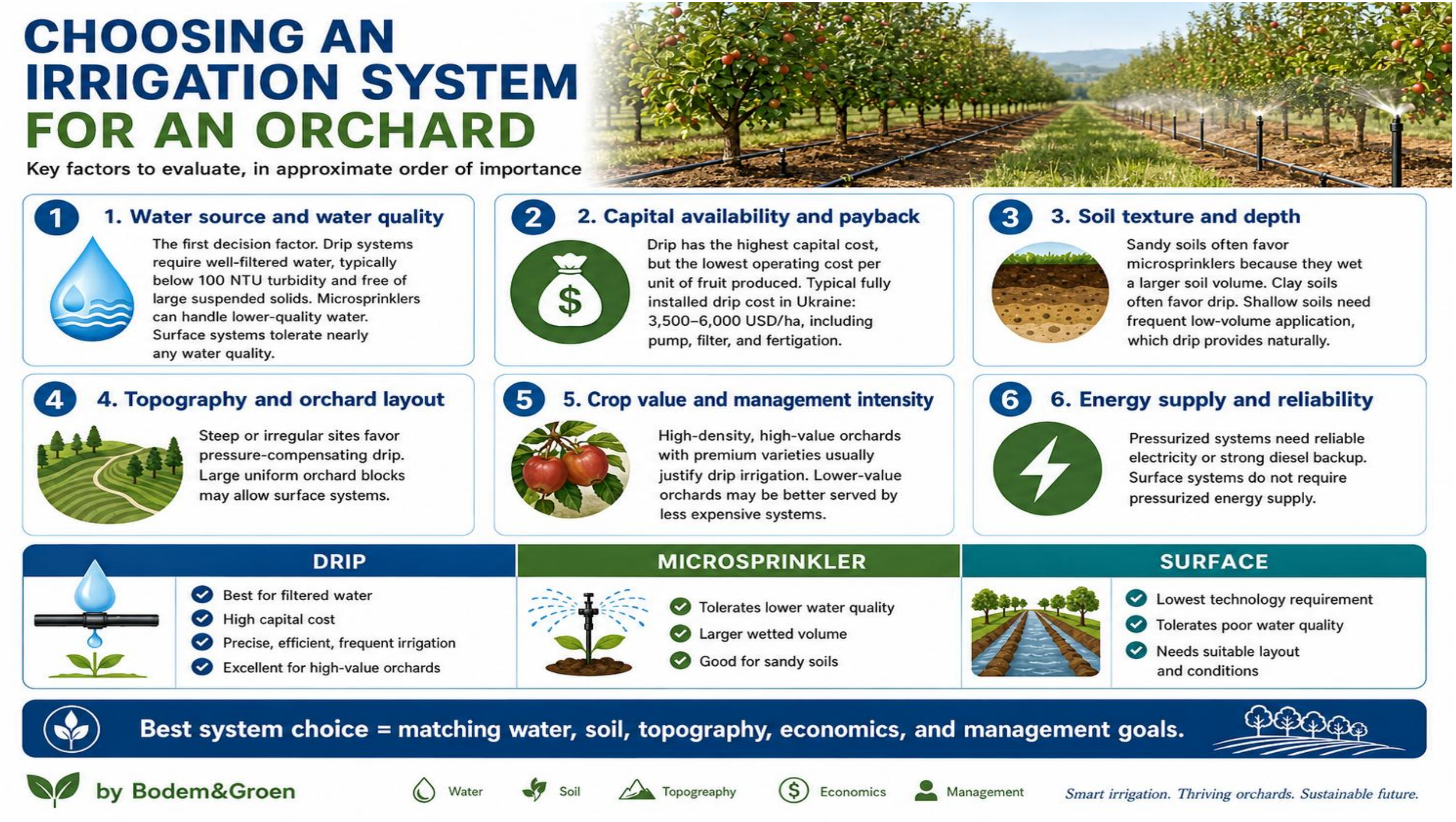
System	Efficiency (%)	Capital (USD/ha)	Energy	Fertigation	Frost protection
Furrow	50–70	500–1,500	None	Difficult	No
Basin	60–75	700–1,800	Low	Difficult	No
Overhead sprinkler	60–75	3,000–5,000	High	Possible	Excellent
Under-tree sprinkler	70–80	2,500–4,000	Medium	Good	Limited
Microsprinkler	80–88	2,800–4,500	Medium	Excellent	Limited
Surface drip	88–95	3,500–5,500	Low–Medium	Excellent	No
Subsurface drip	90–95	4,500–7,000	Low–Medium	Excellent	No

IRRIGATION

Scheduling ?

WHEN to irrigate, and HOW MUCH

Irrigation scheduling answers two questions: WHEN to irrigate, and HOW MUCH water to apply. Three families of approach are in routine use in Ukrainian vegetable production: soil-moisture-based (tensiometers and electronic sensors), plant-based (visual observation, canopy temperature), and ETc-based (daily water balance from weather data). The most reliable schedules combine elements of all three.

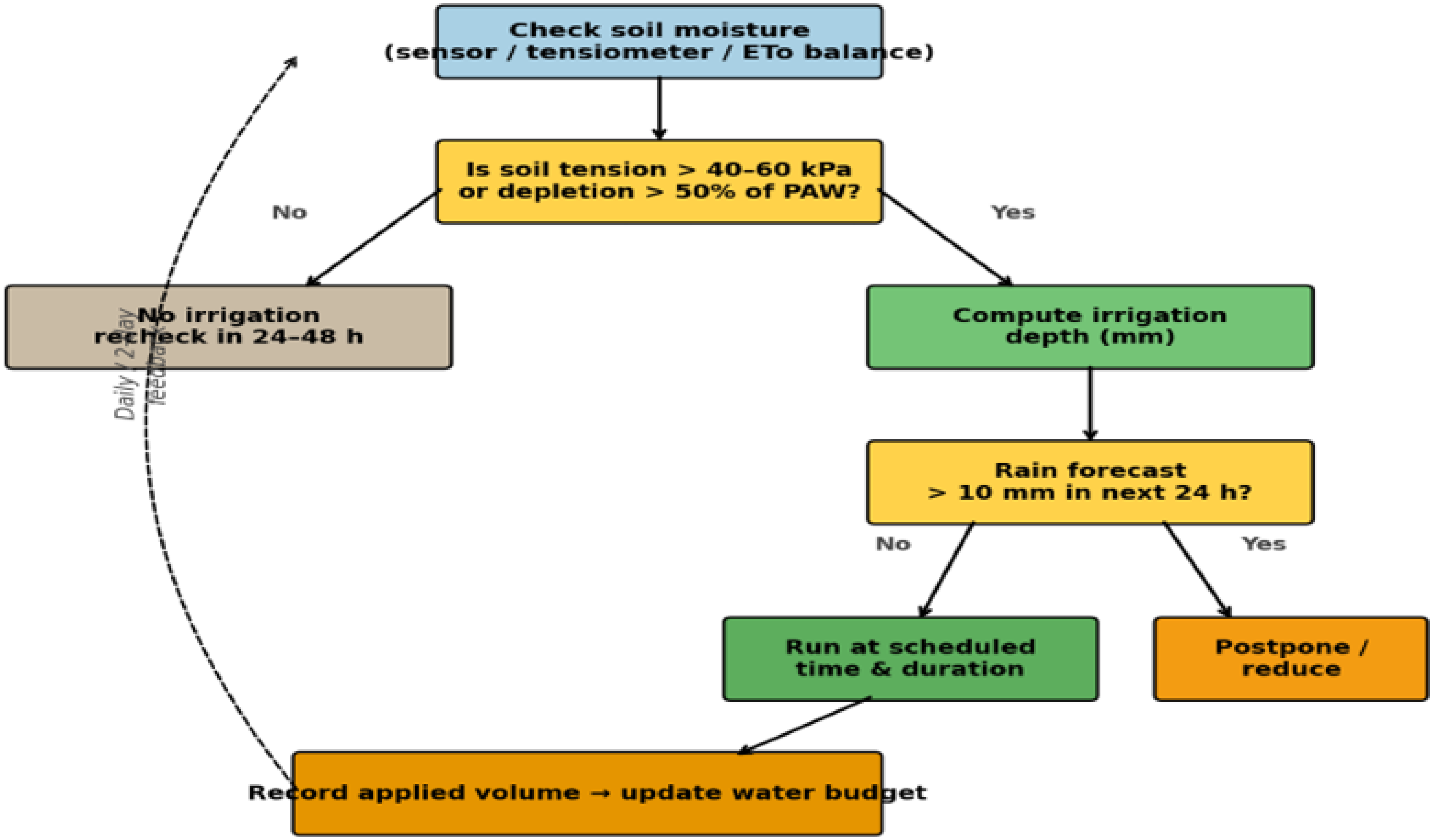

CHOOSING AN IRRIGATION SYSTEM FOR AN ORCHARD
Key factors to evaluate, in approximate order of importance
1. Water source and water quality
The first decision factor. Drip systems require well-filtered water, typically below 100 NTU turbidity and free of large suspended solids. Microsprinklers can handle lower-quality water. Surface systems tolerate nearly any water quality.
2. Capital availability and payback
Drip has the highest capital cost, but the lowest operating cost per unit of fruit produced. Typical fully installed drip cost in Ukraine: 3,500–6,000 USD/ha, including pump, filter, and fertigation.
3. Soil texture and depth
Sandy soils often favor microsprinklers because they wet a larger soil volume. Clay soils often favor drip. Shallow soils need frequent low-volume application, which drip provides naturally.
4. Topography and orchard layout
Steep or irregular sites favor pressure-compensating drip. Large uniform orchard blocks may allow surface systems.
5. Crop value and management intensity
High-density, high-value orchards with premium varieties usually justify drip irrigation. Lower-value orchards may be better served by less expensive systems.
6. Energy supply and reliability
Pressurized systems need reliable electricity or strong diesel backup. Surface systems do not require pressurized energy supply.
DRIP
Best for filtered water
High capital cost
Precise, efficient, frequent irrigation
Excellent for high-value orchards
MICROSPRINKLER
Tolerates lower water quality
Larger wetted volume
Good for sandy soils
SURFACE
Lowest technology requirement
Tolerates poor water quality
Needs suitable layout and conditions
Best system choice = matching water, soil, topography, economics, and management goals.
by Bodem&Groen
Water
Soil
Topogreaphy
Economics
Management
Smart irrigation. Thriving orchards. Sustainable future.

IRRIGATION

Scheduling

Scheduling is the process of deciding when to irrigate and how much water to apply. It is the single most important determinant of irrigation performance — far more important than the choice of hardware. Even the most expensive drip system delivers poor results if it is operated by guesswork; conversely, a modest microsprinkler installation operated to a well-designed schedule will produce excellent fruit yields and quality.

Modern scheduling practice combines three broad approaches: monitoring soil moisture directly, measuring plant water status, and calculating water demand from weather data. The most reliable schedules use at least two of the three, with the others serving as cross-checks. This chapter describes each method in turn and concludes with the integrated decision process used in practice.



MONITORING

Soil moister monitoring

Manuel

Direct measurement of soil moisture is the most intuitive approach to scheduling and forms the basis of most operational systems. Three families of methods are in routine commercial use: tension-based methods (tensiometers and matric-potential sensors), water-content methods (capacitance, time-domain reflectometry, and neutron probe), and the laboratory standard, gravimetric sampling. Each measures a different physical property and has its appropriate role.

Soil moister manuel methode

MONITORING

Soil moister monitoring

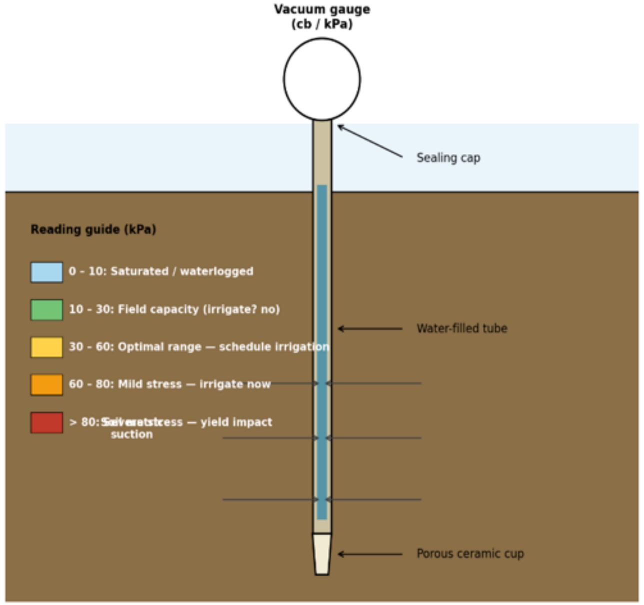
Tensiometer

A tensiometer is a sealed water-filled tube with a porous ceramic tip at the bottom and a vacuum gauge or pressure transducer at the top. As the surrounding soil dries, water is drawn out of the tube through the ceramic tip, creating a partial vacuum that registers on the gauge. The reading expresses the soil matric potential — the force with which water is held in the soil — directly in centibars (cb) or kilopascals (kPa).

Tensiometers are well suited to apple orchards on medium to fine-textured soils. They are inexpensive (typically 30 to 80 USD each), simple to install, and easy to read by inspection. Their principal limitation is a working range of 0 to about 80 cb; in sandy soils that dry rapidly past this point, tensiometers fail to track further drying. For most apple irrigation purposes — where the goal is to maintain matric potential between 15 and 60 cb — this limitation is unimportant.

Standard practice in commercial orchards is to install pairs of tensiometers at 30 cm and 60 cm depth at 4 to 8 representative locations per orchard block. Irrigation is triggered when the shallow tensiometer (which dries first) reaches a target value — typically 30 cb on sandy loam, 40 cb on loam, and 50 cb on clay loam. The deep tensiometer is used to check that irrigation events have been long enough to refill the entire root zone, and to detect over-irrigation (deep tensiometer permanently near 0 cb).

Figure 6.1 — Tensiometer principle and reading guide for apple orchards



MONITORING

Soil moister monitoring

Capacitance and TDR Sensors

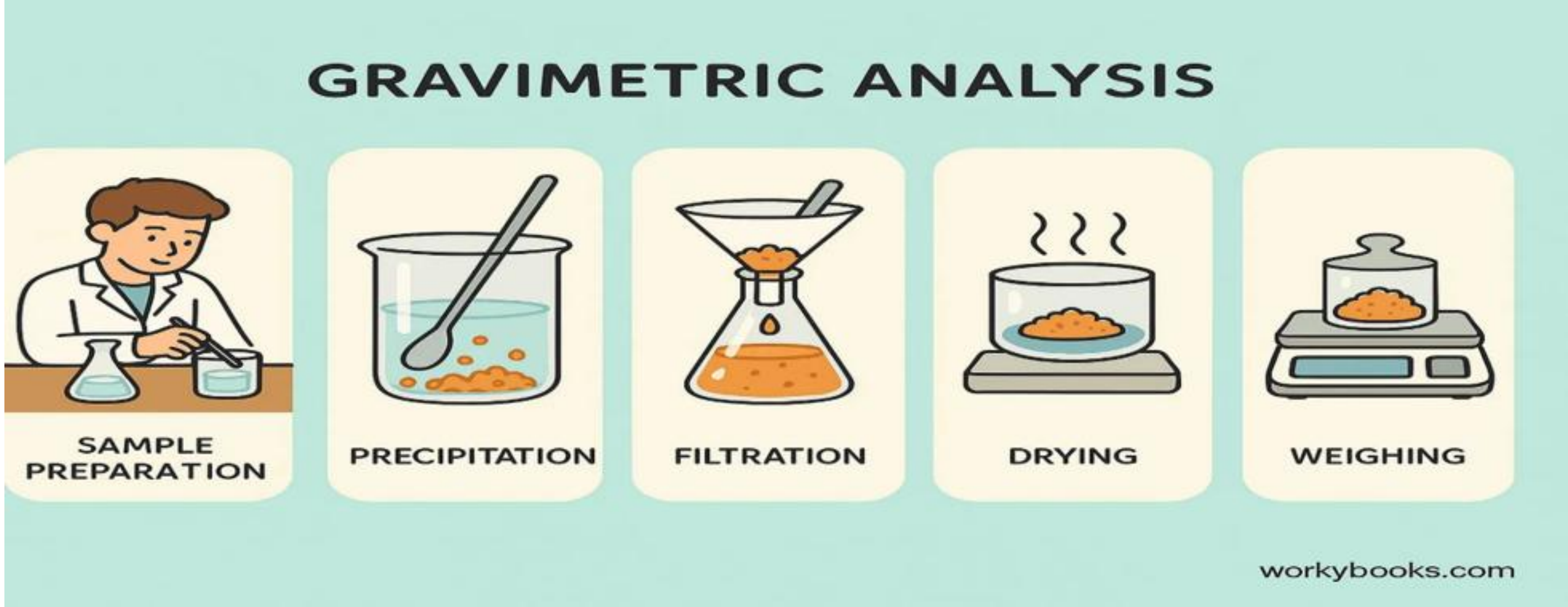
Capacitance sensors (also called frequency-domain reflectometry, FDR) and time-domain reflectometry (TDR) probes measure the dielectric constant of the soil, which is strongly correlated with volumetric water content. They report water content as a percentage by volume and can produce continuous logged data at intervals of 15 minutes or less. Modern probes integrate readings over multiple depths (typically 10, 20, 30, 50, 70, and 100 cm) on a single shaft.

Capacitance and TDR systems provide much richer information than tensiometers: the continuous data clearly show the diurnal pattern of root water uptake, the depth of wetting after irrigation events, and the gradual depletion between events. Modern systems include data telemetry by GSM or LoRaWAN, with real-time web dashboards accessible from a smartphone. Such installations are now standard in larger Ukrainian commercial orchards.
The principal limitations are higher capital cost (typical multi-depth telemetric probes cost 800 to 1,500 USD per installation), the need for soil-specific calibration (factory calibrations may differ from field readings by 5 to 15 percent volumetric water content on stony or organic soils), and dependence on a reliable power supply and data network. For most apple orchards, two to four telemetric probes per block — one in each representative soil type and position — provide adequate spatial coverage.

MONITORING

Plant-based indicators

Gravimetric analysis



MONITORING

Plant-based indicators

Stem Water Potential

MONITORING

Plant-based indicators

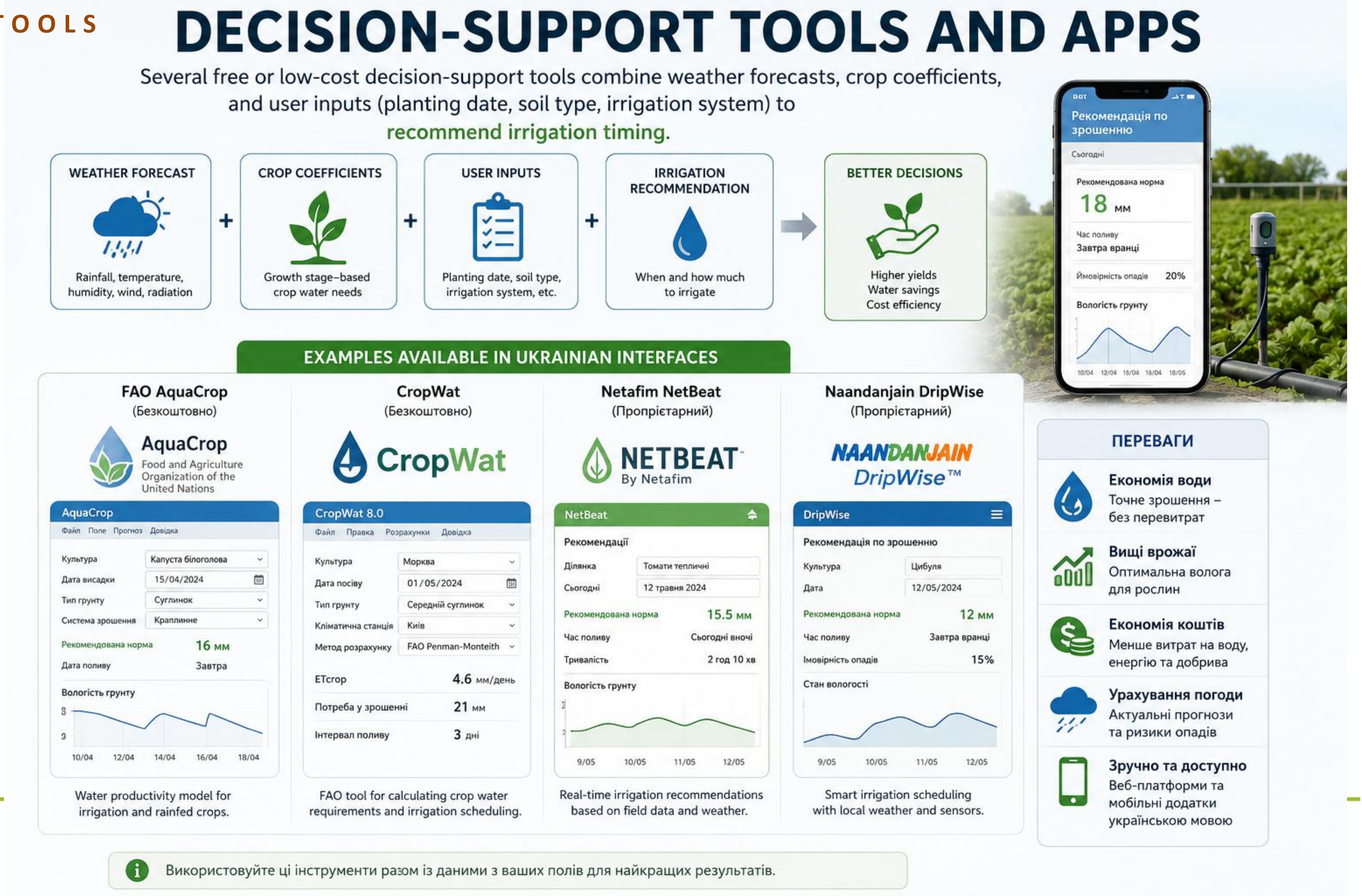
Leaf Temperature

Infrared thermometry of canopy temperature provides a rapid, non-contact measure of stress. Stressed leaves close their stomata, reducing transpirational cooling and rising above air temperature. The difference between canopy and air temperature (Tc − Ta) is the simplest stress index; the crop water stress index (CWSI) normalises this difference to a 0–1 scale using upper and lower reference lines. Apple is moderately conservative in stomatal regulation; clear stress signals require Tc − Ta of more than 3 °C in normal conditions.

Hand-held infrared thermometers make spot readings practical for in-field diagnostics. More sophisticated installations use fixed infrared sensors over each block or — increasingly — thermal imagery from unmanned aerial vehicles (UAVs), which can map canopy temperature and identify stressed zones at the resolution of individual trees. Such technologies are entering routine use in advanced Ukrainian orchards.

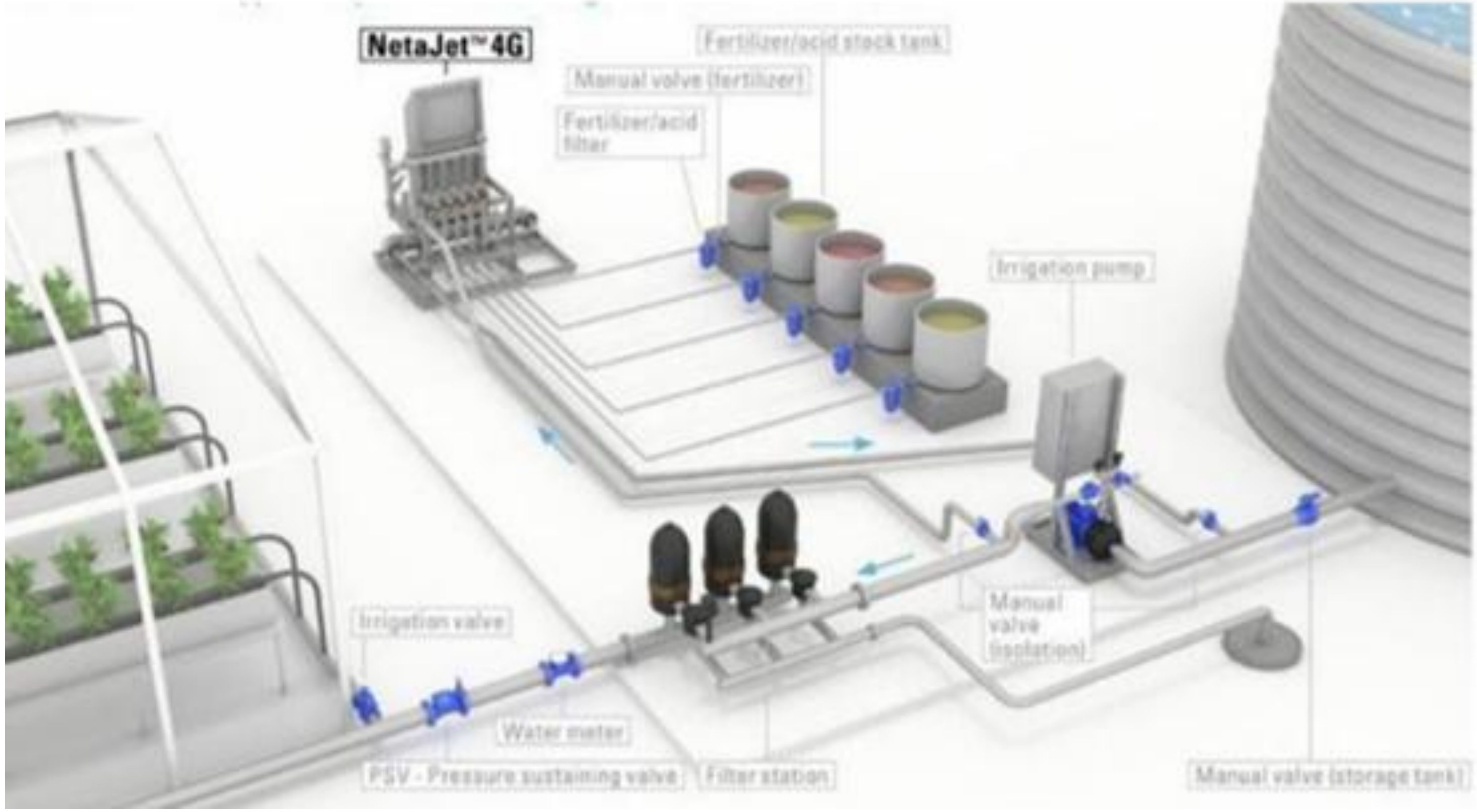
Direct measurement of stomatal conductance with a leaf porometer provides a more sensitive measure of stress than canopy temperature but is too slow for routine commercial use. It remains an important research tool and is occasionally used in diagnostic trials.

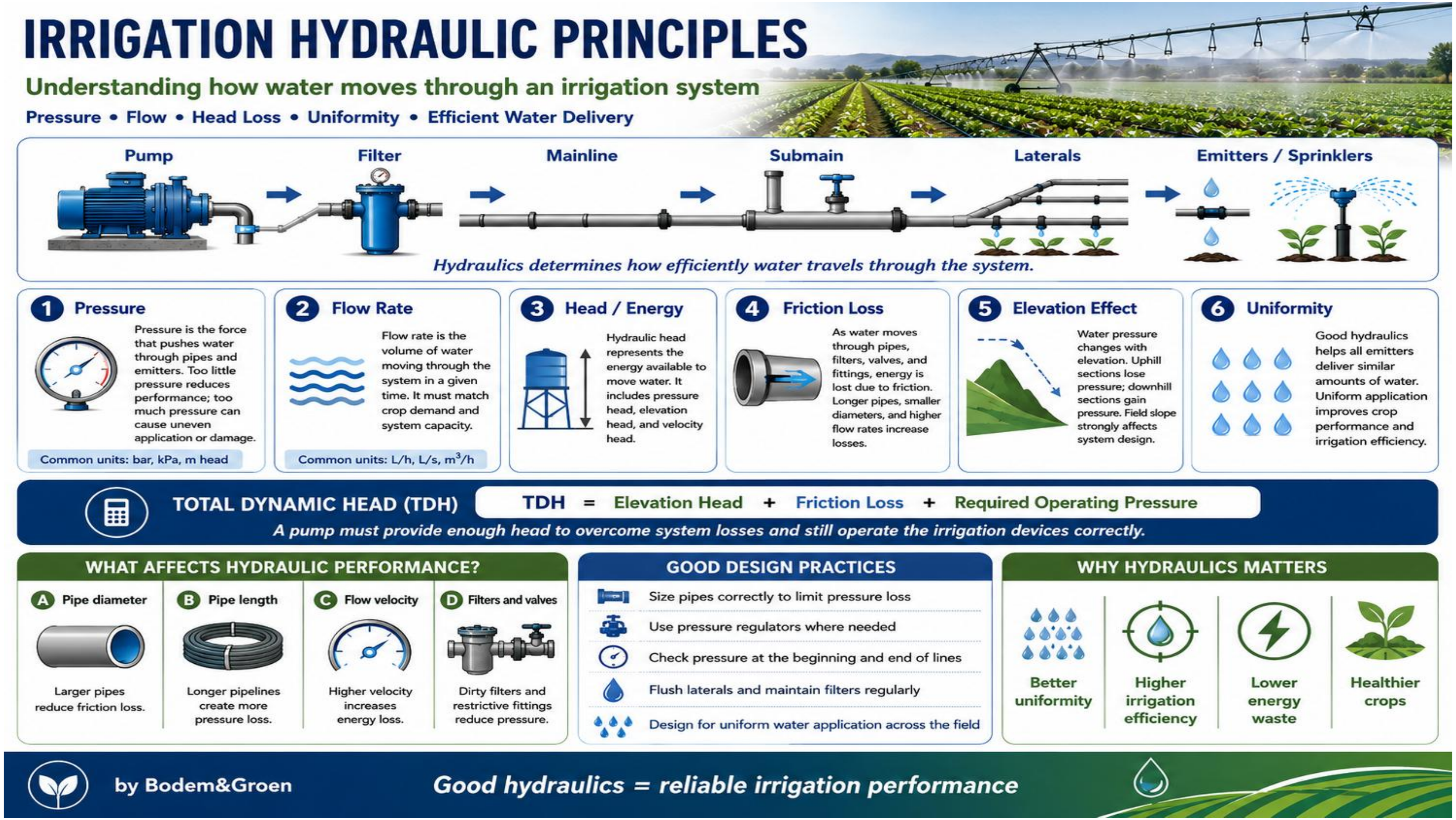
IRRIGATION SUPPORT TOOLS



IRRIGATION SYSTEMS

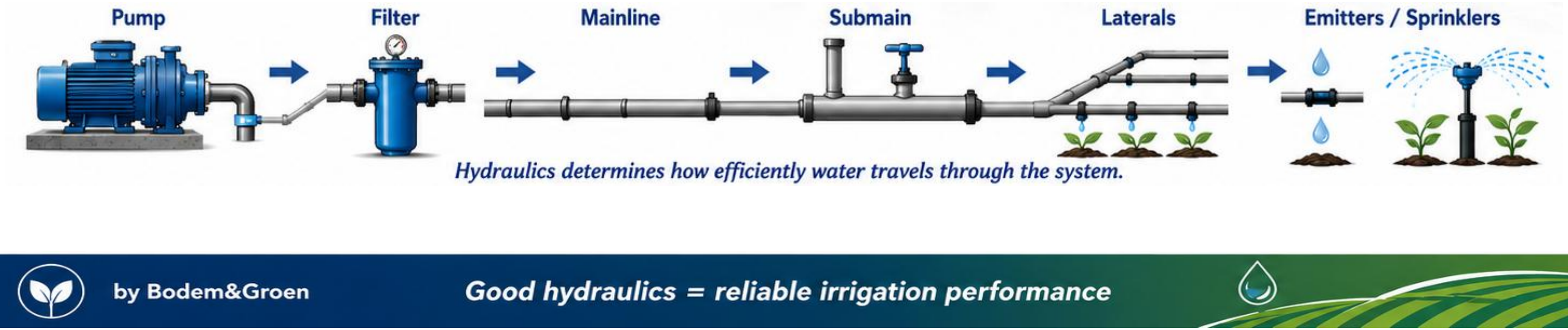
System Desing and Installation




IRRIGATION HYDRAULIC PRINCIPLES
Understanding how water moves through an irrigation system
Pressure • Flow • Head Loss • Uniformity • Efficient Water Delivery
Pump
Filter
Mainline
Submain
Laterals
Emitters / Sprinklers
Hydraulics determines how efficiently water travels through the system.
1 Pressure
Pressure is the force that pushes water through pipes and emitters. Too little pressure reduces performance; too much pressure can cause uneven application or damage.
Common units: bar, kPa, m head
2 Flow Rate
Flow rate is the volume of water moving through the system in a given time. It must match crop demand and system capacity.
Common units: L/h, L/s, m³/h
3 Head / Energy
Hydraulic head represents the energy available to move water. It includes pressure head, elevation head, and velocity head.
4 Friction Loss
As water moves through pipes, filters, valves, and fittings, energy is lost due to friction. Longer pipes, smaller diameters, and higher flow rates increase losses.
5 Elevation Effect
Water pressure changes with elevation. Uphill sections lose pressure; downhill sections gain pressure. Field slope strongly affects system design.
6 Uniformity
Good hydraulics helps all emitters deliver similar amounts of water. Uniform application improves crop performance and irrigation efficiency.
TOTAL DYNAMIC HEAD (TDH)
TDH = Elevation Head + Friction Loss + Required Operating Pressure
A pump must provide enough head to overcome system losses and still operate the irrigation devices correctly.
WHAT AFFECTS HYDRAULIC PERFORMANCE?
A Pipe diameter
Larger pipes reduce friction loss.
B Pipe length
Longer pipelines create more pressure loss.
C Flow velocity
Higher velocity increases energy loss.
D Filters and valves
Dirty filters and restrictive fittings reduce pressure.
GOOD DESIGN PRACTICES
Size pipes correctly to limit pressure loss
Use pressure regulators where needed
Check pressure at the beginning and end of lines
Flush laterals and maintain filters regularly
Design for uniform water application across the field
WHY HYDRAULICS MATTERS
Better uniformity
Higher irrigation efficiency
Lower energy waste
Healthier crops
by Bodem&Groen
Good hydraulics = reliable irrigation performance

System Desing and Installation

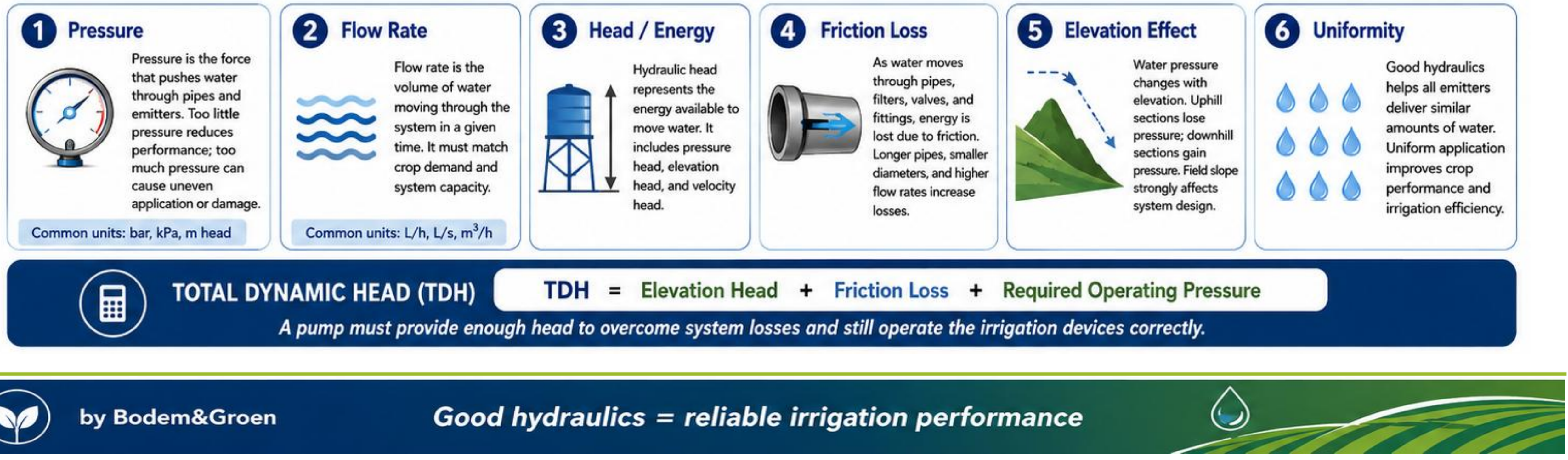
Hydraulic Principles



IRRIGATION SYSTEMS

System Desing and Installation

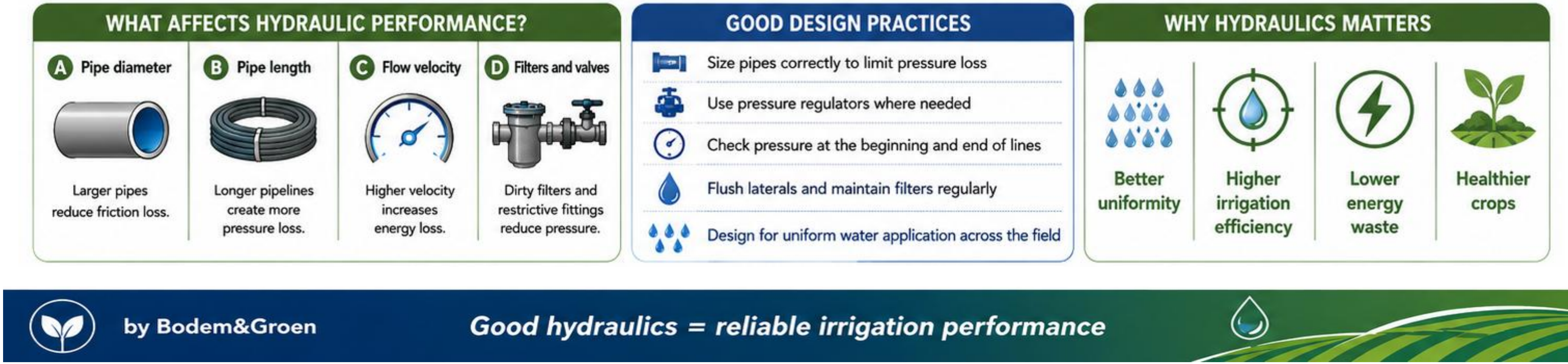
Hydraulic Principles



IRRIGATION SYSTEMS

System Desing and Installation

Hydraulic Principles



IRRIGATION SYSTEMS

Pump and Filtration Requirements

The pump and filtration train is the heart of the irrigation system. Pump selection is determined by the system flow rate, total dynamic head (TDH), the available power supply, and the variability of demand among different operating zones. For most commercial Ukrainian apple orchards, electric centrifugal pumps directly coupled to three-phase motors are standard, with submersible pumps where the water source is a deep well and surface pumps for shallow wells, ponds, or rivers..

Pump capacity should match the largest single zone flow rate plus an allowance of 5 to 10 percent for filter pressure rise and gradual wear. Variable-frequency drives (VFDs) on the pump motor are increasingly common in new Ukrainian installations: they allow the pump speed to be matched to the actual zone flow, reducing energy consumption by 20 to 40 percent compared with throttled fixed-speed operation and providing soft-start that reduces hydraulic shock and extends equipment life.
Filtration is critical for drip and microsprinkler systems and is the most common cause of avoidable irrigation failures. Filter selection depends on water source and emitter sensitivity:

IRRIGATION SYSTEMS

Pump and Filtration Requirements

Filtration is critical for drip and microsprinkler systems and is the most common cause of avoidable irrigation failures. Filter selection depends on water source and emitter sensitivity:

- Surface water (ponds, rivers, canals): typically requires sand-media filtration as primary stage (capacity 50 to 100 µm), followed by screen or disc filtration for fine polishing (80 to 130 mesh, equivalent to 110 to 180 µm).
- Groundwater from wells: usually requires only screen or disc filtration (130 to 200 mesh) for typical drip emitters, unless iron, manganese, or biological activity is significant.
- Drip emitters with very small orifices (under 1 L/h): require finer filtration (200 mesh or finer); larger emitters and microsprinklers tolerate coarser filtration.

Sand filters are sized by water flow rate and water quality; typical capacity is 30 to 50 m^3/h per filter tank, with multiple tanks operated in parallel for larger systems. They require backflushing — automatic in modern installations — when the pressure drop across the filter exceeds about 0.5 bar. Disc and screen filters are also backflushable and have lower energy consumption than sand filters; they are appropriate where biological load is low.

IRRIGATION SYSTEMS

Pump and Filtration Requirements

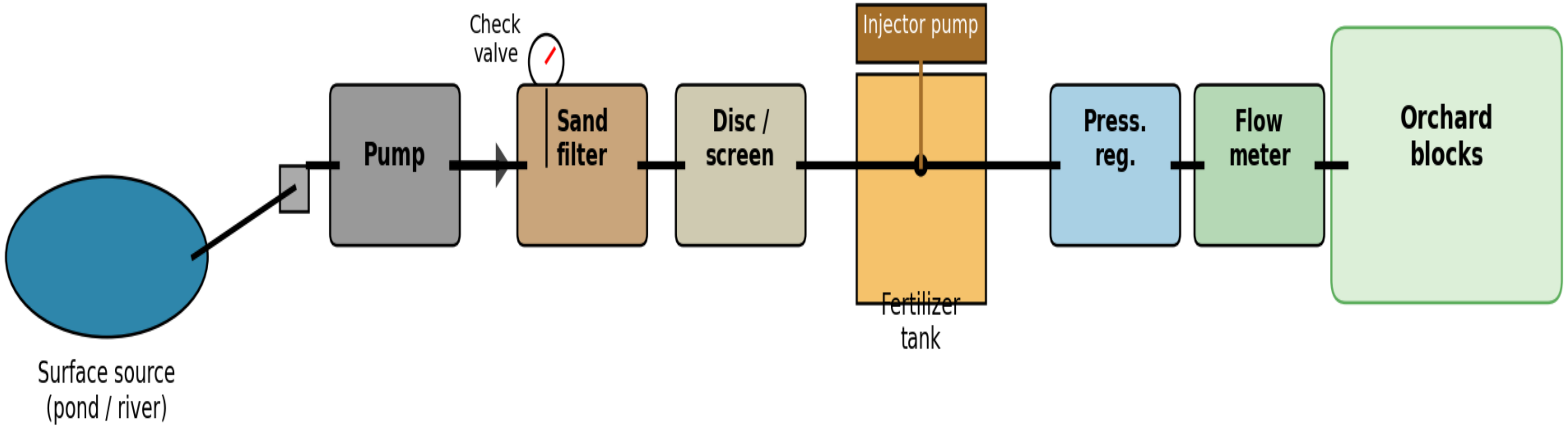


Figure 1 — Schematic of a typical pump and filtration train for an apple orchard drip system: (1) intake screen, (2) primary pump, (3) sand or hydrocyclone filter for bulk solids, (4) injection point for fertigation, (5) secondary screen or disc filter for fine filtration, (6) pressure regulator, (7) flow meter, (8) main shut-off valve to field.

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IRRIGATION FILTRATION GUIDE

Recommended primary and final filters by system and water source

System / water source	Primary filter	Final filter (mesh)	Comment
Drip / clean borehole	Hydrocyclone	120 mesh disc	Add small sand filter if Fe > 0.2 mg/L
Drip / surface canal	Sand media	120 mesh disc	Chlorinate continuously 1–2 mg/L
Drip / on-farm pond	Sand media	120–150 mesh disc	Algae growth – shock chlorinate monthly
Sprinkler / any source	Screen 50 mesh	—	Lower filtration demand than drip
Subsurface drip (SDI)	Sand media	155 mesh disc	Plus pressure-compensating emitters

Match filtration to both water quality and emitter sensitivity.

IRRIGATION SYSTEMS

Pipe layout

The pipe layout of a typical Ukrainian commercial drip-irrigated apple orchard consists of:

- A main line from the pumphouse to the orchard, sized for full system flow and built of pressure-rated PE or PVC (typically 90 to 160 mm diameter, depending on flow).
- Sub-mains running perpendicular to tree rows, each serving one hydraulic zone (typically 63 to 110 mm).
- Lateral lines running along each tree row, with integrated or attached emitters (typically 16 to 20 mm).
- Optional flushing lines at the far end of each row, connecting all laterals in a zone to a common flush valve.

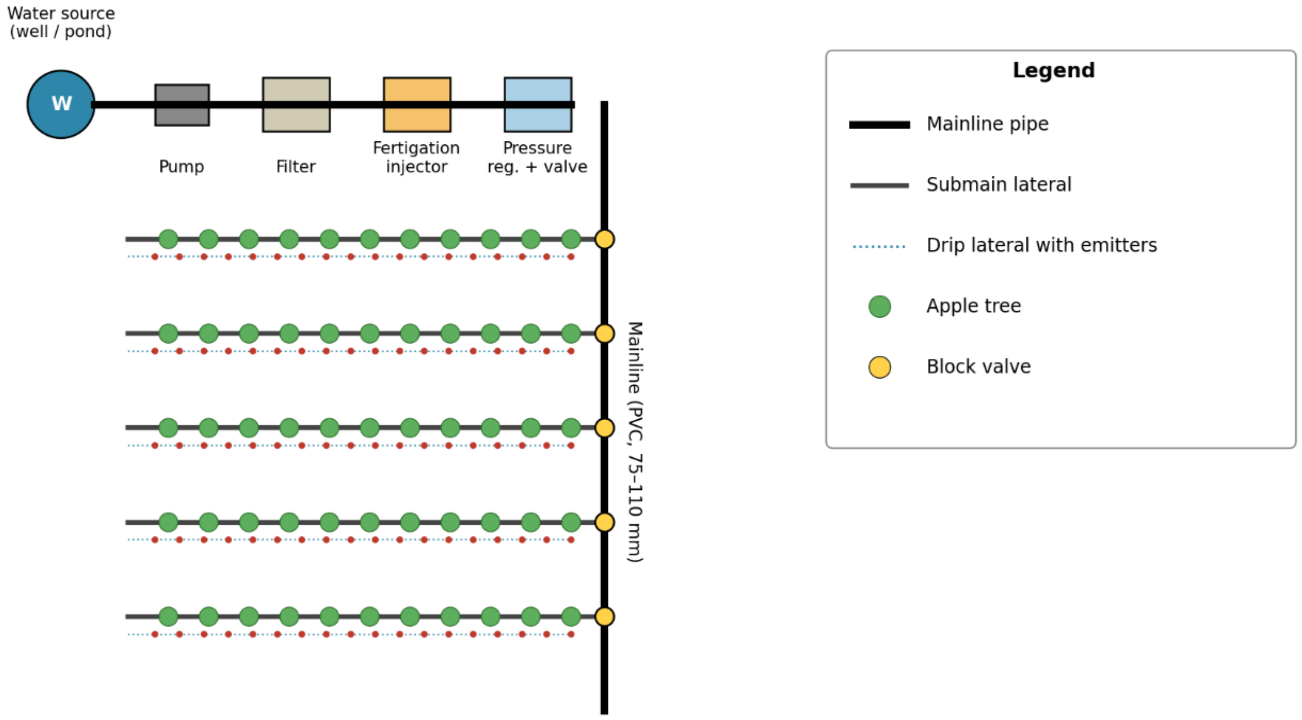
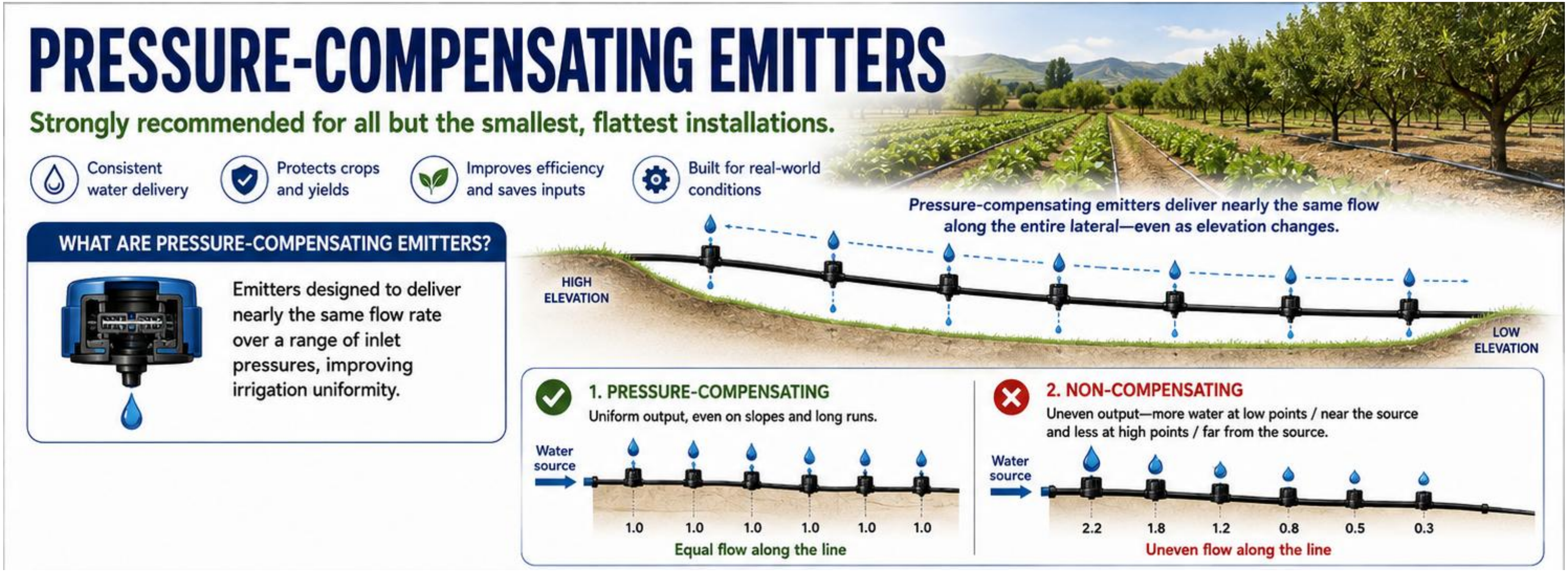


Figure 37 Plan view of a typical drip irrigation layout for an apple orchard: main line (heavy black), sub-mains servicing each block (medium), laterals along each tree row (thin), with emitters spaced along the laterals. Hydraulic zones are demarcated by zone valves; each zone is operated as an independent unit on a programmed schedule.

Pressure-compensating Emitters



IRRIGATION SYSTEMS

Pressure-compensating Emitters

Pressure-compensating

Pressure-compensating emitters are strongly recommended for all but the smallest, flattest installations. They maintain uniform discharge across a wide pressure range (typically 80 to 350 kPa), automatically compensating for elevation differences and friction losses along the lateral. The slight additional cost (5 to 10 percent of total lateral cost) is repaid in higher uniformity and lower operational stress.

IRRIGATION SYSTEMS

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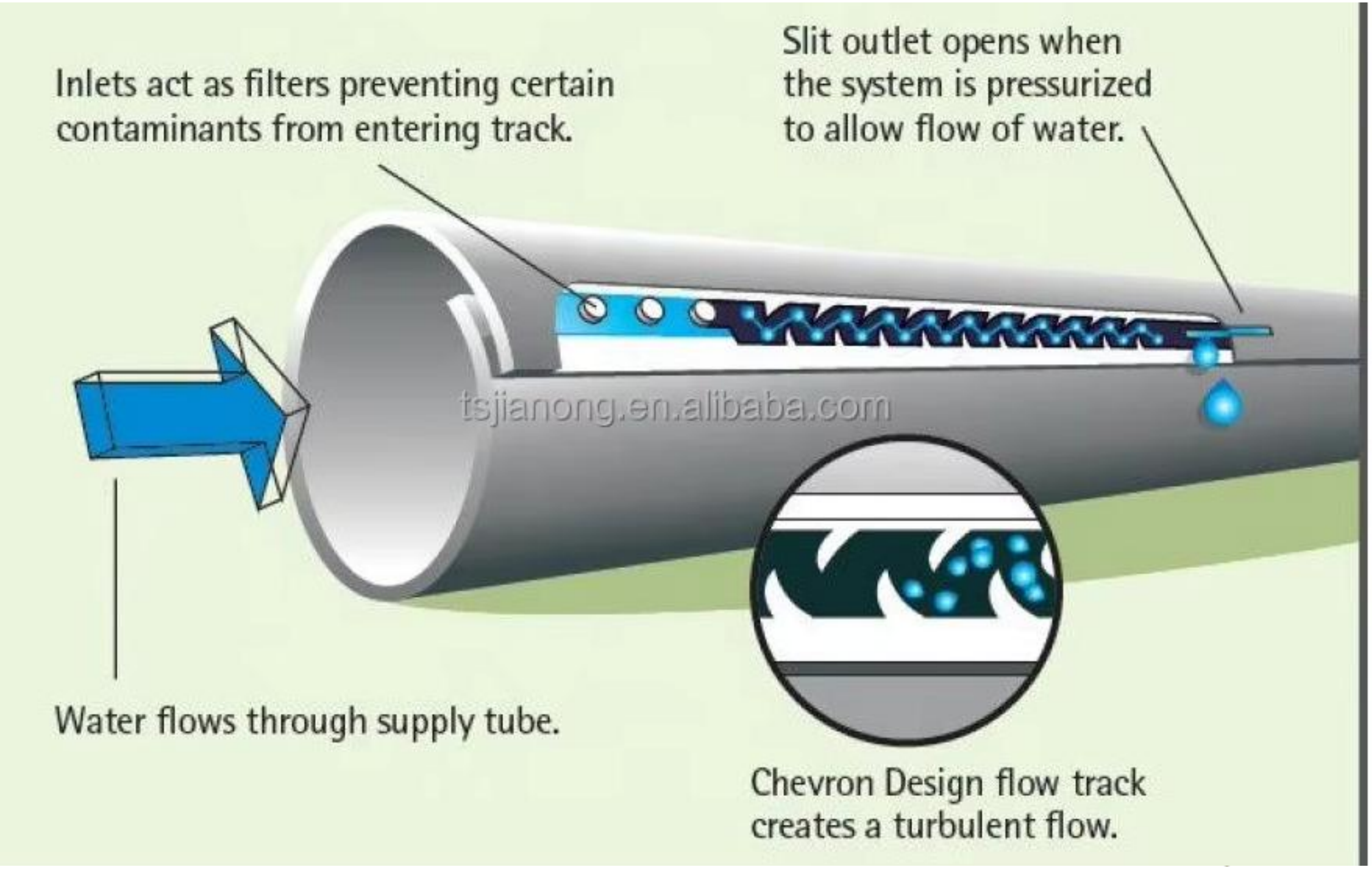
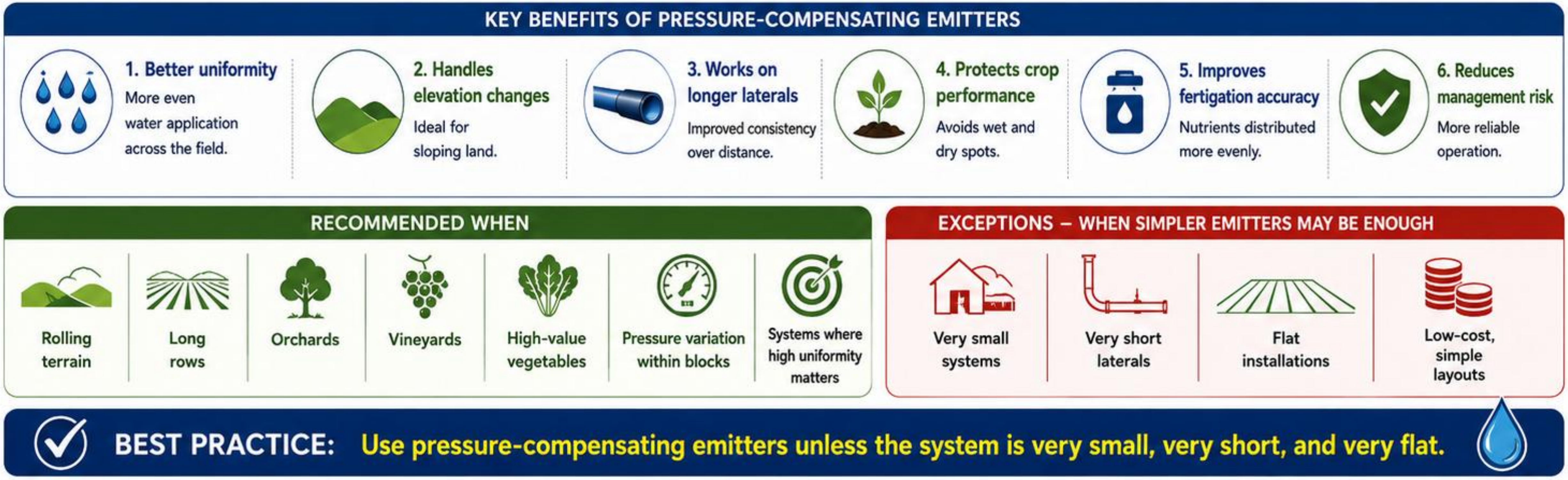


IRRIGATION SYSTEMS

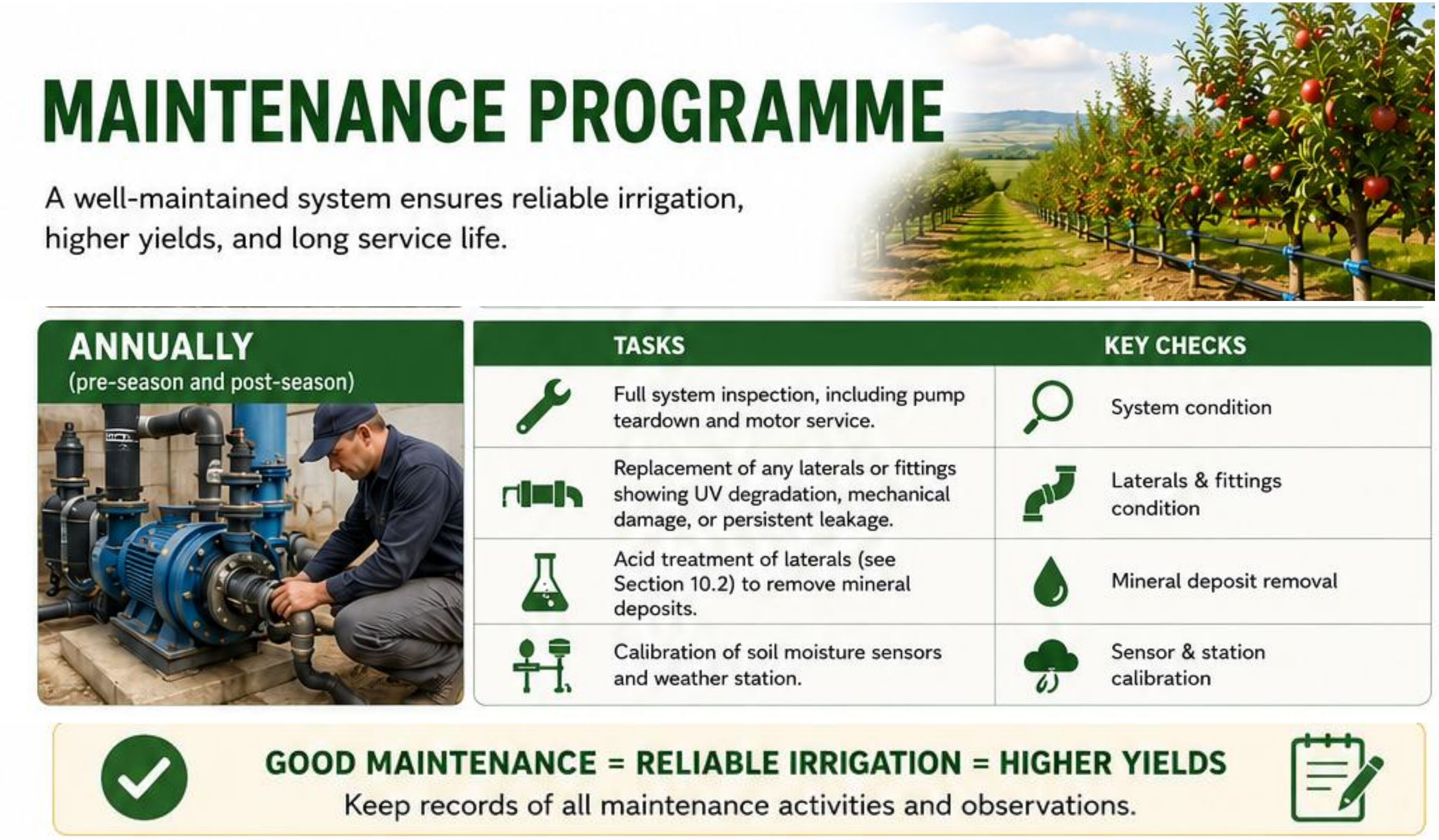
Pressure-compensating Emitters

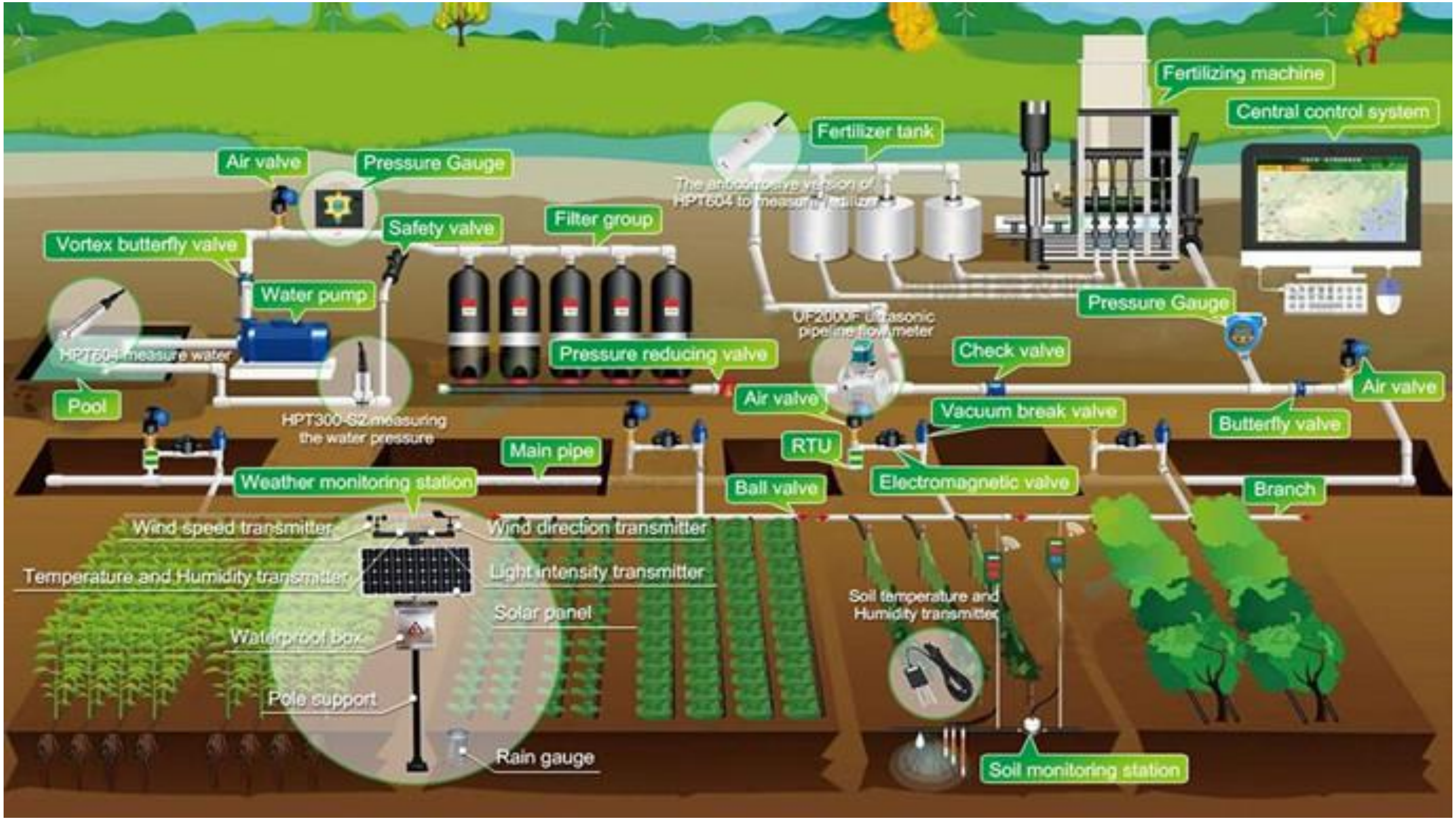


IRRIGATION SYSTEMS

Operation

Routine System checks




Fertilizing machine
Central control system
Fertilizer tank
Air valve
Pressure Gauge
Safety valve
Filter group
Vortex butterfly valve
Water pump
HPT604 measure water
Pool
HPT300-S2 measuring the water pressure
Pressure reducing valve
Pressure Gauge
Check valve
Air valve
Air valve
Vacuum break valve
Butterfly valve
RTU
Main pipe
Weather monitoring station
Ball valve
Electromagnetic valve
Branch
Wind speed transmitter
Wind direction transmitter
Temperature and Humidity transmitter
Light intensity transmitter
Solar panel
Waterproof box
Soil temperature and Humidity transmitter
Pole support
Rain gauge
Soil monitoring station

IRRIGATION SYSTEMS

Installation

Best Practices

Whatever the design, the system’s long-term performance depends on installation quality. Common installation problems that can severely compromise an otherwise good design include:

- Inadequate trench depth for buried pipework, leading to mechanical damage from cultivation and frost heave in cold winters.
- Imperfectly cleaned or jointed pipe, allowing debris into the system that subsequently clogs emitters.
- Mismatched fittings (different manufacturers, different pressure ratings) producing failures at the joints.
- Inadequate flushing of new pipe before commissioning, leaving manufacturing debris that destroys filters and emitters in the first weeks of operation.
- Insufficient air valves and pressure-relief valves at high points and at the pump discharge.
- Incorrect or absent labelling of valves, making subsequent troubleshooting difficult.

Standard installation practice for a Ukrainian commercial apple orchard drip system includes: pre-installation site marking and verification of tree row geometry; trenching for buried mains at 0.6 to 1.0 m depth (below the frost line); pressure-testing of all buried pipe before backfilling; thorough flushing of the entire main and sub-main network at design flow rate; commissioning of filters with a controlled increase in flow over the first hour; and a 30-day post-installation inspection to identify and correct any defects under warranty.

IRRIGATION SYSTEMS

Installation

Pipe Layout and Spacing

Mainlines and sub-mainlines are typically buried (60–80 cm depth) and made of PVC or PE. Drip laterals are above-ground (surface drip) or 15–35 cm below the surface (SDI). For carrot and beet sown in twin-row beds 1.4 m wide, one lateral per bed with 30 cm emitter spacing and 2 L/h emitters gives an instantaneous application rate of 4.8 mm/h. For cabbage at 0.6 m × 0.5 m, one lateral per row with 0.5 m emitter spacing and 2 L/h emitters delivers 2.4 mm/h. For onion planted in twin or quadruple rows on 1.2 m beds, two laterals per bed with 0.2–0.3 m emitter spacing are appropriate.

IRRIGATION SYSTEMS

Operation

MAINTENANCE PROGRAMME

A well-maintained system ensures reliable irrigation, higher yields, and long service life.

DAILY during the irrigation season

TASKS	KEY CHECKS
Check pump and motor for unusual noise, vibration, or leaks; verify operating pressure at the pump discharge.	Pressure at pump discharge
Inspect filter pressure differential and backflush if elevated above set point.	Filter pressure differential
Verify that the programmed irrigation cycle has run as intended; check log of valve operations.	Irrigation cycle & valve log
Walk one block per day on a rotation to detect leaks, missing emitters, and damaged laterals.	Leaks, missing emitters, damaged laterals

GOOD MAINTENANCE = RELIABLE IRRIGATION = HIGHER YIELDS

Keep records of all maintenance activities and observations.

IRRIGATION SYSTEMS

Operation

Routine System checks

IRRIGATION SYSTEMS

Operation

Routine System checks

MAINTENANCE PROGRAMME

A well-maintained system ensures reliable irrigation, higher yields, and long service life.

MONTHLY

TASKS	KEY CHECKS
Flush each lateral by opening the end cap and running the system for 1 to 2 minutes until water runs clear.	Clear flush water
Disassemble, inspect, and clean a sample of emitters (typically 1 percent of total) to detect any clogging trends early.	Emitter condition & clogging trends
Check accuracy of flow meter; record cumulative water use.	00234 Flow meter accuracy & cumulative use
Test all pressure switches, alarms, and automatic shutdowns.	Alarms & shutdown function

GOOD MAINTENANCE = RELIABLE IRRIGATION = HIGHER YIELDS

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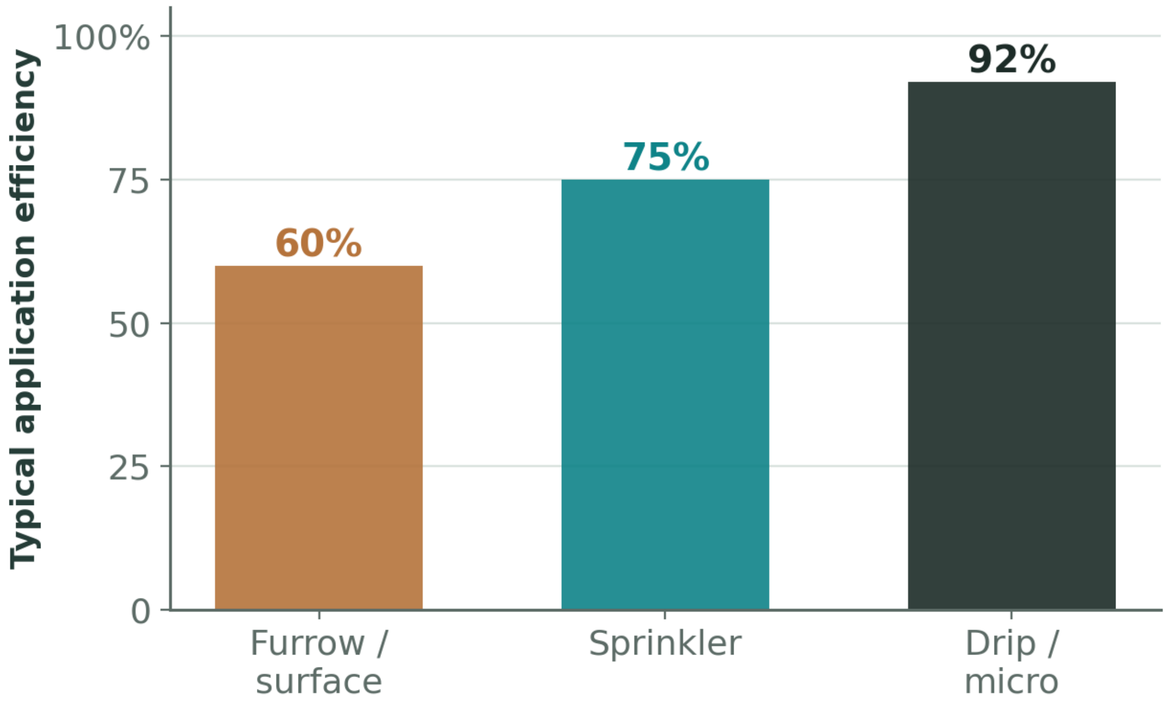
CHOOSING

Sprinkler vs drip — at a glance



Application efficiency: share of water reaching the root zone

	Sprinkler	Drip
Efficiency	70–85%	85–95%
Uniformity	Good	Very high
Area wetted	Whole field	Root zone
Wind / evap loss	Moderate	Very low
Pressure / energy	Higher	Lower
Salts on leaves	Possible	Avoided
Best soils	Most*	All, esp. sand

**cut the application rate on clay to avoid runoff*

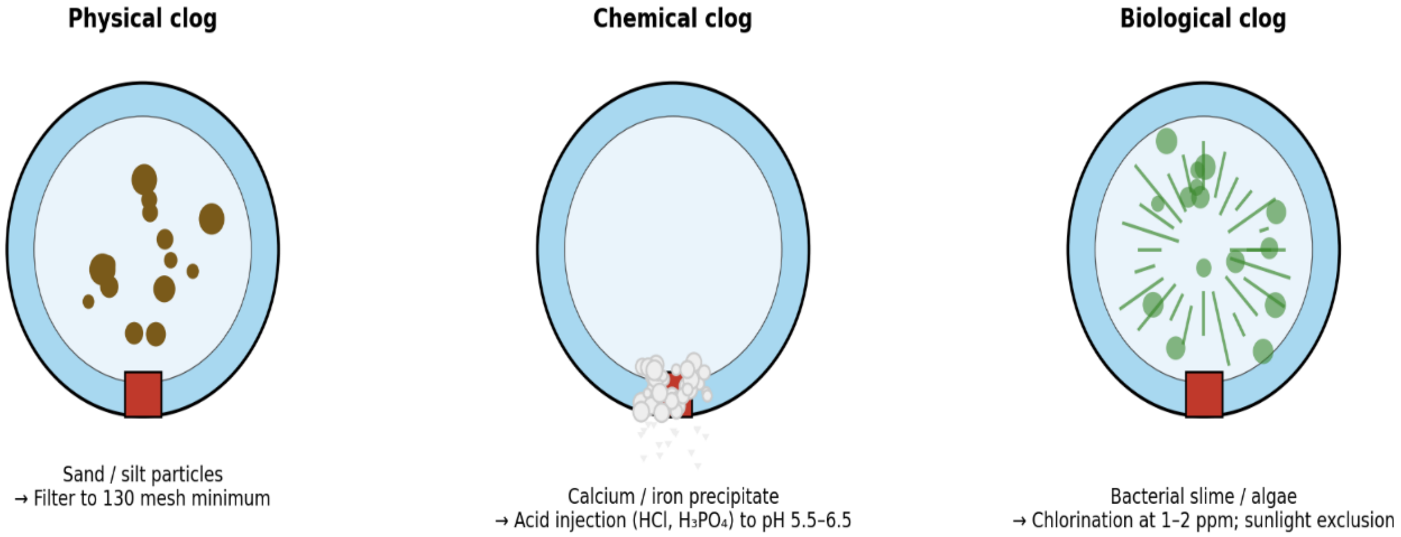
IRRIGATION SYSTEMS

Operation

Preventing and Resolve Clogging

Chemical clogging is caused by precipitation of calcium carbonate (the most common in Ukrainian waters), calcium phosphate (from fertigation), iron oxide, and manganese oxide. Prevention requires: water analysis at the design stage; acid injection to maintain pH below 6.5 (typically sulphuric or phosphoric acid for routine treatment, nitric acid for occasional pulse-treatment); and avoidance of incompatible fertiliser combinations. Treatment of established mineral clogging is by acid pulse: an acid solution (typically pH 2–3) is circulated through the system for 30 to 60 minutes, then flushed thoroughly with clear water. This is normally a post-season operation.

Physical clogging is caused by sand, silt, organic debris, or filter media that has passed downstream of filtration. Prevention requires: appropriately sized filtration for the water source (Chapter 9); regular flushing of laterals; and prompt response to any increase in filter pressure differential. Treatment is mechanical: backflushing the filter, flushing the laterals at high velocity, and — if individual emitters are blocked — physical cleaning or replacement.



IRRIGATION SYSTEMS

Preventing and Resolve Clogging

TYPE OF CLOGGING	CAUSES	PREVENTION	TREATMENT
PHYSICAL CLOGGING	Caused by sand, silt, organic debris, or filter media that has passed downstream of filtration.	• Appropriately sized filtration for the water source (Chapter 9). • Regular flushing of laterals. • Prompt response to any increase in filter pressure differential.	**Mechanical:** • Backflushing the filter. • Flushing the laterals at high velocity. • If individual emitters are blocked — physical cleaning or replacement.
$CaCO_3$ $Ca_3(PO_4)_2$ Fe_2O_3 MnO_2 **CHEMICAL CLOGGING**	Caused by precipitation of calcium carbonate (the most common in Ukrainian waters), calcium phosphate (from fertigation), iron oxide, and manganese oxide.	• Water analysis at the design stage. • Acid injection to maintain pH below 6.5 (typically sulphuric or phosphoric acid for routine treatment, nitric acid for occasional pulse-treatment). • Avoidance of incompatible fertiliser combinations. pH < 6.5	**Acid pulse:** An acid solution (typically pH 2–3) is circulated through the system for 30 to 60 minutes, then flushed thoroughly with clear water. This is normally a post-season operation. 30–60 min
BIOLOGICAL CLOGGING	Caused by algae, bacterial slime, and the iron-bacteria complexes characteristic of some groundwaters.	• Light-exclusion of water in surface tanks and reservoirs. • Periodic chlorine shock-treatment (typically 5 to 10 ppm free chlorine for 30 to 60 minutes, then flushing). • Avoidance of long stagnant periods. • Acidification also suppresses bacterial growth and helps prevent biological clogging. Cl pH < 6.5	**Chlorine pulse:** For established biological clogging, apply a chlorine pulse at higher concentration (20 to 50 ppm), with full flushing afterwards. Cl 20–50 ppm

Good design, appropriate filtration, regular maintenance and water quality management are the keys to preventing and controlling clogging and ensuring uniform irrigation and high yields.

IRRIGATION SYSTEMS

IRRIGATION TROUBLESHOOTING TABLE

Symptoms, probable causes, and recommended actions for orchard irrigation systems

Symptom	Probable cause	Recommended action
Low pressure at zone head	Pump worn / pipe leak / closed valve	Inspect pump output, check for leaks, verify valves
High pressure at zone head	Closed downstream valve / scaled regulator	Check zone valves and pressure regulator function
Wet patches across blocks	Buried main leak / lateral split	Locate leak by inspection or flow tracking
Dry trees in middle of row	Clogged emitters / damaged lateral	Flush lateral, replace emitters or section
Trees at row end stressed	Lateral length too long / inadequate flush	Check uniformity, flush regularly, consider PC emitters
Filter clogs rapidly	Source water deteriorated / algae bloom	Test water, install pre-filter or shading
Emitters drip after shutdown	No check valves / no anti-drain emitters	Install check valves, replace with anti-drain emitters
Uniform yellowing despite irrigation	Waterlogging / root disease	Check drainage, dig pit, assess root health
Salt crusts on soil surface	Saline water / inadequate leaching	Test water, plan leaching irrigation
Emitters output declines over years	Mineral scale / biological buildup	Annual acid and chlorine treatments

Fast diagnosis and timely maintenance improve irrigation uniformity, crop health, and system life.

by **Bodem&Groen**

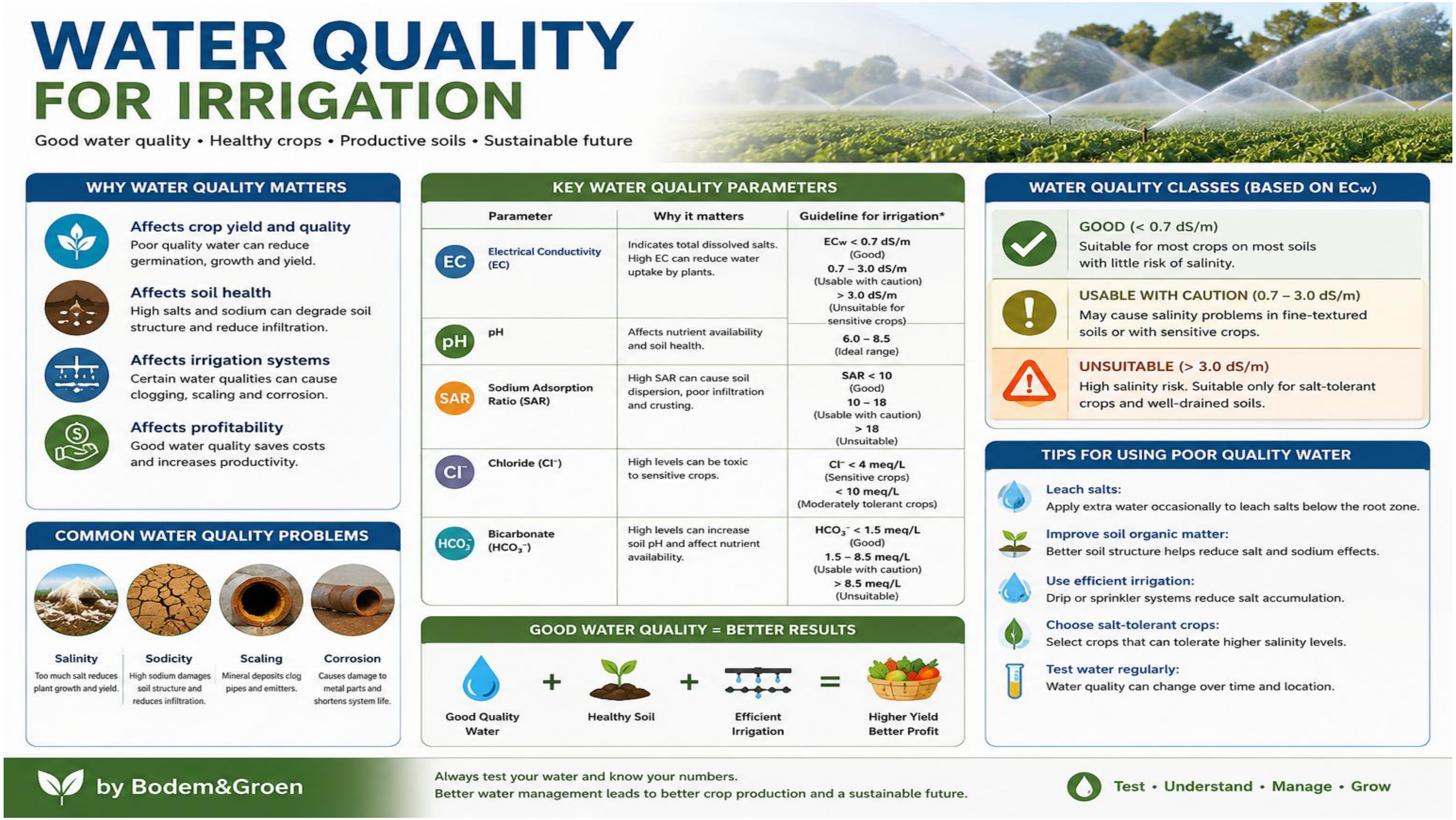
IRRIGATION SYSTEMS

Winter Season

Ukrainian winters can produce freezing of water in irrigation pipes, with consequent damage from expansion. Winterization is therefore a critical pre-winter task in all orchard regions. A proper winterization sequence includes:

- Apply the final irrigation of the season (the "winter watering"), typically in mid-October, to bring the soil profile to field capacity before freeze-up. This protects roots from desiccation during freeze-thaw cycles.
- Inject acid through the system to maintain pH at 5.5 to 6.0 in the final irrigation event, then flush briefly to clear the lines without removing the residual acid that suppresses biological activity over winter.
- Drain the system. Open all flush valves, drain valves, and lateral end caps; remove water from low points and from the pump and filter assemblies. Compressed-air blow-out is recommended for sub-mains and mains where complete drainage by gravity is not possible.
- Remove and store indoors all easily damaged components: pressure regulators, flow meters, solenoid valves, controllers, sensors. Cover and protect the pump and motor against ice and animal damage.
- Inspect and document the system condition for spring start-up.

Surface drip laterals are usually left in place over winter. They tolerate moderate freezing if fully drained. The principal winter risks are mechanical damage from rodents, hares (which gnaw on plastic), and accidental damage during dormant pruning operations. Inspection in late winter to identify and repair such damage before spring start-up is recommended.

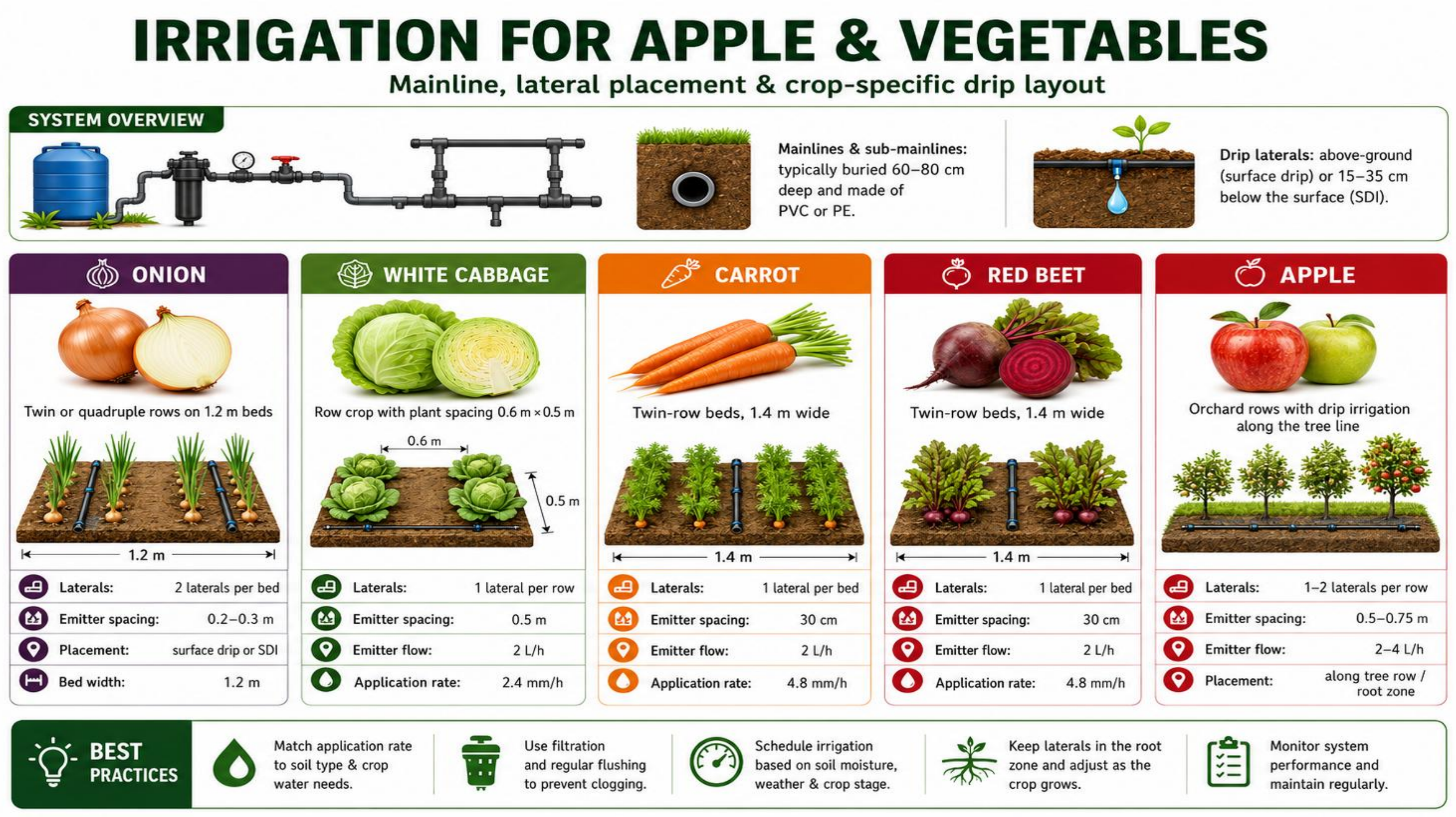

WATER QUALITY
FOR IRRIGATION
Good water quality • Healthy crops • Productive soils • Sustainable future
WHY WATER QUALITY MATTERS
Affects crop yield and quality
Poor quality water can reduce germination, growth and yield.
Affects soil health
High salts and sodium can degrade soil structure and reduce infiltration.
Affects irrigation systems
Certain water qualities can cause clogging, scaling and corrosion.
Affects profitability
Good water quality saves costs and increases productivity.
COMMON WATER QUALITY PROBLEMS
Salinity
Too much salt reduces plant growth and yield.
Sodicity
High sodium damages soil structure and reduces infiltration.
Scaling
Mineral deposits clog pipes and emitters.
Corrosion
Causes damage to metal parts and shortens system life.
KEY WATER QUALITY PARAMETERS
Parameter
Why it matters
Guideline for irrigation*
EC
Electrical Conductivity (EC)
Indicates total dissolved salts. High EC can reduce water uptake by plants.
ECw < 0.7 dS/m (Good)
0.7 – 3.0 dS/m (Usable with caution)
> 3.0 dS/m (Unsuitable for sensitive crops)
pH
pH
Affects nutrient availability and soil health.
6.0 – 8.5 (Ideal range)
SAR
Sodium Adsorption Ratio (SAR)
High SAR can cause soil dispersion, poor infiltration and crusting.
SAR < 10 (Good)
10 – 18 (Usable with caution)
> 18 (Unsuitable)
Cl⁻
Chloride (Cl⁻)
High levels can be toxic to sensitive crops.
Cl⁻ < 4 meq/L (Sensitive crops)
< 10 meq/L (Moderately tolerant crops)
HCO₃⁻
Bicarbonate (HCO₃⁻)
High levels can increase soil pH and affect nutrient availability.
HCO₃⁻ < 1.5 meq/L (Good)
1.5 – 8.5 meq/L (Usable with caution)
> 8.5 meq/L (Unsuitable)
GOOD WATER QUALITY = BETTER RESULTS
Good Quality Water + Healthy Soil + Efficient Irrigation = Higher Yield Better Profit
WATER QUALITY CLASSES (BASED ON ECw)
GOOD (< 0.7 dS/m)
Suitable for most crops on most soils with little risk of salinity.
USABLE WITH CAUTION (0.7 – 3.0 dS/m)
May cause salinity problems in fine-textured soils or with sensitive crops.
UNSUITABLE (> 3.0 dS/m)
High salinity risk. Suitable only for salt-tolerant crops and well-drained soils.
TIPS FOR USING POOR QUALITY WATER
Leach salts:
Apply extra water occasionally to leach salts below the root zone.
Improve soil organic matter:
Better soil structure helps reduce salt and sodium effects.
Use efficient irrigation:
Drip or sprinkler systems reduce salt accumulation.
Choose salt-tolerant crops:
Select crops that can tolerate higher salinity levels.
Test water regularly:
Water quality can change over time and location.
by Bodem&Groen
Always test your water and know your numbers.
Better water management leads to better crop production and a sustainable future.
Test • Understand • Manage • Grow

IRRIGATION

Water Conservation

Rainwater Harvesting

On-farm storage ponds and tanks turn winter and spring rainfall into summer irrigation supply. A pond holding 4 000–6 000 m³ per irrigated hectare is sufficient to bridge a six-week drought on most southern Ukrainian vegetable rotations. Roof catchment from large packing sheds and machinery buildings, channelled to lined ponds, supplies high-quality, low-sediment water that is particularly suitable for drip irrigation of fresh-market produce.


IRRIGATION FOR APPLE & VEGETABLES
Mainline, lateral placement & crop-specific drip layout
SYSTEM OVERVIEW
Mainlines & sub-mainlines: typically buried 60–80 cm deep and made of PVC or PE.
Drip laterals: above-ground (surface drip) or 15–35 cm below the surface (SDI).
ONION
Twin or quadruple rows on 1.2 m beds
1.2 m
Laterals: 2 laterals per bed
Emitter spacing: 0.2–0.3 m
Placement: surface drip or SDI
Bed width: 1.2 m
WHITE CABBAGE
Row crop with plant spacing 0.6 m × 0.5 m
0.6 m
0.5 m
Laterals: 1 lateral per row
Emitter spacing: 0.5 m
Emitter flow: 2 L/h
Application rate: 2.4 mm/h
CARROT
Twin-row beds, 1.4 m wide
1.4 m
Laterals: 1 lateral per bed
Emitter spacing: 30 cm
Emitter flow: 2 L/h
Application rate: 4.8 mm/h
RED BEET
Twin-row beds, 1.4 m wide
1.4 m
Laterals: 1 lateral per bed
Emitter spacing: 30 cm
Emitter flow: 2 L/h
Application rate: 4.8 mm/h
APPLE
Orchard rows with drip irrigation along the tree line
Laterals: 1–2 laterals per row
Emitter spacing: 0.5–0.75 m
Emitter flow: 2–4 L/h
Placement: along tree row / root zone
BEST PRACTICES
Match application rate to soil type & crop water needs.
Use filtration and regular flushing to prevent clogging.
Schedule irrigation based on soil moisture, weather & crop stage.
Keep laterals in the root zone and adjust as the crop grows.
Monitor system performance and maintain regularly.

IRRIGATION APPLE

Stage and Water Demand

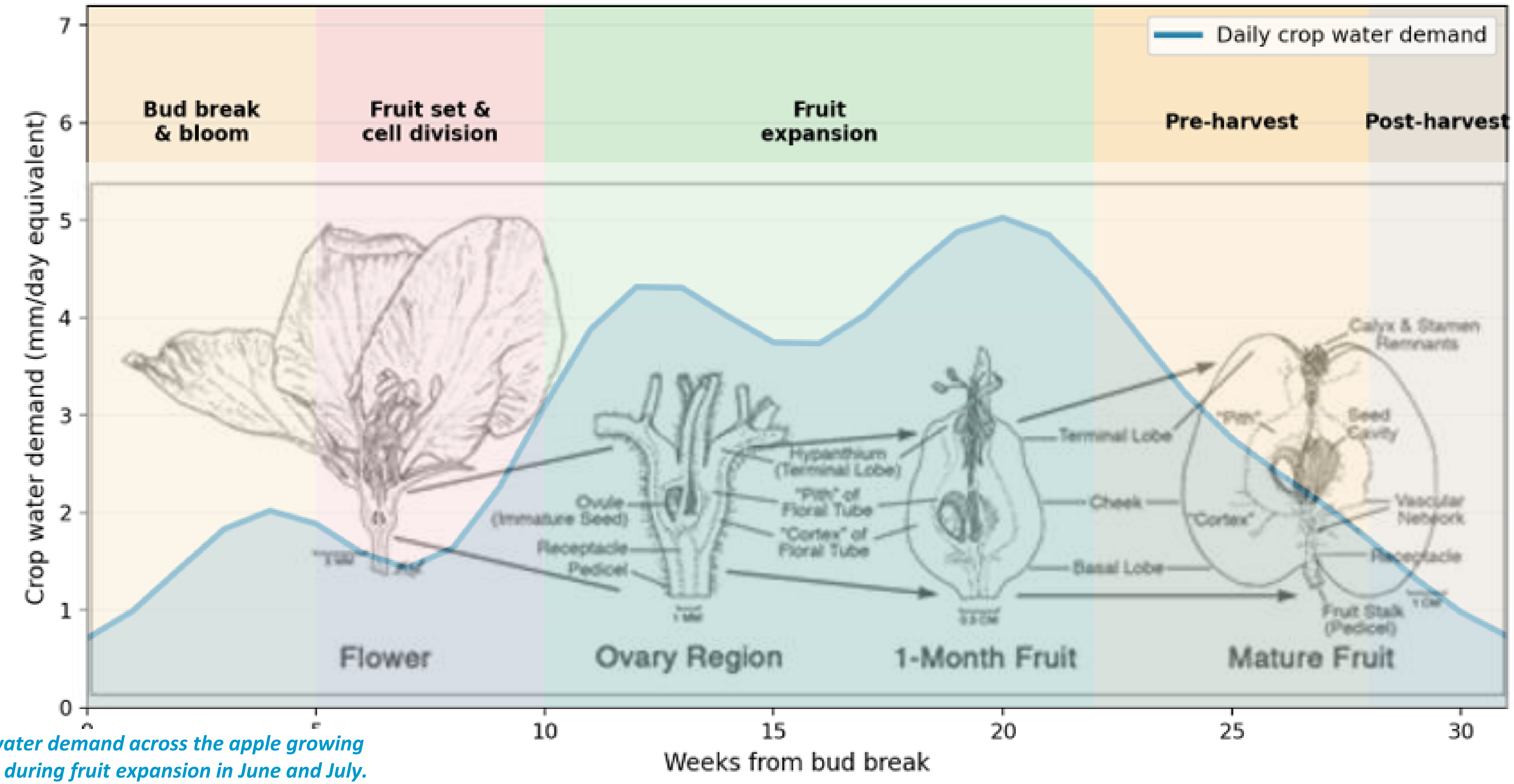
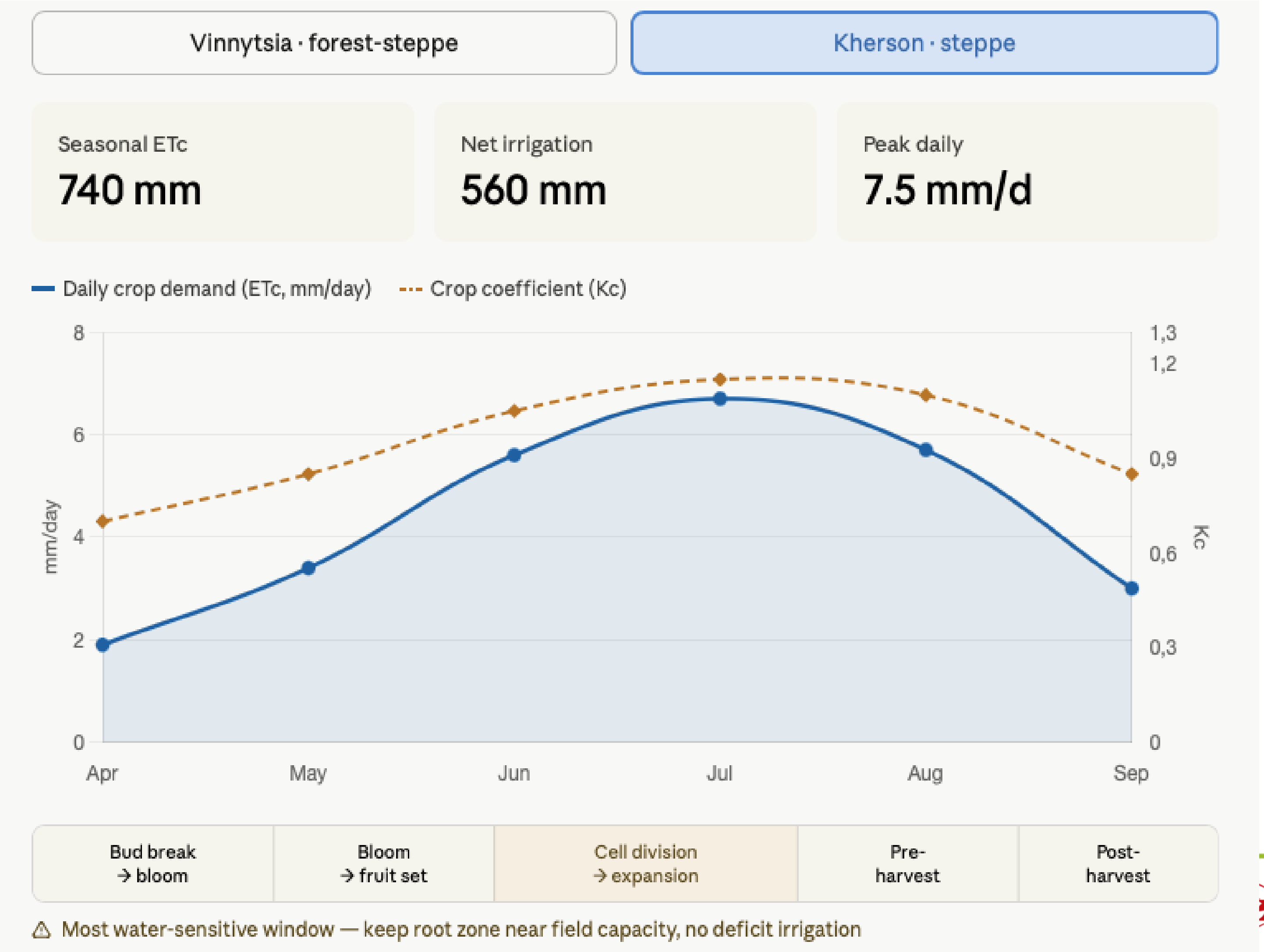


Figure 5 — Critical growth stages and approximate daily water demand across the apple growing season under central-Ukrainian conditions. Demand peaks during fruit expansion in June and July.

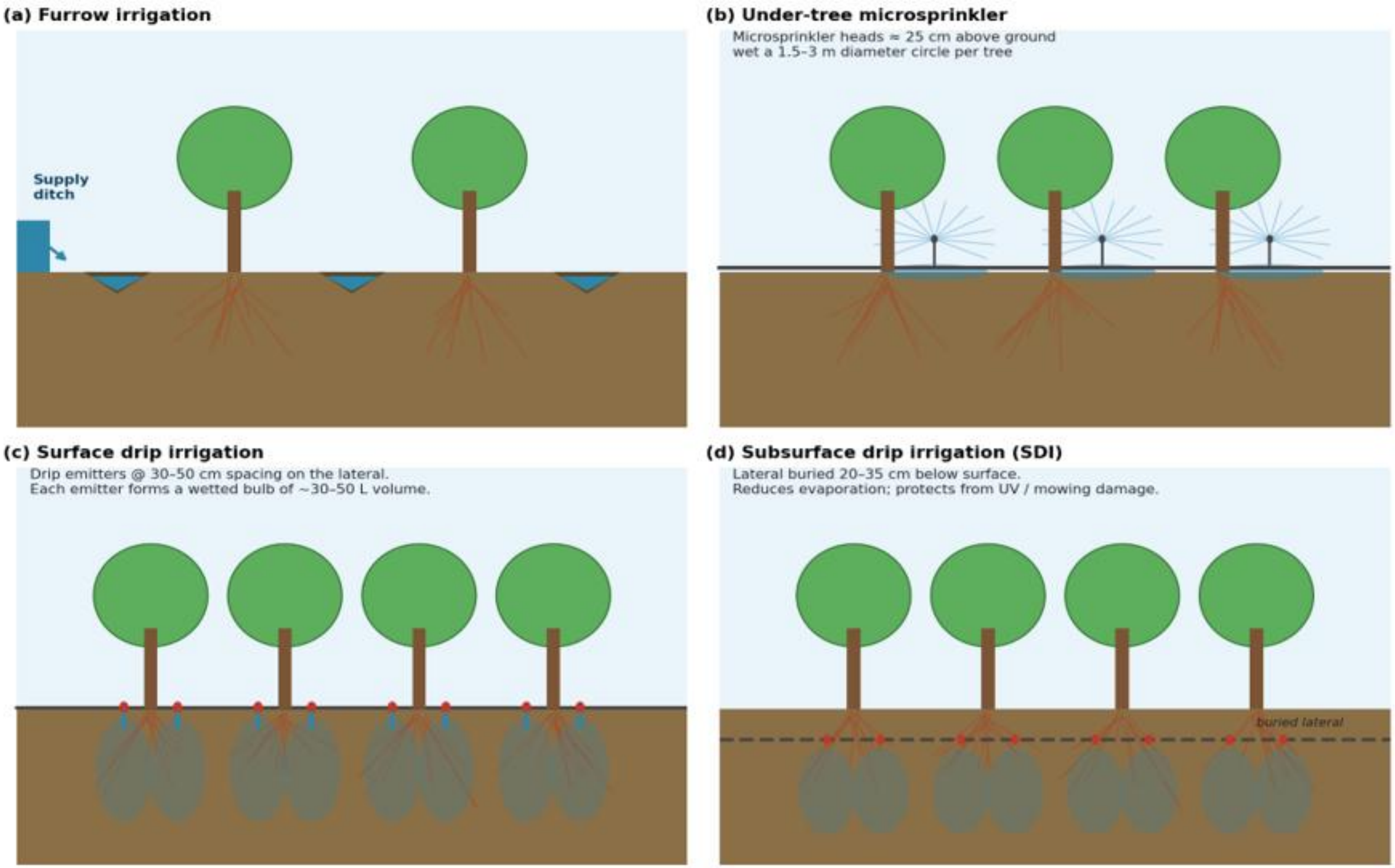
IRRIGATION APPLE

When and how much to irrigate



IRRIGATION APPLE

Systems Apple



Schematic comparison of four irrigation systems used in apple orchards: (a) furrow irrigation, (b) microsprinkler, (c) surface drip, (d) subsurface drip irrigation (SDI). System choice influences water-use efficiency, capital cost, labour requirement, and suitability for fertigation.

Thank you for your attention!