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Exploring Technology's Role in Food Security



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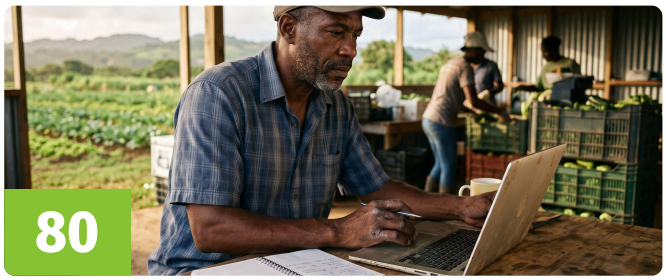

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TECHNOLOGY & INNOVATION

The Question Comes Before the Image

Advisory Review by **Dr. Dexter Davis**

Satellite and drone imagery can reveal valuable differences across a farm, but only when the technology matches the question. This article explains how resolution, revisit timing, cloud cover, sensor type, NDVI, thermal data, and map processing shape what an image can actually tell you, helping readers know what to ask for before paying for imagery or acting on the results.

Satellite pictures and drone-based maps are not interchangeable, and neither one is a general-purpose tool. What separates them is how much ground goes into a single pixel, how often that ground gets a clear look, and which wavelengths are being recorded.

Thirty meters by thirty meters. That is 900 square meters of ground, enough to hold a small planting, a shed, a headland, and a drain.

On a Landsat 8 or 9 image, that whole square is one pixel in most of the wavelength bands the satellite records. In each of those bands, the pixel holds a single value, drawn from everything inside the square.

This is what spatial resolution means, though the term is easily mistaken for sharpness. Spatial resolution describes how much ground goes into a single measurement.

Three things limit what a view from above can tell you, and all three are settled before anyone presses a button: how finely the ground is divided, how often it gets looked at, and what the sensor is set up to record. Get any of them wrong for the question you are asking and you end up holding a perfectly good image that cannot answer it.

The Size of the Thing You Need to Find

Not every band on Landsat 8 and 9 records at 30 meters. One finer band works at 15 meters, and the two thermal bands are measured at 100 meters and resampled to 30 when the image is delivered. Sentinel-2 goes finer, down to 10 meters, but only in some of its bands, and this is the part that trips people up. It carries thirteen bands working at three different scales: four at 10 meters, six at 20, and three at 60.

Instead of asking whether a satellite is high resolution, ask which of its bands your job needs. The bands decide what can be measured, and their spatial resolution decides how much detail you get.

A patch smaller than the pixel does not disappear. It contributes to the value that pixel records, mixed in with everything else in the same square. What it cannot do is appear as a separate feature you can point at, however much it moves the number.

The grid is no help with this either. Pixels fall on a fixed layout that is not connected to your boundaries, so the edge of a plot runs through pixels that are part crop and part road, or part crop and part somebody else's bush.

A drone changes the terms entirely. On Landsat and Sentinel-2, pixel sizes are a property of the mission, fixed in orbit years before your field became interesting to anyone. With drone imagery, the resolution depends on the camera and the drone's flying height, and the height is set when the



A Drone Changes the Scale

With drone imagery, the level of detail depends on the camera and flying height. That makes flight planning part of the imaging decision.

flight is planned. The detail can run down to the centimeter level, far finer than either Landsat or Sentinel-2 can deliver.

Between One Usable Image and the Next

Landsat 8 and Landsat 9 share the work. Each passes over the same ground every sixteen days, offset from one another by eight, so between them that ground can be imaged every eight days. Sentinel-2 comes back more often: every ten days for a single satellite, and every five days at the equator with the standard two-satellite pairing.

Those numbers describe how often a satellite can look. They say nothing about how often it will ‘see’.

Each time a satellite records your block, you get a chance at a usable image, not a guarantee of one. Clouds can hide the ground, and in the tropics that happens often. When the oldest Sentinel-2 satellite was kept in service after its replacement took over in 2025, part of its new work was adding looks over tropical Africa and South America, regions frequently under heavy cloud.

The interval that matters, then, is the gap between one usable image of your block and the next, and that depends on the cloud sitting over that block as well as on the orbit. The practical way to find yours is to check what the archive actually holds for those coordinates across a season.

A drone eases both limits. It normally flies beneath the clouds, so cloud cover does not hide the ground from it the way it does from an optical satellite, and a flight can be arranged for the week that matters instead of waiting on an orbit. It still depends on the weather and on having an operator available, and patchy cloud can leave spots and streaks in the images as the light changes.

Radar satellites deal with clouds another way. They send out their own signal rather than waiting on sunlight, so they can work day or night, and the microwaves they use pass through clouds and most weather. The returning signal responds to the

Spatial resolution describes how much ground goes into a single measurement.

structure, roughness, and moisture of the surface, and reading it is a different skill that takes different training. Radar is worth knowing about, but it records different information from an optical image.

Red, Near-Infrared, and What They Cannot Separate

An ordinary camera produces images much like what your eye sees. A multispectral sensor records light in separate bands, such as red and near-infrared, and near-infrared is light your eye cannot see. A thermal sensor detects thermal infrared radiation emitted by a surface, which can be used to estimate its temperature. These sensing capabilities can be combined in different ways on satellites and drones. Sentinel-2 is multispectral and has no thermal band at all.

NDVI, the Normalized Difference Vegetation Index, is built from two of those bands, red and near-infrared. Healthy green leaves absorb much of the red light that reaches them and reflect a great deal of near-infrared, so comparing the two gives a single number for greenness. It is one of the most widely used measures in crop imagery. It reads differences in vegetation density and changes in crop condition, and it does that well.

What it will not do, is tell you why. A block reading low against the rest of the field is telling you that something is different about the vegetation there. More than one thing can produce that reading: too little water, a nutrient shortage, pest or disease damage, or simply a thinner stand. The index has no means of telling them apart. The answer comes from the ground, with somebody standing in the block.

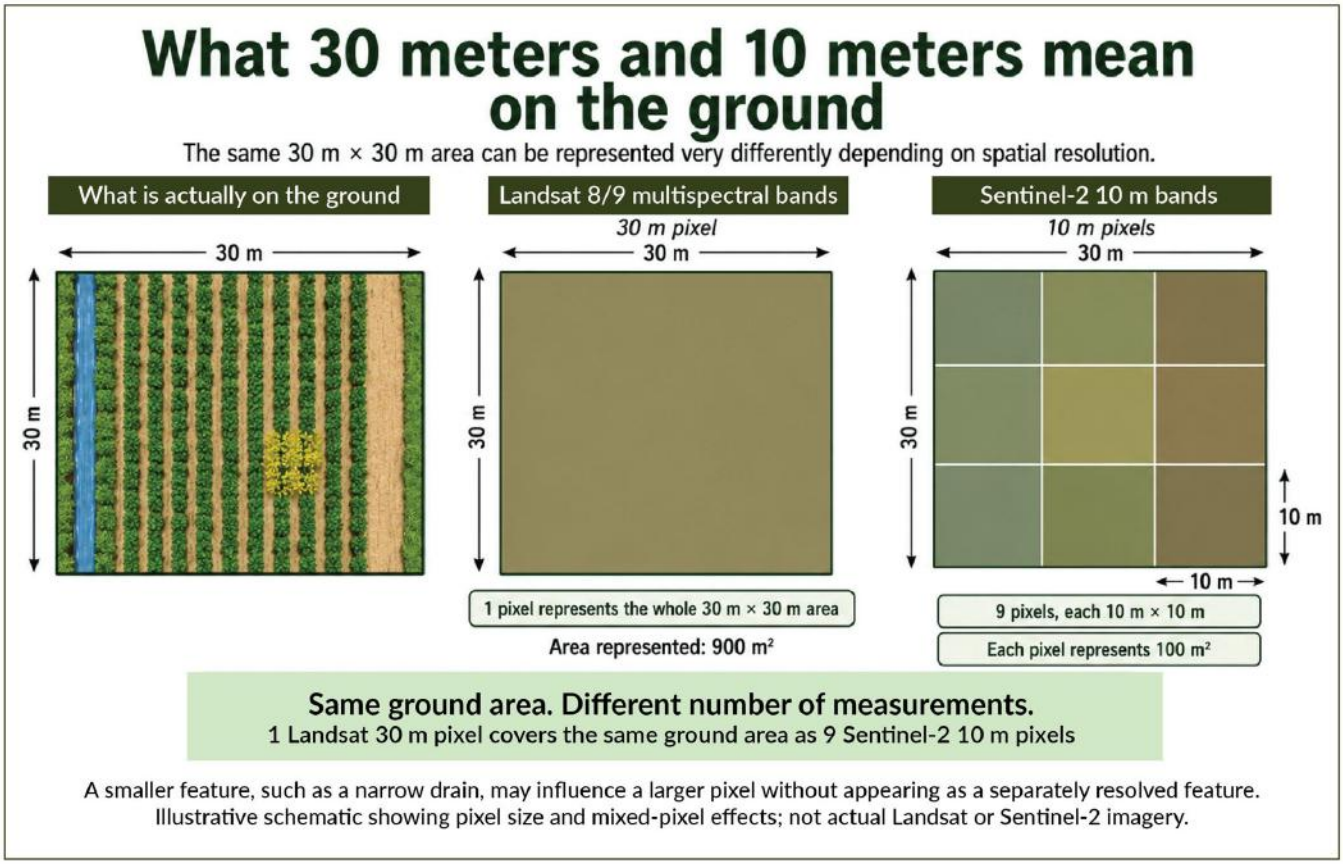
The index also loses sensitivity as the canopy closes. Once cover is full, NDVI levels off, and differences that still matter to the crop become harder to pick out.

And sometimes it is the wrong measurement altogether. In one irrigation trial, NDVI distinguished the rainfed block from the fully irrigated one but could not cleanly separate the treatments in between, and the researchers concluded a thermal sensor would have shown the cooling effect of irrigation better. It was one trial on one crop, so read it as an illustration rather than a rule. The measurement has to suit the question.

One more point connects back to detail. On Sentinel-2, the red and near-infrared bands usually used for NDVI are both native 10-meter bands. NDVI from that satellite can therefore be calculated at 10 meters rather than at the coarser 20- or 60-meter scale of some of its other bands. On Landsat and Sentinel-2, then, what you choose to measure also limits how finely you can see it. With the right sensors, a drone can do some of the same analysis: a multispectral camera gives it NDVI, and a thermal camera gives it surface temperature, both at a detail set by the camera and the flying height.

The Work Between the Flight and the Map

Landsat and Sentinel-2 products arrive already georeferenced, tied to real-world coordinates on the ground. A mapping drone records location as well: its GPS and motion sensors log the position and angle of the camera for every frame, and with RTK correction, that position can be accurate to within a few centimeters. What a drone flight does not deliver is a finished map. It comes back as many overlapping frames, each a photograph of part of a



field, and they have to be stitched into one georeferenced map before an index can be calculated across the block. That takes software, and some training to use it well.

Then somebody has to read the result. In the irrigation work above, that took skill: some differences were plain, and others were genuinely hard to call.

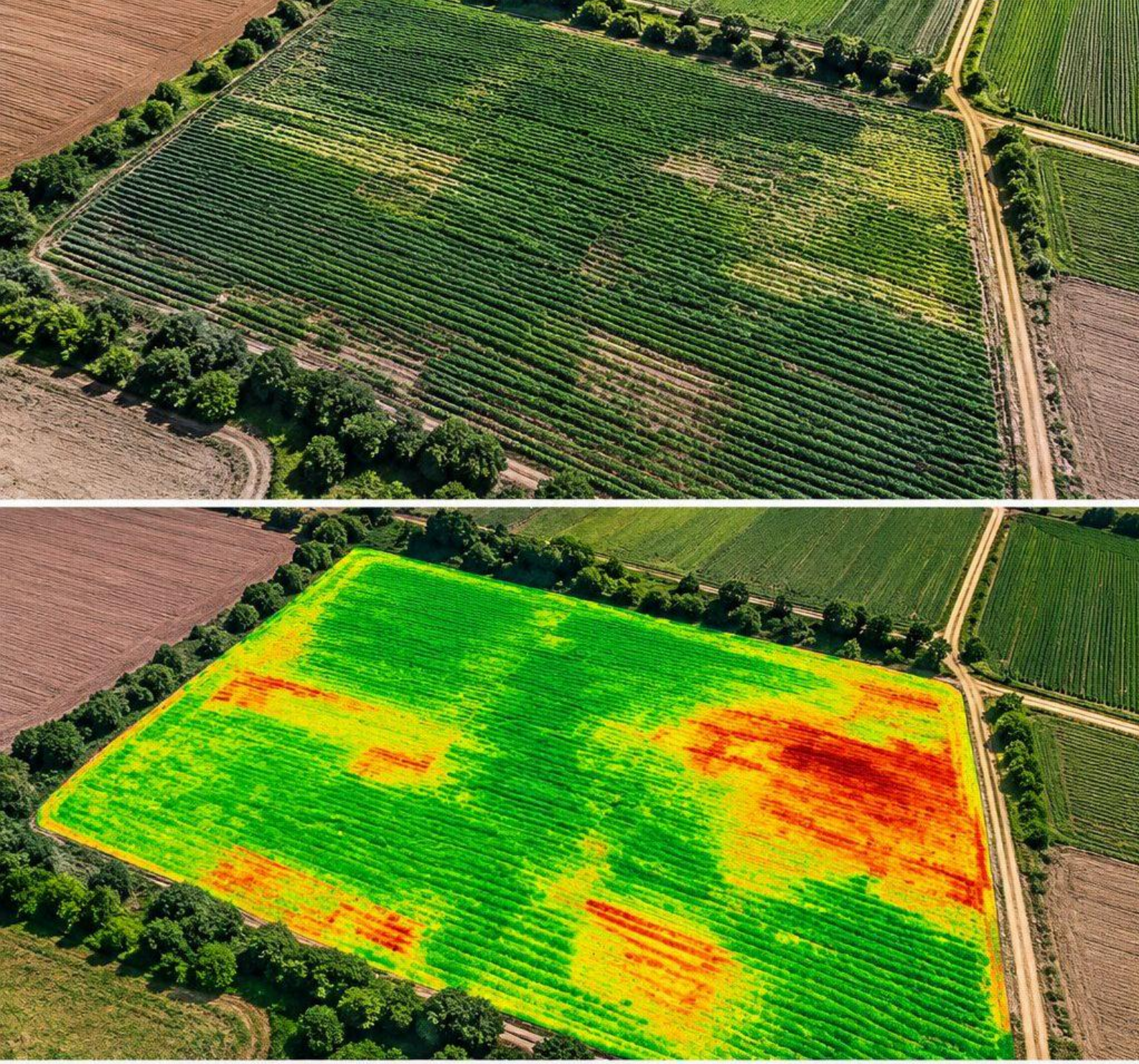
Georeferencing is what lets one image be laid over another. An observation lined up with your boundaries, and with the same block a month earlier, becomes a comparison. Held on its own, it is just a picture.

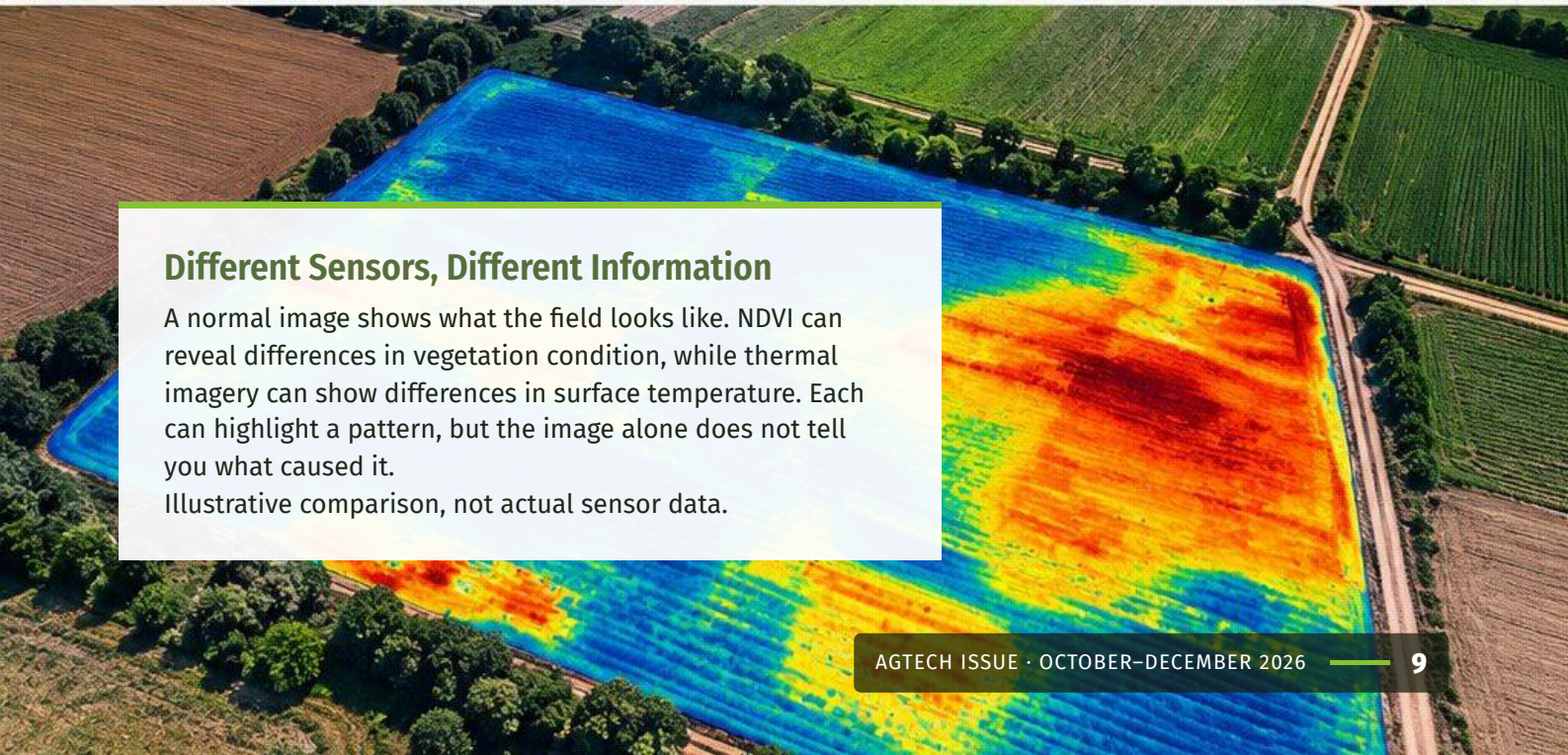
There is a regional version of all this. When a drone and mapping program for rice in Guyana held its closing ceremony in August 2024, officials reported that the country's rice-growing areas had been mapped, along with which varieties were planted where and what stage each crop had reached. The plan announced at the ceremony was to offer the resulting services to farmers free of cost. The important part is where the expertise sat: with the national rice board, whose extension and technical officers were trained as drone pilots and data analysts, rather than with each grower.

Asking for the Right Thing

All of this comes back to what you are trying to see. Before anyone quotes you for imagery, or before you spend an afternoon in a free archive, it pays to be able to answer four questions plainly. How small is the feature you need to pick out? When does it need to be seen, and how often? What has to be measured about it: greenness, temperature, or simply what it looks like? And what do you expect to receive at the end: a set of files, or a map that somebody has already made sense of?

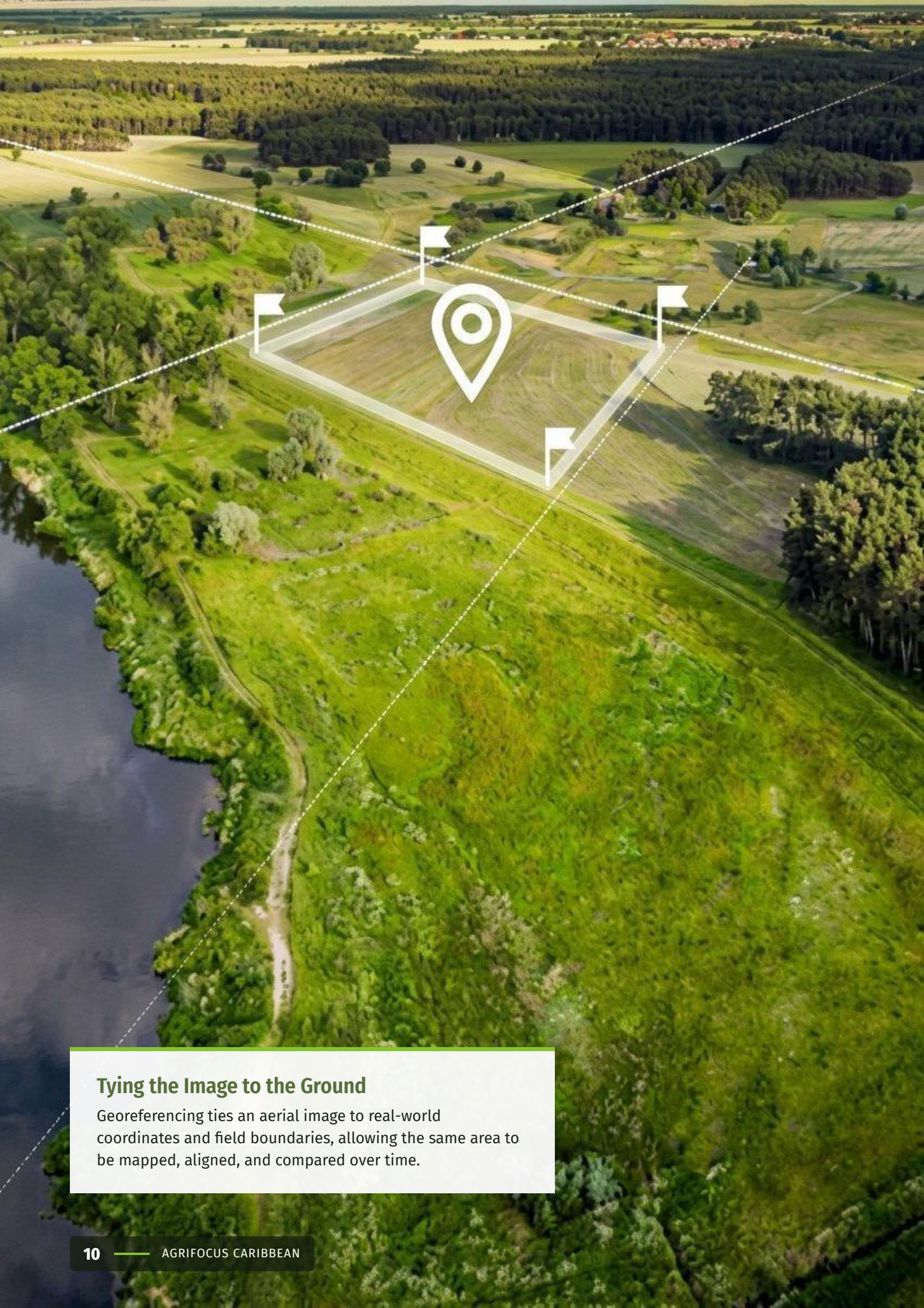
Answer those and the choice narrows sharply. Skip them and you can end up holding an image that is technically excellent but no use for your question.





Different Sensors, Different Information

A normal image shows what the field looks like. NDVI can reveal differences in vegetation condition, while thermal imagery can show differences in surface temperature. Each can highlight a pattern, but the image alone does not tell you what caused it.
Illustrative comparison, not actual sensor data.



Tying the Image to the Ground

Georeferencing ties an aerial image to real-world coordinates and field boundaries, allowing the same area to be mapped, aligned, and compared over time.



ADVISORY REVIEW

Dr. Dexter Davis

Dexter Davis is a lecturer and currently Head of Department of Geomatics Engineering and Land Management at the University of the West Indies St. Augustine Campus Trinidad W.I. He holds a BSc in Land Surveying from the University of the West Indies and a Ph.D. in Surveying Science, focusing on Digital Photogrammetry from the Department of Geomatics, the University of Newcastle-upon-Tyne.

As a lecturer, he has delivered undergraduate, postgraduate and certificate level and short-term training courses in areas including Basic Surveying, Photogrammetry, Digital Photogrammetry, Geodesy, GPS, GIS, and Remote Sensing. Over the years, he has worked as a consultant and project manager on several projects, including photogrammetric analysis, GPS, deformation and hydrographic surveys as well as GIS design.

Dr. Davis has over 25 years work experience in the surveying industry as well as academia locally in Trinidad, regionally in the Caribbean and internationally.

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TECHNOLOGY & INNOVATION

Irrigation by Measurement: Using Soil-Moisture Data in Caribbean Fields

Advisory Review by **Professor David O. Yawson**

Soil-moisture sensors can improve irrigation decisions, but only when their readings are tied to the crop, soil, rooting depth, and the way water moves through the field. The article explains sensor types, placement, calibration, drip-irrigation patterns, data interpretation, and automation, showing how growers can turn readings into better-timed watering rather than simply collecting numbers.

A soil-moisture reading only earns its place when you can connect it to the crop's roots, the soil it sits in, and the water your system needs to deliver.

Soil moisture content is an important factor that determines crop yield. Irrigation helps supply the soil and crop plants with sufficient water for growth and yield. Irrigation costs money, and many Caribbean islands have challenges with irrigation water supply. Sensors help monitor or measure soil moisture to inform adequate irrigation. A soil-moisture sensor can be working perfectly and still send your irrigation the wrong way. Put it in the wettest spot along a drip line and the field looks better supplied than it is. Read a percentage off a phone screen without knowing what that number means in your soil, and you have a tidy way to collect figures that never improve the crop.

Across the region, FAO-supported training and pilot projects have introduced affordable soil, water, and environmental sensors to small-scale vegetable growers, including participants in Antigua and Barbuda, St. Kitts and Nevis, and Jamaica. Readings can be viewed on mobile devices or online dashboards. The equipment can answer an old question with better evidence than guesswork or a calendar: does the crop need water now? But the answer takes more than pushing a probe into the ground. You have to know what the device measures, where its reading comes from, and how the soil changes after rain or irrigation.

The first number on the screen is a starting point, not a decision. You must be confident that the sensor is calibrated and is performing accurately according to the calibration standards. Check the readings against other measurements or standards before arriving at a decision because the decision to irrigate can quench the thirst of your crops, or choke the oxygen supply to the roots, or leach precious nutrients beyond the reach of the roots.

Check the soil by hand

In a well-watered field, plants tend to extract more water from the topsoil (up to about 15 cm deep). Dig into the subsurface to check if it is wet or dry. Sometimes sticking a finger fully into the soil can give an indication of wetness, but digging a bit deeper is better. If the soil is wet a few centimeters below the surface, the root zone may be just fine if the probe says the soil is wet. This check at different spots can help validate the readings from the sensors. Observe the crops in each spot you check for signs of water stress.

Done regularly, this builds the judgment every sensor depends on. It requires no specialized equipment, and it gives you a field reference to compare with the screen later.



Dig a Bit Deeper

A dry surface can hide moist soil beneath. Check several spots against the sensor reading.

What your soil can hold

Behind the hand test sits one idea worth carrying into everything else. Soil holds water like a sponge, between two limits. The upper limit is field capacity, the water left after excess water has largely drained away. Apply more water than the root zone can hold, and the excess may drain below the roots or run off, sometimes carrying dissolved fertilizer with it. At the lower limit, known as the permanent wilting point, the water left in the soil is held too tightly for most crop roots to use. Irrigation normally has to begin well before the soil reaches the permanent wilting point, because crop stress starts earlier. The usable water is the range between those two limits, and the whole job of irrigation is to keep the root zone within this range.

Soil type sets how wide that range is. Sandy soils hold little and let go of it fast. Clay soils generally hold more water and release it more slowly. Where infiltration or drainage is limited, overwatering can lead to waterlogging. This is why a watering routine borrowed from another field so often disappoints: the soil underneath is behaving differently. It is also why no single reading means the same thing everywhere. A reading of 25 percent water content does not carry the same irrigation meaning in sand as it does in clay. It is important to understand what the sensor is telling you and what it means practically for irrigation. When you know your field, the sensor information can be tied to simple equations in Excel to determine the adequate amount or volume of water to apply.

What the sensor is actually telling you

“Moisture” sounds simple until two sensors report it in completely different ways.

Some probes estimate how much water is present, as a percentage of the soil's volume. Capacitance and time-domain reflectometry, or TDR, sensors work this way, and they give you a number that rises and falls as the soil wets and dries. Others measure how hard the water is to

pull out: the tension, or effort, the roots have to make. Tensiometers and granular matrix sensors report this. The reading is low when the soil is wet and climbs as it dries. Both can guide irrigation well, but you cannot read them the same way. One tells you roughly how much water is around the probe. The other tells you how difficult that water is for the plant to get.

Either way, it is important to know your sensor, and the number needs a local reference before it means anything. A trigger figure pulled off the internet for tomatoes in some other soil will not transfer to the peppers in yours. Crop, growth stage, rooting depth, soil texture, drainage, and your system's delivery all shift the point where water should go on and how much to apply at a given time.

Where you put the probe decides what it's worth

A sensor reads only the small pocket of soil around it. It knows nothing about the rest of the field, which makes placement one of the most important choices you make.

Put it somewhere that fairly represents the crop, soil, and watering in that part of the holding, not an unusually wet dip that stays moist after everywhere else has dried, and not a hard, baked rise that calls for water while the rest of the field is fine. If your ground carries clearly different soils or drainage zones, each may need its own sensor. One probe cannot stand in for both a heavy, slow-draining patch and a sandy strip that dries in a day.

Depth matters as much as position. A newly transplanted vegetable is living in the upper soil; a mature tree is drawing from a much deeper layer. Reading at two depths usually tells you more than one: a shallow probe tracks conditions in the upper part of the root zone, while a deeper one shows whether water is reaching the lower roots or moving below them. Set the depths from your crop's actual rooting, and if you are unsure, an extension officer or agronomist can help you



One Reading, Two Soils

Sand holds little water and lets it go fast. Clay generally holds more, so the same 25 percent reading means something different in each.

The first number on the screen is a starting point, not a decision.

place them.

Where to place a probe under drip irrigation

Drip complicates all of this, because it wets only part of the soil. Water leaves an emitter and spreads down and sideways into a wetted bulb whose shape depends on soil texture and structure, emitter flow, and how much water is applied. It is often narrower and deeper in sand and spreads farther sideways in finer-textured soils. A probe sitting right under an emitter can stay wet while roots a little further out are drying. One placed beyond the wetted zone can call shortage while the crop nearer the line is fine.

There is no single right distance from an emitter. What you want is a spot inside the wetted root zone, far enough from the outlet that you are not just measuring the stream straight below it. So look: run the system, let the water move, then dig beside a few emitters with an auger or a narrow hole and see how far it has spread down and across. Place the probe to match that pattern, and check it again when roots expand, emitters clog, or pressure shifts, because the pattern moves.

Installation can ruin a good sensor

The probe has to sit snug against the soil. Air pockets around it can distort the reading, especially on sensors that judge water from the soil's electrical properties. The common mistake is dropping a probe into a loose, oversized hole and packing disturbed soil around it, which may behave differently from the undisturbed soil nearby. Follow the manufacturer's instructions, seat the probe firmly at the depth you meant, and disturb as little soil as you can.

Then protect it. Guard the cable from equipment, rodents, sun, and standing water, and mark the spot clearly enough that nobody finds it months later with a fork or a cutlass. Write down the date, depth, crop, soil, and where the probe sits relative to the row and the emitter. When two sensors start disagreeing later, those notes are often what explains why.

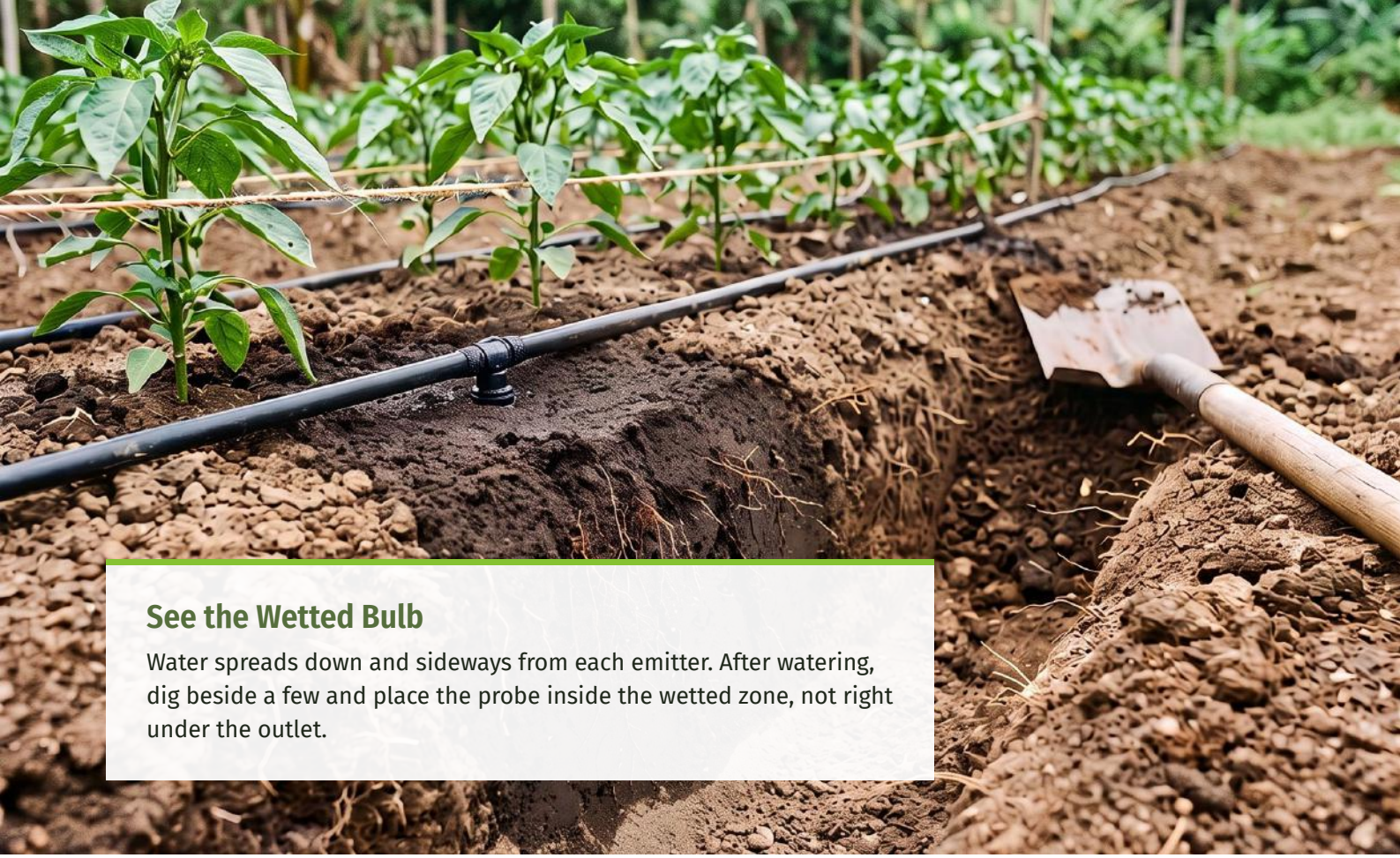
Let the field set your numbers

A raw reading means little until you have watched it move through one full wetting and drying cycle. Record it before you irrigate. Note how long the system runs and, if you can, how much water it puts down. Watch the shallow probe during and after, then follow the deeper one as water works down. After excess water has largely drained away, the settled reading can serve as an approximate field-capacity reference for the soil around that probe.

Then keep recording as the crop draws the water down and the soil dries. Rain, mulching, cultivation, crop growth, and hot or windy weather all change the pace. Out of that pattern, and with guidance on how much your crop can safely dry before it loses ground, you build a trigger that fits your field: water before the shortage bites, but not so early that the root zone never gets to breathe. This takes more than one irrigation to learn. A sensor bought on Monday should not be running the pump on Tuesday.

Reading the pattern, not just the number

Once you know the normal rhythm, the data starts showing you more than wet and dry.



See the Wetted Bulb

Water spreads down and sideways from each emitter. After watering, dig beside a few and place the probe inside the wetted zone, not right under the outlet.

A sharp rise in the shallow reading after watering confirms the water got that far. A later lift in the deeper probe shows it moving down through the root zone. If the shallow sensor jumps but the deep one never stirs, the run may have been too short to reach the lower soil, or the probe is outside the wetted zone, or a hard layer is holding the water up. A deep probe that remains very wet for long stretches also deserves attention. Drainage may be restricted, or more water may be moving below the active roots than the crop can use. If fertilizer is applied through the system, that movement may also carry nutrients below the root zone. And a flat line when the system was supposed to run points you toward a clogged emitter, low pressure, a broken line, or a failed sensor. The graph tells you where to look, not which fault it is; that is still a walk down the row.

That is the real value of a reading over a controller's report. A timer can tell you that a valve opened for thirty minutes. The soil reading shows whether water reached the monitored depth. The basic system checks still matter. Emitters need inspection, filters need cleaning, and flow should be compared across the field. Uneven water delivery still has to be corrected through inspection, maintenance, or changes to the irrigation system.

Trust the sensor when it keeps matching the field

Some electronic probes use a general factory calibration developed for a range of mineral soils. That may be adequate for following whether conditions are becoming wetter or drier, but site-specific calibration can improve the accuracy of the water-content value, particularly for capacitance sensors. Readings from some sensor types can be less accurate in soils with high clay content or salinity, and fertilizer salts can affect some electronic sensors, which matters if you fertigate or



Two Things a Logger Adds

Frequent readings, sent to your phone, and a stored record. Guard its cable and mark the spot where the probe sits.

use irrigation water with elevated salinity.

Before you buy, ask whether the device has been tested in a soil like yours, whether it can be calibrated to your soil, and how salinity affects it. When a reading looks wrong, check it against the ground rather than assuming the screen must be right. Dig beside the probe and feel the soil. Compare it with another device if you have one. Look at the roots and the crop. A sensor reading "wet" next to plants that are clearly stressed is telling you to investigate, not to relax. The sensor earns its keep by matching what the field shows, again and again.

What a connected system adds

A handheld meter may be enough for a small plot: walk over, read it, and write it down. A connected system adds two things: frequency and a stored record. A logger can read all day and send it to your phone, so you can see how fast the soil dries, whether last night's watering reached depth, and how the profile answered the rain.

It also adds costs and questions worth settling before you pay. The price on the probe is only part of it. Include the gateway, data plan, batteries, solar equipment, spare cables, and software fees. Find out whether the system stores readings locally when the signal drops, whether a subscription is required, and what equipment is included beyond the probe. Ask what happens to your records if the app or cloud service is discontinued, and whether you can export and store the data independently. A sensor worth having survives the conditions your farm actually runs in: heat, rain, insects, weak signal, and power cuts.

Let automation come last

Some systems will switch the water on at a set trigger and off when the soil recovers, which saves constant checking on a farm with several zones or under cover. But automation raises the price of a bad reading. A poorly placed probe can hold the

pump off while part of the crop dries; a failed one can water when there is no need; a blocked emitter right by the sensor can leave that spot parched and set the system overwatering everything else on the line.

So bring it in slowly. Watch the sensor through enough cycles to know its normal behavior. Test the trigger while you are still supervising. Keep a manual override, a maximum run time, and an alert for odd readings. And build rain into the logic: a shower may wet the top and leave the root zone dry, or a long soaking may mean holding the schedule off for days, not just the day of the storm. A sound setup considers soil readings alongside rainfall, weather conditions, crop stage, and field inspection. Each answers a different part of the question.

One good decision is enough to start

A first install does not need to run the whole farm. Put it in one representative zone, on one crop. Record before and after each watering, note the rain, and watch the two depths. After a few cycles the pattern starts answering real questions: Are you starting too early? Is the water reaching the lower roots? How long does this soil hold enough? Are you putting on more than the root zone can keep?

That alone can sharpen a decision, well before any controller enters the picture. The data earns its place when it improves the next irrigation by changing the timing, shortening an excessive run, exposing a clogged line, or helping the crop avoid water stress.





CHECKLIST

A practical first run

1. Record the probe's spot, depth, and distance from the row and the emitter
2. Note the crop, its stage, the soil, and the irrigation method
3. Take a reading before you water
4. Log when the system starts, how long it runs, and the volume if you know it
5. Watch how the shallow and deep readings respond
6. Check the soil beside the probe by hand and compare it with the screen
7. Repeat through several waterings and rains before you set any automatic trigger

BEFORE YOU SPEND

Before you buy, ask

?

What does it measure, and in what units?

?

How many probes come with it, and can it read more than one depth or zone?

?

Does it need calibrating to my soil, and how do clay, salinity, or fertilizer salts affect it?

?

Does it keep recording when the internet is down?

?

Can I download and keep the records myself?

?

Are there subscription or cellular charges?

?

Who handles installation, repairs, and spare parts?

?

Can I override any automatic watering command?





ADVISORY REVIEW

Professor David O. Yawson

David Yawson is Professor of Agrifood Systems and Environmental Resilience and Director of the Centre for Resource Management and Environmental Studies (CERMES) at The University of the West Indies, Cave Hill Campus, Barbados.

He holds a BSc in Agriculture with honors from the University of Cape Coast, an MSc in Geo-Information Science from Wageningen University, and a PhD in Geography and Environmental Science from the University of Dundee and The James Hutton Institute.

His teaching experience includes soil science, agricultural water management, agricultural climatology, GIS, remote sensing, and drones. He leads the Land Management and Environmental Resilience specialization at CERMES, and his research focuses on managing land, nutrients, water, and food resources sustainably in a changing climate.

Professor Yawson has academic and professional experience in Africa, Europe, and the Caribbean and provides consultancy services to UN agencies, governments, and NGOs.

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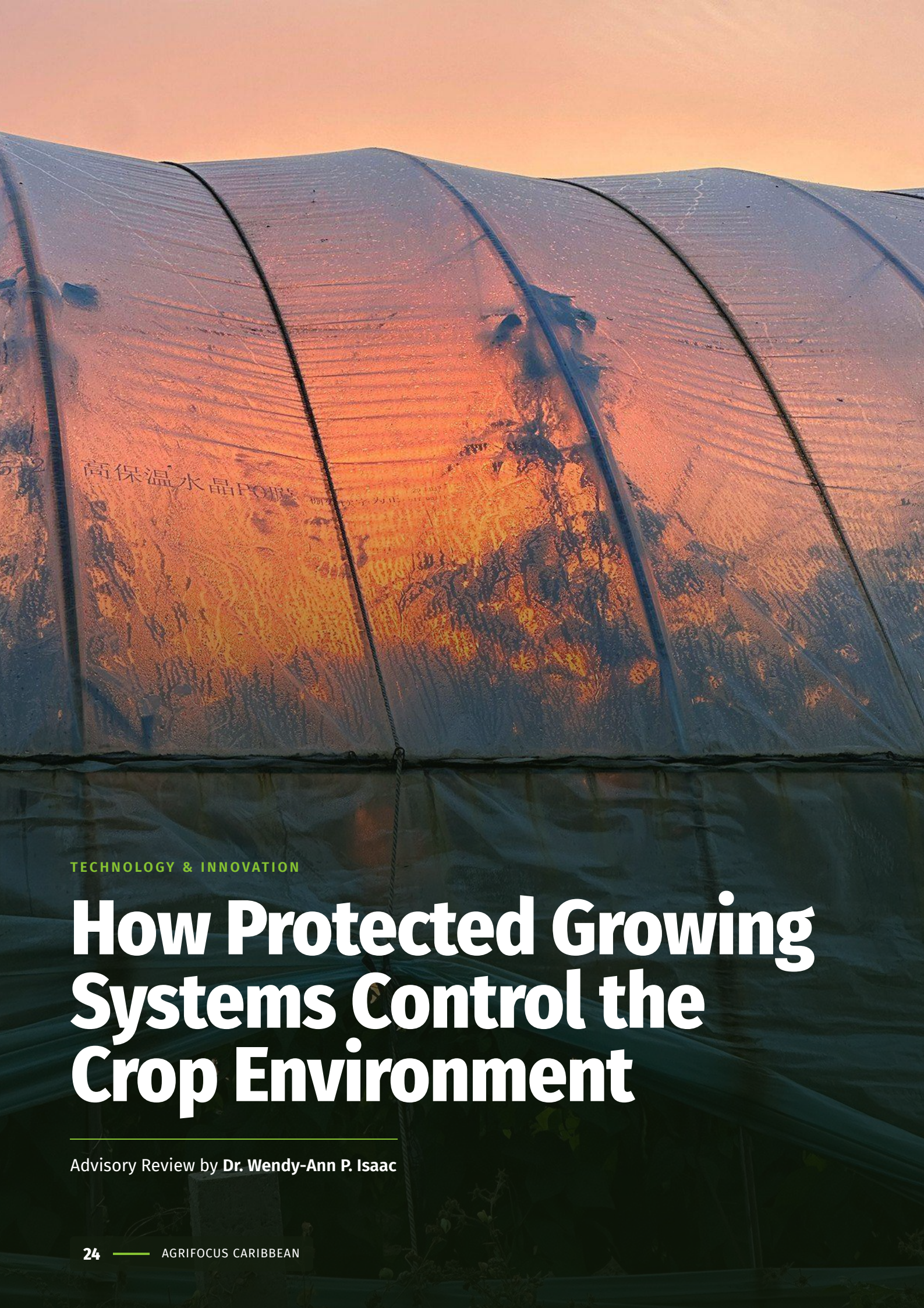


TECHNOLOGY & INNOVATION

How Protected Growing Systems Control the Crop Environment

Advisory Review by **Dr. Wendy-Ann P. Isaac**

Protected growing is not simply about putting crops under cover. Roofs, films, shade, insect mesh, ventilation, and growing media all change rainfall, light, heat, airflow, pest pressure, and root conditions. This article examines how those elements work together, and the trade-offs involved when one design choice improves one condition while creating another challenge in hot, humid Caribbean environments.

Coverings, vents and growing media are the working parts of protected production. Most of what they do comes from the properties of the material and the shape of the building rather than from power, and that is both why they suit the region and where their limit sits.

A naturally ventilated greenhouse cools itself using the shape of its roof and whatever wind happens to be passing, rather than with fans. In the simplest structures the vents are fixed or opened by hand. That is the central idea in passively ventilated protected production, and it explains why the technology suits the region: the working parts are the covering materials and the geometry, and most of it runs without electricity. It also sets the limit, because a structure that relies on wind cannot make wind.

The family of structures runs from a rain shelter, which is a roof and little else, through net houses and shade houses covered in different grades of netting, to a screen-enclosed greenhouse carrying film overhead and mesh down the walls. What separates them is which material goes where. The frame carries the load; the coverings and the shape of the building do the work on the crop's environment.

Five conditions are managed at once:

- Rainfall reaching the crop
- Radiation reaching the crop
- Airflow through the structure
- What can get in: pests, and beneficial insects where they are used
- What happens at the roots, where soil has been replaced

Each is handled by a different part of the structure, and they interact.

Water: What the Roof Changes

Film over the crop does more than keep it dry. Rain no longer lands on leaves, and soil no longer splashes onto them, which changes how fungal and bacterial diseases spread. Where the crop grows in a nutrient solution, the roof is also what keeps rain from diluting it, one reason soilless production is recommended inside a structure rather than in the open. What a roof does not do is remove humidity, which builds up under cover and brings its own disease pressure.

The film itself is a manufactured product with specifications worth checking. Film for tropical exposure should be UV-stabilized, which governs how long it lasts before the material degrades. An anti-drip additive changes the surface so condensation spreads into a sheet instead of



The Covering Does More Than Keep Rain Out

A film roof shields the crop from direct rainfall and soil splash, while the covering and screened sides also influence light, heat, humidity and airflow inside the structure.

gathering into droplets that fall on the crop. An anti-dust additive on the outer face slows the build-up that cuts light. Film is commonly sold in thicknesses between 120 and 200 microns, and thicker film lasts longer and resists heavy weather better, though thickness alone will not make a house storm-proof: tear strength, fastening, and frame spacing all matter. Multilayer film carries these properties on different faces, anti-drip inward and anti-dust outward, so it has to go up the right way round.

Light and Heat Are Two Different Problems

A covering reduces the total light entering the structure, but film also scatters what passes through. Light then reaches the leaf from many angles instead of one, which eases saturation on the upper leaves and carries more down to the lower ones. The gain is in how the light is spread through the canopy, not in how much of it arrives.

Heat is the separate problem. The CARDI Tropical Greenhouse Growers Manual warns that at low altitude, film transmitting more than about 70 percent can let in more heat than the crop can carry. Spectrally selective film, sold in the region as anti-thermic or cold plastic, is made for exactly that. It filters incoming radiation to pass photosynthetically active radiation, the part of sunlight the plant uses to grow, while holding back near-infrared, which is mostly heat. The same trade names are used elsewhere for films designed to hold heat in at night, so ask for separate figures for light transmission and near-infrared rejection rather than buying on the name.

Shade cloth is rated by what it blocks, so 30 percent cloth excludes 30 percent of the light and passes 70. What makes the rating usable is that a crop's response to light levels off above a saturation point. Regional guidance gives approximate reference figures of 25,000 lux for lettuce, 55,000

The screen doing your pest exclusion is also reducing your airflow and your light.

for cucumber and 70,000 for tomato. Treat those as screening values rather than fixed limits, since the response shifts with cultivar, leaf age, temperature and position in the canopy. Past the useful range, extra radiation adds little and raises leaf temperature and stress. You can check your own light cheaply: a lux meter is inexpensive and portable, and readings belong at the top of the canopy at several points through the day. Color counts too. Pale cloth reflects heat while dark cloth absorbs it, and reflective nets carrying aluminum strips are used to cut heat load and put more sunlight on the lower leaves.

Reading a Mesh Specification

Insect netting is specified by three things at once: the threads per inch, the thickness of the thread, and the pore left between them. Raise the thread count and the pore shrinks, and two things fall away together, light transmission and air movement. The screen doing your pest exclusion is also reducing your airflow and your light.

A regional product table shows how tightly the three are coupled. It lists a 50-mesh screen with openings of about 0.26 by 0.83 mm on a 0.23 mm thread, excluding whiteflies and aphids at a shade factor near 25 percent. A 40-mesh screen in the same table has openings of about 0.4 by 0.83 mm on the same thread, and keeps out leaf miners and caterpillar larvae but not whitefly, at a shade factor near 23 percent. Those dimensions belong to those particular products, not to every net sold under that count, which is the reason to ask for the measured aperture and thread size instead of the mesh number.

Other regional tables list other products, and their figures will not line up with these. The companion guide, What Are You Protecting the Crop From?, works from a table built around 58-mesh and 32-mesh screens. Neither set is a standard for the count; both are specific to the products measured.

Thrips set the practical limit. Netting fine enough to exclude thrips also excludes aphids, whiteflies and leaf miners, so the insect that governs the specification is the smallest one you actually have.

The fabric is only part of the barrier. A double-door entry, two doors in series closed automatically by springs or counterweights, is what lets the enclosure survive someone walking in with a crate, and it has to stay shut through the whole cycle, harvest included. Netting also works the other way: where beneficial insects have been released, the mesh keeps them inside and working.

None of it holds once the screen is dirty. The same guidance gives an example of a dirty net dropping ventilation from 50 percent to 5 and lifting its shade factor from 25 to 80. A dirty screen therefore raises the temperature and cuts the light at the same time as it loses the airflow.

Air: Where the Design Runs Out

Ventilation is the exchange of the air inside for the air outside. In the hot, humid lowlands below 500 m, internal temperatures above 40 °C by mid-morning are not unusual, so moving that air out is the central design problem.

The mechanism is wind and buoyancy together. Wind drives air in at the sides, warm air inside grows lighter and rises, and roof vents release it at the top. A split roof creates a pressure difference that draws hot air off the ridge. Sidewall height sets how much air sits between the crop and the

covering, and a fully enclosed structure wants at least 3 m of that buffer where mean daytime temperatures pass 28 °C. Orientation matters because wind puts positive pressure on the windward side and lower pressure on the leeward side, and that difference is what pushes air through the side and roof openings.

Regional guidance then sets a target. For the inside temperature to sit close to the outside temperature, the structure needs to exchange its entire volume of air about once every minute (roughly sixty air changes per hour). The guidance is blunt about what that means in practice: at some Caribbean sea-level sites the wind is neither consistent nor strong enough to achieve it, and no passive design will make up the difference.

There are several ways to move more air, and each carries a penalty. Coarser mesh, stripping the mesh from roof vents, and opening the sides will all help, and every one of them admits more pests. Extractor fans do the job directly, pulling air out across the covering mesh, but they need reliable power and extra bracing to carry the weight. A good number of the region's protected structures stand away from the grid, so powered cooling is not available to them at all.

A Finer Screen Changes More Than Pest Entry

Smaller openings can exclude smaller pests, but greater restriction also reduces airflow and light. The measured aperture and thread size matter more than mesh count alone.



Smaller openings stop whiteflies, but they also cut airflow and light movement.

Fine mesh blocks tiny pests

What a Substrate Has to Replace

Soil does several jobs at once. It holds the plant up, stores water, releases nutrients, keeps air around the roots, and buffers change so nothing shifts too fast. Take it away and each of those jobs has to be supplied on purpose.

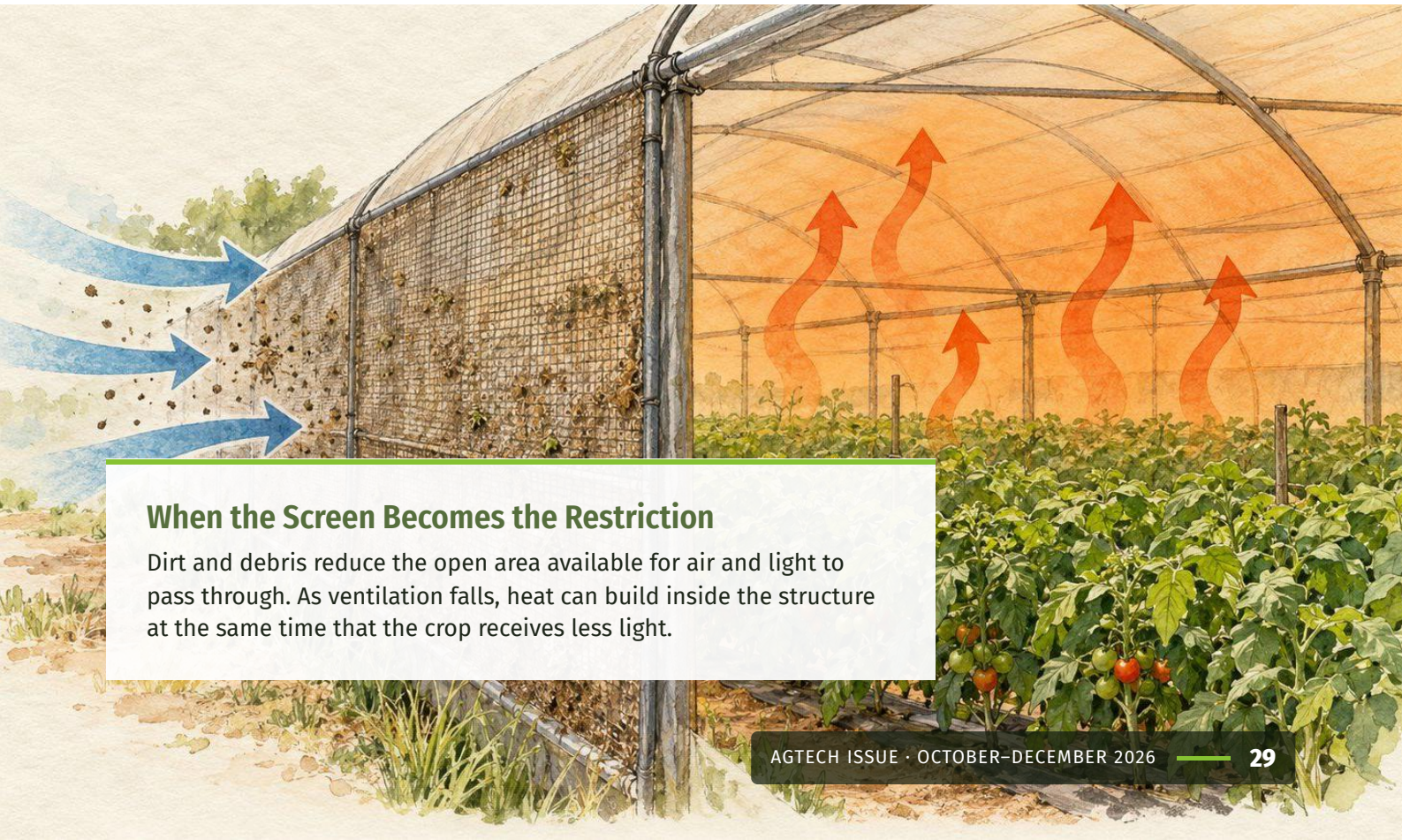
That is why a growing medium is specified rather than simply chosen. For leafy vegetables the published ranges, measured by volume after irrigation and drainage, are total porosity of 50 to 80 percent, air space of 10 to 30, water holding capacity of 45 to 65, and available water of 25 to 35, with a pH of 5 to 6 and electrical conductivity of 0.2 to 1.5 dS/m. Read them together and the difficulty is plain: the material has to hold water and hold air in the same volume at the same time.

Oxygen around the roots is a hard constraint, and crops differ in how much shortage they will tolerate. Published guidance puts tomato's requirement at around 7 mg per liter and notes that lettuce copes with about 4. Oxygen also dissolves less readily as water warms, which is why nutrient solution is commonly held near or below 25 °C, and in a lowland structure holding it there is real work.

One Change Moves the Others

Fit finer mesh to keep whitefly out and airflow drops, with heat and humidity climbing behind it. Add shade to bring the temperature down and you have taken light from a crop that may have needed it. Roof the crop against rain and irrigation stops being optional, and where the root zone is a recirculating solution, water quality and concentration matter daily.

Published guidance puts it plainly: structures, coverings and climate equipment do not by themselves guarantee a yield. The benefit comes when every factor affecting production is managed together, on the site where the structure stands.



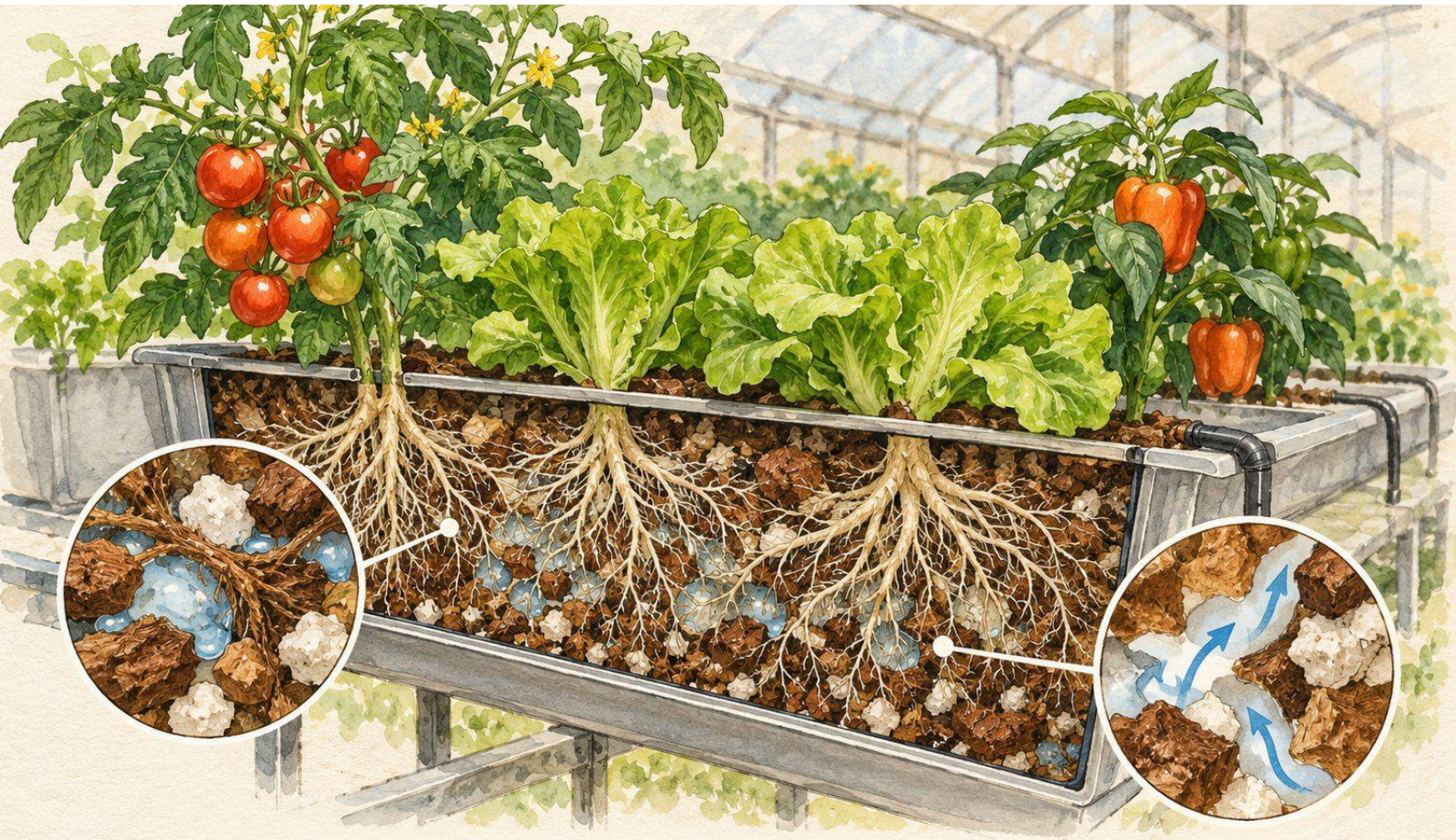
When the Screen Becomes the Restriction

Dirt and debris reduce the open area available for air and light to pass through. As ventilation falls, heat can build inside the structure at the same time that the crop receives less light.

Also on the AgriFocus Caribbean platform. If you are still deciding what to build, the companion guide, What Are You Protecting the Crop From?, works through choosing among rain shelters, net houses, shade structures, screen-enclosed greenhouses, and soilless systems, and covers site, elevation, water supply, storm exposure, crop, buyer, and operating cost.

Water and Air Share the Root Zone

Once soil is replaced, the growing medium has to store water while leaving enough pore space for oxygen around the roots. Managing one property affects the other.



The root zone must hold moisture and oxygen in the same space.

Substrates balance air and water



ADVISORY REVIEW

Dr. Wendy-Ann P. Isaac

Dr. Wendy-Ann P. Isaac is a Senior Lecturer in Weed Science and Agronomy, Faculty of Food and Agriculture, at The University of the West Indies, St. Augustine, Trinidad and Tobago. With a career spanning more than two decades, her research and teaching encompass sustainable crop production systems, integrated weed management, food security, climate-smart agriculture, and the intersection of agriculture with culture, community, and sustainable tourism.

Dr. Isaac holds a Ph.D. in Crop Science and a Master of Applied Science in Agronomy from Lincoln University, New Zealand. She is the author and co-editor of six books and has published more than 30 refereed journal articles and 26 book chapters with international publishers. A passionate advocate for Caribbean food sovereignty, Dr. Isaac leads research on seed security, agro-ecological production systems, and the role of local food culture in building resilient communities.

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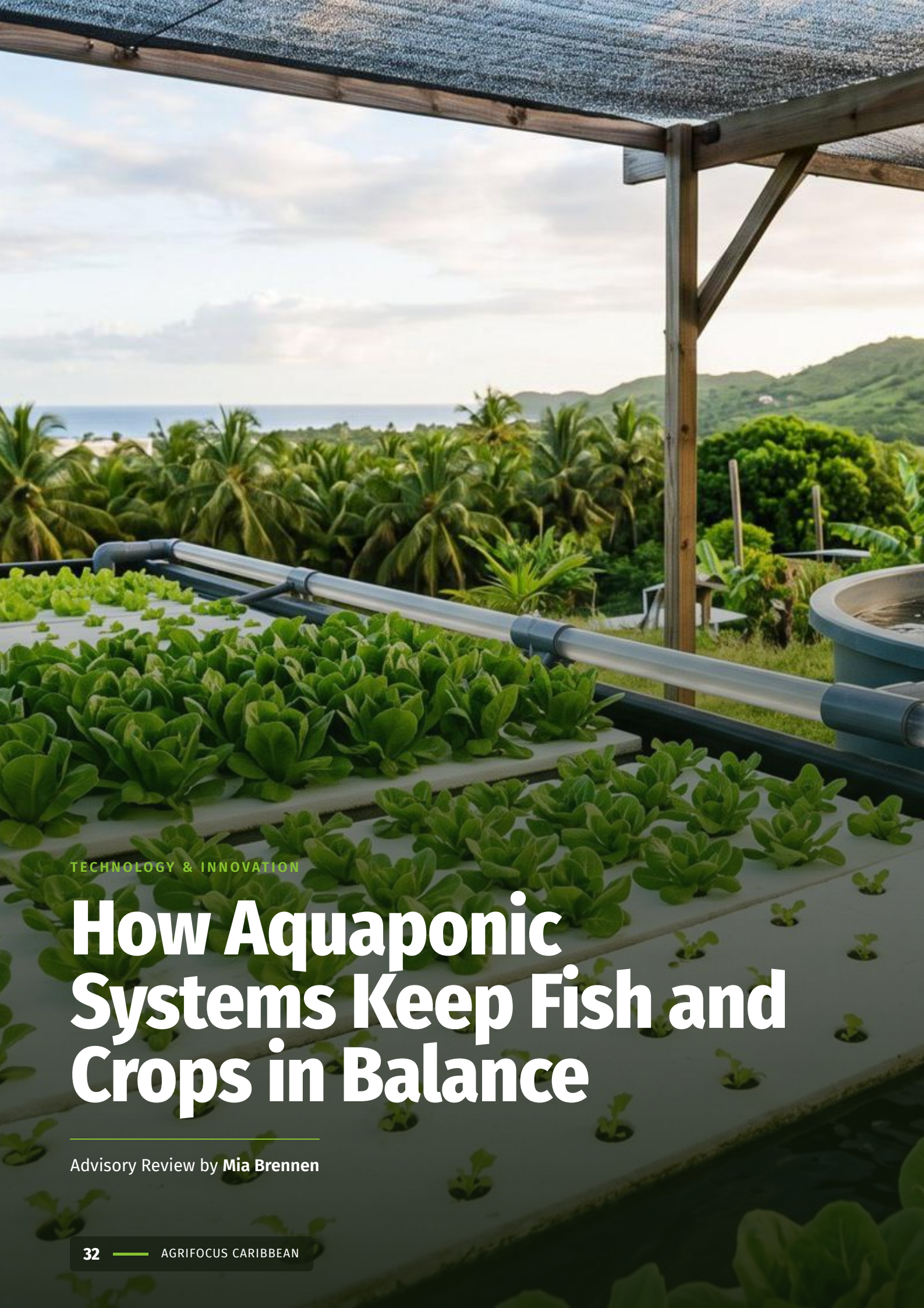


TECHNOLOGY & INNOVATION

How Aquaponic Systems Keep Fish and Crops in Balance

Advisory Review by **Mia Brennen**

Aquaponics depends on keeping fish, plants, and bacteria productive within the same recirculating system. Following the water through filtration, nitrification, feeding, plant production, and water-quality management, this article examines stocking, pH, oxygen, power, pest control, and harvest scheduling, showing why the system succeeds only when its biology, equipment, and production planning remain in balance.

Feed the fish and the same water fertilizes the crop. Holding that arrangement steady means keeping conditions that suit three living things at once, on a schedule that also has to produce something you can sell.

Harvesting a bed of lettuce takes out the plants that had been drawing nutrients from the water, and the fish carry on eating and producing waste as they did the day before. Put seedlings into the cleared space and the demand on the water changes again over the following weeks as they grow into it. The feeding decision and the planting decision are made at opposite ends of the same system, and neither one can sensibly be made without the other in view.

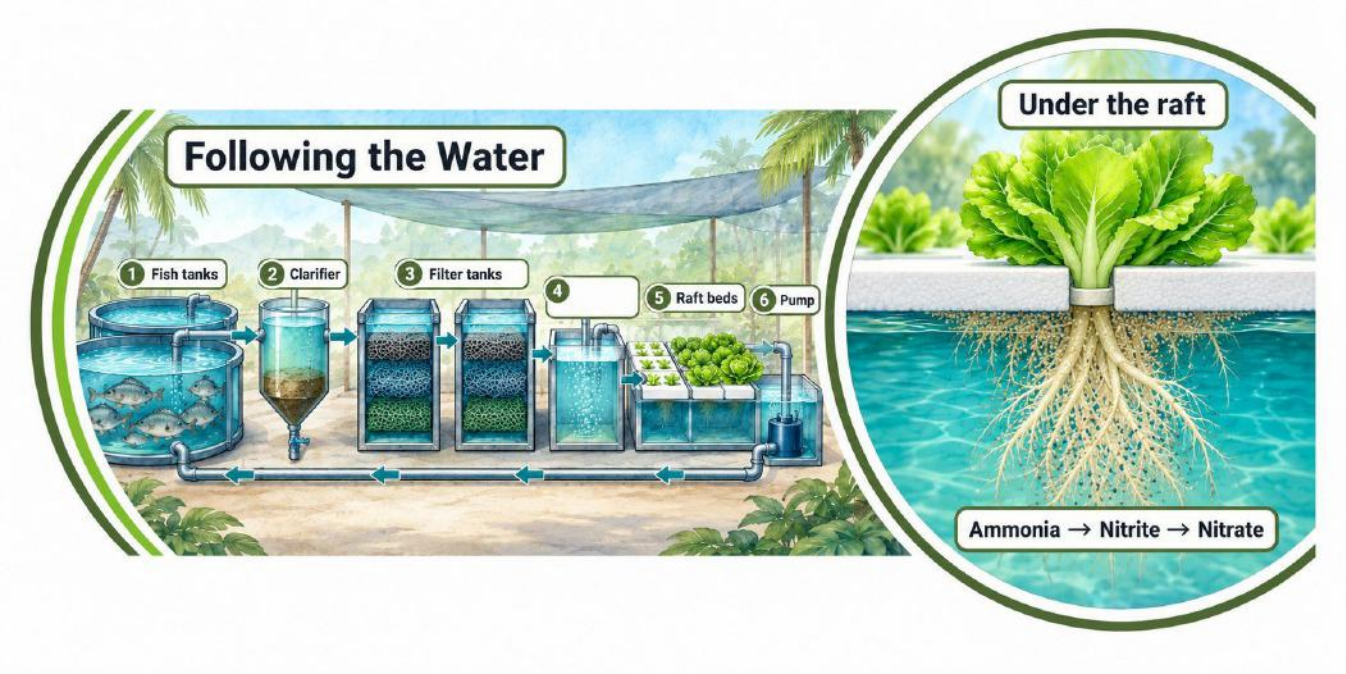
That is aquaponics: fish production and soilless crop production joined on a single recirculating loop, with bacteria doing the conversion in between. Three sets of living things depend on the same water, they want different conditions from it, and there is only one body of water to give them.

Following the Water

Part of the feed becomes fish and much of the rest becomes waste in two main forms that need entirely different handling. Feces and uneaten pellets are solid material that can be filtered out. Ammonia, a metabolic waste product excreted mainly through the gills, dissolves into the water, where no amount of settling or straining will remove it. A system therefore needs mechanical treatment and biological conversion running together, and it needs them in the right order.

In one documented aquaponic system, the solids came out first: water leaving the rearing tanks passed through clarifiers, where the flow slowed enough for the heavier particles to settle and be drained away, taking out about half the particulate load. Filter tanks packed with orchard netting caught the finer material further along the circuit, and that netting was cleaned once or twice a week. After the filters came a degassing tank, where air diffusers vented the hydrogen sulfide, methane and nitrogen given off by trapped sludge before the water reached the plants.

The reason for taking the solids out early is that organic matter left in circulation goes on decomposing wherever it settles, and decomposition consumes dissolved oxygen while producing more ammonia and carbon dioxide. Fine particles that reach the growing area cause a more specific problem. They accumulate on the roots and create pockets that oxygen cannot penetrate. Because roots need oxygen for the active transport involved in nutrient uptake, a root buried in fine



The water's path through one documented raft system.

sludge takes up less than it should, even though the nutrients are there in the water around it.

Removing every particle as quickly as possible carries its own cost, because those solids are also feeding the crop. As microorganisms break them down, they release inorganic nutrients that the plants can use, a process called mineralization, and the same organisms compete with root pathogens while they work. Strip the water too thoroughly and you may find yourself buying fertilizer to replace what mineralization would otherwise have supplied. Most of the fecal waste should be out before the water reaches the plants. Some retention is useful, and how much depends on how heavily the system is loaded.

The dissolved ammonia takes a different route. Two groups of bacteria work in sequence, one converting ammonia to nitrite and the other converting nitrite to nitrate. Ammonia and nitrite are both toxic to fish, while nitrate is relatively harmless and is the preferred form of nitrogen for growing plants. That is what makes the whole arrangement work in the first place. A biofilter is a large quantity of surface area held wet and oxygenated so that those bacteria have somewhere to establish, and a new installation has to run long enough to build that population before it can safely carry the feeding load it was designed for.

This conversion, called nitrification, is not confined to the biofilter. The same bacteria colonize every wetted surface in the system: tank walls, pipe interiors, the roots themselves and, in raft systems, the undersides of the floating sheets. Nutrient film channels carry only a shallow stream and offer far less surface, so they generally still need a biofilter of their own. The design recommendation is a single pump doing the circulating, with gravity moving the water through the rest of the circuit.

Matching Feed to Growing Area

A key design criterion in an aquaponic system is the ratio of daily feed input to plant growing area. Tank volume will not establish it, because fish of different sizes eat different amounts, and it is the feed rather than the fish that carries the nutrients into the water.

For raft systems, the general design range is 60 to 100 grams of feed per square meter of growing area per day. The documented system described

above used ratios within that range for tilapia grown with lettuce, basil and several other crops. On ten square meters of planted raft, that works out to between 600 grams and one kilogram of feed a day.

Push the ratio too high and dissolved salts accumulate faster than the crop can take them up and may reach levels that damage it. Exchanging more water will slow the buildup, but the ratio itself is what has moved, and the rate of accumulation falls once the daily feed allotment and the plant area are brought back into proportion. Run it too low and the plants develop deficiencies and need supplementing. Hydroponic plants grow well across a wide span of nutrient concentrations, so the range is better understood as a design target than as a threshold with trouble waiting on either side of it.

The raft range does not transfer unchanged to other growing methods. Gravel beds and nutrient film channels hold far less water than raft channels, so the same daily feed produces a much higher concentration in a much smaller volume, and the recommended figure for them is roughly a quarter of the raft ratio. Water replacement, the nutrients already present in the source water, how completely the solids are removed and how long the crop takes to mature all move the figure as well.

The standing crop should generally not exceed about half a pound per gallon, near 60 kilograms per 1,000 liters, which supports fast growth and efficient feed conversion while keeping crowding stress down. Harvest densities of 0.51 and 0.59 pounds per gallon were recorded for Nile and red tilapia in that system, just above that level, so treat half a pound per gallon as a design target rather than a physical limit. For small units, a more conservative stocking of about 20 kilograms per 1,000 liters is recommended because lower stocking densities make the system easier to manage and more resilient to shocks.

If the crop looks short of nutrients, more feed is



Photo: Mia Brennen
Aquaponics raft beds at the Cape Eleuthera Institute, The Bahamas, 2023. Raft growing area is used in balancing daily feed input with crop demand.

If the crop looks short of nutrients, more feed is not automatically the answer.

not automatically the answer. A deficiency may result from water chemistry affecting nutrient availability, or from shortages of nutrients such as potassium, calcium or iron that may need separate supplementation. Uneaten pellets rot where they land, use up dissolved oxygen while they do it and can bring on disease, which is why standard practice is to clear whatever is left after thirty minutes and cut the next portion accordingly. Whatever extra feed goes in has to stay within what the fish will actually eat and what the treatment components can process.

Staggered planting helps keep nutrient uptake relatively steady as crops are harvested and replaced, and the documented system shows how precisely it was worked out. In that system, Bibb lettuce reached market size three weeks after transplanting, so three growth stages were cultivated at once and a third of the crop harvested every week. Red and green leaf lettuce took four weeks, so four stages ran together and a quarter came out weekly. The harvest fell on the same day each week, which kept nutrient uptake from the water relatively constant and made marketing arrangements workable at the same time. Three years of continuous operation produced 148 lettuce crops. Holding a sequence like that means seedlings should be ready on the day a growing space clears and fingerlings should be ready when a rearing tank is emptied, which makes the nursery and the fish supply part of the production system rather than arrangements to be made when the need arises.

The Chemistry All Three Share

Balancing feed against growing area governs how concentrated the nutrients in the water become. It does not, on its own, make the water suitable for the fish, the bacteria and the plants at the same time, because each needs different chemical conditions, especially pH.

The nitrifying bacteria work best between pH 7.0 and 9.0, and their activity is reduced below 7.0. Most hydroponic vegetables grow best between 5.8 and 6.2. Aquaponic systems are maintained close to 7.0 as the compromise between those requirements, and for small units a working band of 6 to 7 is recommended. Neither figure is a number to chase with constant adjustment.

For the crop, availability matters as much as quantity, and iron is the clearest illustration. It becomes less available to roots as pH rises, so a plant can show every sign of iron deficiency while the iron it needs is present in the water around it. Raising the feed input will do nothing about a shortage caused by chemistry rather than by supply.

For the fish, pH changes what the ammonia in the water is doing. Dissolved ammonia exists in two forms, and the un-ionized form is far more toxic than ammonium. The proportion sitting in that more toxic form rises with both pH and temperature, which is why an ammonia reading has to be interpreted alongside those two measurements rather than on its own. It also means that raising pH to get more work out of the biofilter increases the toxicity of the ammonia the biofilter has not yet converted. In recirculating systems, un-ionized ammonia-nitrogen should be kept below 0.05 milligrams per liter.

Nitrification changes the water as it works, producing acid and consuming alkalinity, which is the water's capacity to neutralize acidity. Biofilters perform best where total alkalinity is around 100 milligrams per liter or more, expressed as calcium

carbonate, since alkalinity is what allows the water to resist a change in pH rather than swing with it. Some of the additions used to counter that acid also carry nutrients, which lets one operation serve two management needs at once. Potassium and calcium commonly need supplementing in aquaponics, and in the documented system, potassium hydroxide and calcium hydroxide were added alternately, correcting the pH and supplying those nutrients at the same time. These bases should be added gradually, because a rapid rise in pH can shift more ammonia into its toxic un-ionized form. The same pairing can be used in other systems, but the amounts cannot simply be copied, because they depend on each system's water volume, feeding rate and source water. Iron has to be handled separately, supplied as a chelate that stays soluble at the operating pH.

Dissolved oxygen, pH, temperature, the nitrogen compounds and alkalinity are the measurements worth taking regularly, and ordinary test kits and a thermometer cover them. Keeping a record of the results is what makes a slow drift visible, because a drift shows up across a run of readings in a way it never does in a single one. A single low oxygen reading, on the other hand, can call for action immediately.

A conductivity meter adds useful information about total dissolved salts. Feed, supplements and source water all contribute to that load, so a rising reading is a reason to look for the cause rather than a diagnosis in itself. Levels of 200 to 400 parts per million of total dissolved solids are reported to produce good results in aquaponic systems. That is well below the 1,000 to 1,500 of a mixed hydroponic solution, because in aquaponics the nutrients arrive continuously instead of being mixed in batches and replaced. The meter cannot tell you which nutrient has changed, and it does not replace ammonia, nitrite or dissolved oxygen tests.

> **Neither figure is a number to chase with constant adjustment.**

Water Coming In and Power Staying On

Source water becomes part of the chemistry every time the system is topped up, so its salt content needs attention. Sodium should be kept below 50 milligrams per liter, because above that it interferes with the uptake of potassium and calcium, and in lettuce the reduced calcium shows up as tip-burn on heads that would otherwise have been sold. Salt is added to manufactured fish feed, though feed bought in large quantities can be ordered without the added salt, provided leaving it out does not affect fish health. The water supply is the other input worth attention. The documented systems were run on collected rainwater because groundwater on semiarid islands generally carries more salt than aquaponics will tolerate. Where sodium does climb past the limit and the plants show it, a partial water exchange may be needed. Municipal water can be used once it has been dechlorinated, and surface water is avoided because it can bring disease-causing organisms in with it.

Water supply was built into an aquaponics project reported in Portland, Jamaica, in 2020. The funding covered the technology and its construction together with a water catchment facility, solar power technology, a greenhouse, a nursery and provision for operations and training. Portland had been identified the year before among



the parishes worst affected by drought and falling surface water.

Inside the loop, circulation and aeration are separate jobs, and knowing what each piece of equipment does tells you what impacts an interruption will have. Circulation moves water between the tanks, the treatment components and the growing area. Aeration puts oxygen into it. An air-lift pump can do both at once, but many installations separate the two functions. The documented system did, using a half-horsepower pump for circulation while two blowers, one for the fish side and one for the plant side, supplied air to the diffusers. Fish, bacteria and roots all draw on that same oxygen. A working figure for small units is 5 milligrams per liter or above; that system was held near 80 percent saturation, about 6 to 7 milligrams per liter.

When circulation stops, nutrient film channels and drained gravel beds hold very little water, and the crop comes under water stress quickly. Raft roots stay immersed and are protected from drying, though they still need oxygen. When aeration fails, the fish and the bacteria go on consuming oxygen while the equipment that was replenishing it has stopped. In a typical intensively loaded recirculating system, failure of aeration or oxygenation can cost the entire fish crop within half an hour. That timing should not be assumed to hold unchanged for a lightly stocked aquaponic unit, but the practical point holds either way: where circulation and aeration run on separate machines, backup for the circulation pump alone leaves the aeration uncovered.

The equipment runs continuously, and it runs on electricity, which is a significant portion of an aquaponic system's operating budget. The pumps and the power source are therefore worth working out carefully at the design stage, and photovoltaic supply is worth costing out as part of that. Where aquaponic systems in the region have not done well, it has been suggested that setup has been an important factor, and that they need consistent power rather than a great deal of it. That sits inside a wider regional constraint, since several Caribbean small island developing states face increasing

freshwater scarcity alongside a dependence on imported fossil fuel for the energy demand associated with groundwater extraction and seawater desalination. Solar changes where the power comes from, but it does not change the fact that the pumps and blowers have to run through the night, so the power plan has to cover the hours without sun.

Treating One Crop Without Harming the Other

Because the fish and the plants share the same water, a treatment used on one reaches the other, which limits what can be done on either side. A pesticide's registration for a vegetable crop alone does not establish that it is suitable for use in a connected aquaponic system. Therapeutants for fish parasites and diseases should also be avoided, since the vegetables may absorb and concentrate them. Salt, the standard response to nitrite trouble and to several fish complaints, damages the plants. The restriction on pesticide use makes crop production in an aquaponic system harder than it would otherwise be.

What remains is largely biological and physical: resistant varieties, exclusion, traps and the manipulation of growing conditions, with parasitic wasps and ladybugs used against whitefly and aphids. In the documented systems, caterpillars were controlled by spraying twice weekly with *Bacillus thuringiensis*, a microbial product used as an insecticide. Whatever category a treatment falls into, it has to be assessed against the other crop before it goes near the tanks. Root pathogens are the harder case. *Pythium* appeared in those systems during the warm months and cut production, easing off as water temperature fell in winter.

None of this makes pest management easy or guarantees control. It means the approach has to be worked out before the tanks are stocked, because once both sides of the system are running, the response that would ordinarily be reached for on one side is no longer open.



Water and Power Around the System

An aquaponic setup can combine rainwater storage, solar generation, fish tanks, raft growing beds and a seedling nursery. Solar can reduce dependence on grid or fossil-fuel power, but circulation and aeration still require a reliable supply when the sun is not available.



What the Region Has Built and Sold

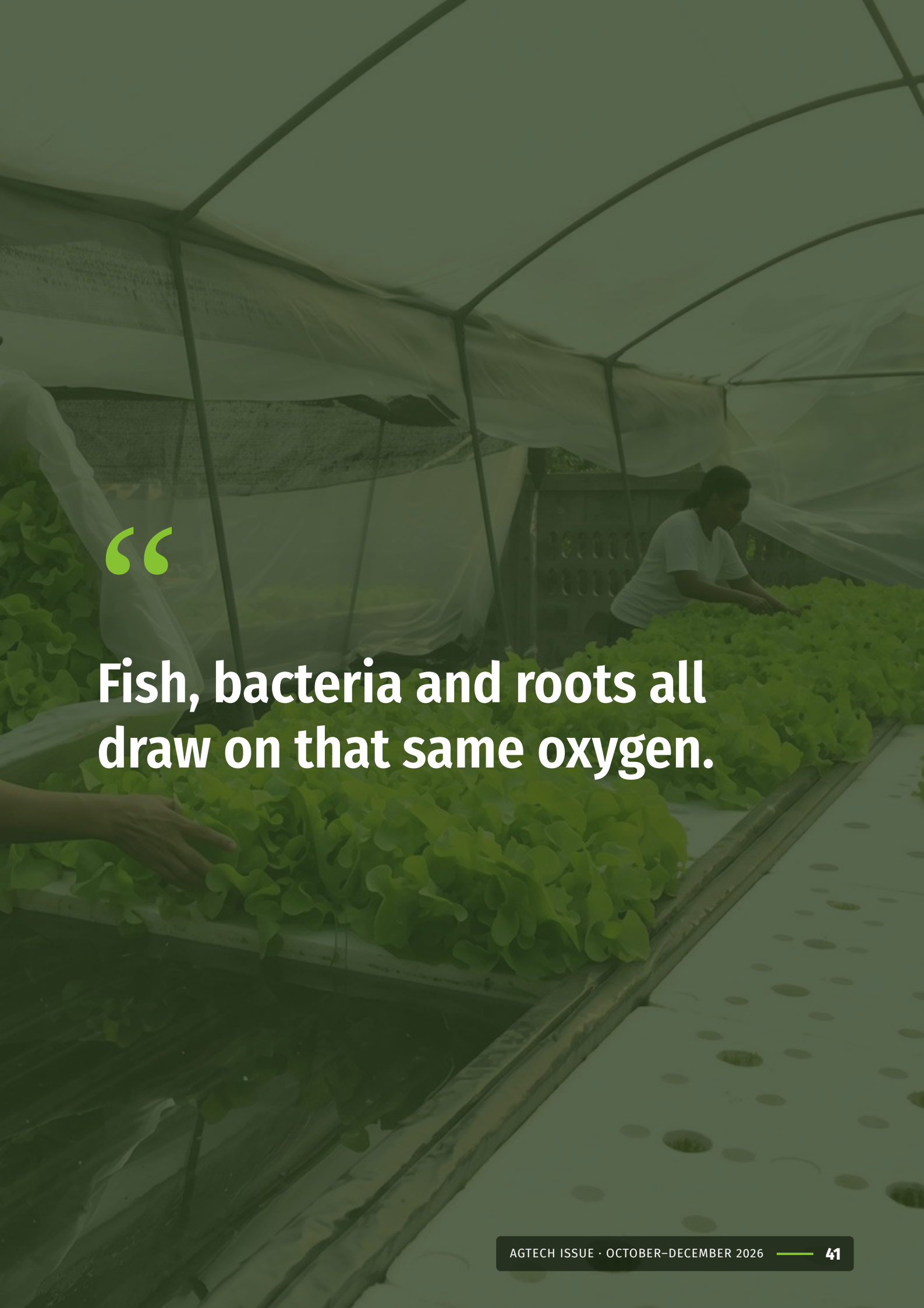
A 2023 review of aquaculture in Barbados found that scarcity of land and water had pushed the island's few commercial-scale ventures into recirculating systems. Most of those businesses had not been sustainably profitable, and most had not moved beyond a pilot phase. Small backyard operations rearing tilapia in tanks and in aquaponics arrays became the predominant forms of aquaculture on the island instead. The finding concerns recirculating aquaculture broadly rather than an aquaponics failure rate, and the published summary does not say why the commercial ventures struggled.

At the regional level, there was general consensus that the Caribbean lacks skilled people in aquaculture, with the observation that without enough trained people, taking a system from a project to a commercial operation is problematic.

A farm and training center in Antigua and Barbuda, established in 2016 with support for the development of its training facilities, was reported in January 2022 to be producing approximately 24,000 pounds of tilapia a year and an estimated 3,500 heads of lettuce a month, and to have trained participants from five other Caribbean countries.

The schedule is what ties the biology to the selling, because staggered planting keeps nutrient uptake relatively steady inside the tanks while the same arrangement puts a predictable quantity on a buyer's table. The useful measure of an aquaponic system is less the yield it can reach at its best, and more the harvest it can sustain and sell through one cycle after another, with the water, the feed, the power and the labor accounted for.

> **Root pathogens are the harder case.**



> Fish, bacteria and roots all draw on that same oxygen.



Shared water links the fish and crop sides of an aquaponic system, so any treatment has to be considered for both.



ADVISORY REVIEW

Mia Brennen

Mia Brennen is an aquaculture researcher and certified Project Management Professional (PMP) with extensive experience in freshwater and marine aquaculture. Having studied and worked across several Caribbean countries and the Pacific, she brings a strong understanding of aquaculture within diverse island contexts. Her expertise includes aquaponics, tilapia production, freshwater prawn hatchery and nursery operations, and the culture of marine crustaceans and molluscs.

As Aquaculture Manager at the Cape Eleuthera Institute in The Bahamas, she leads applied research and sustainable aquaculture initiatives supporting regional food security and responsible resource use, among other research initiatives. She also contributes to regional education and capacity-building through invited presentations, lectures and training courses.

Mia is a PhD candidate at the University of Plymouth. Her doctoral research focuses on developing aquaculture feeds from locally available Caribbean ingredients to reduce reliance on imported inputs and strengthen sustainable production in small island developing states.

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TECHNOLOGY & INNOVATION

Cooling Technology for Broiler Houses in Hot and Humid Conditions

Advisory Review by **Professor Edwin I. Ekwue**

Cooling broilers in hot, humid conditions is not simply a matter of adding fans or water. This article explains how temperature and humidity affect a bird's ability to lose heat, then examines building design, air movement, evaporative pads, direct surface wetting, monitoring, water supply, and backup power, showing the limits and management demands that come with each level of environmental control.

Heat and humidity act on a bird together. How much moisture the air around your birds can still take up plays a large part in deciding which cooling technology earns its place.

Data loggers at bird height recorded temperature and humidity through the second half of the grow-out in three open-sided broiler houses at the University of the West Indies Field Station in Valsayn. In the afternoons, mean temperatures sat between 27.1 and 29.0 degrees Celsius, with relative humidity between 64.5 and 68.7 percent. The birds' own afternoon rectal temperatures ran from 41.40 to 42.00 degrees Celsius and rose as the space allowed per bird was reduced. The researchers concluded that the flock was under chronic heat stress and that the microclimate inside the houses deserved attention.

The production figures are worth reading with that in mind: stocking density had no significant effect on body weight, feed conversion or mortality at 42 days, though feed intake and live weight at slaughter both fell as space per bird was reduced. None of these was the kind of result that forces you to act. The study picked up the heat-stress pattern because it measured the house microclimate, the birds' physiological response and their production performance separately.

Where a Bird Can Send Its Heat

A broiler sheds heat by four routes: conduction, convection, radiation and evaporation. The first three all depend on the surroundings being cooler than the bird, so as house temperature climbs toward body temperature, they become steadily less effective. Evaporation does not depend on that same temperature gradient, though its effectiveness falls as the surrounding air becomes more humid. Unless water is applied to the bird from outside, evaporation takes the form of respiratory heat loss through panting.

Panting works only to the extent that the surrounding air can take up more moisture, because heat leaves a wetted surface as water evaporates into less saturated air. Extension guidance published in 2025 uses about 70 percent relative humidity as a practical management threshold: hold in-house humidity at or below roughly that figure, and birds tolerate fairly high temperatures because their evaporative respiration still has somewhere to send the heat.

High temperature and high humidity together are what sharply restrict your birds' ability to shed heat.

Start With the Building

Before anything is switched on, the structure is either helping or working against you, and it costs nothing to run. Orientation is decided once and



Orient house east to west, insulate or raise roof, and use ridge vents and fans to remove heat and keep air moving over the birds.

Building Design Keeps Birds Cooler

Designing Heat Out of the House

A raised roof, ridge ventilation, open sides and steady air movement help limit heat buildup and carry warm air away from the birds before additional cooling systems are considered.

cannot be revisited: in the tropics, running the house east to west is preferred because it presents the shorter walls to the sun. Two Trinidad engineering surveys reached that conclusion nearly two decades apart, the first in 2003 by E. I. Ekwue, M. Gray and A. Brown, and the second in 2021 by E. I. Ekwue, C. Lewis and C. Bharat.

The roof is a heat source in its own right, and current extension guidance counts roofing and insulation among the factors that load heat into a house. Zinc sheet keeps rain out but readily absorbs and re-radiates heat. The 2003 survey recommended insulating zinc roofs or raising them, and noted that local houses were already being built taller than before to improve ventilation. Roof shape helps in another way: a ridge or monitor opening lets hot air escape instead of gathering over the birds.

Stocking density belongs here too, as a thermal variable. The Valsayn study found that afternoon rectal temperature rose significantly as space per bird fell. For this reason, density is often reduced through the warmer months. But lowering density also cuts the number of birds the house earns from, which makes it a trade-off rather than a free win.

Moving the Air

When the 2021 survey studied Trinidad poultry farms through a questionnaire, interviews and farm visits, only about a third reported any form of

temperature control, and for those farms, that meant fans at the pens and a sprinkler arrangement. The survey was small, but the president of the local poultry association told the researchers plainly that heat stress is the biggest problem birds face in Trinidad.

Fans matter because moving air carries heat away directly and reduces how much the bird has to rely on panting, the route that humidity closes down. In tunnel houses, sufficient air speed over the birds does more in hot weather than anything else fitted to the building.

Maintenance is therefore a performance question rather than a housekeeping one. Dirty shutters, worn or slipping belts and neglected fans can cut air speed by 20 percent or more, and in a house running at reduced air speed, the birds reach heat stress at temperatures that would otherwise be comfortable.

Two Ways to Use Water

Water can be used to cool the air or to cool the bird. The two approaches behave very differently once humidity is high, and that distinction decides most of what a cooling budget buys.

Pads cool the air. The water is not chilled; the cooling comes from evaporation as air is drawn through the wetted pad, so the amount available is set by the temperature and humidity of the outside air. University of Georgia engineering guidance offers a test you can run on your own site. In humid climates, the wet bulb temperature through the day sits close to the overnight low, so take the current outside temperature, subtract the overnight low, and multiply the difference by three quarters. That gives a rough estimate of the cooling a pad system can be expected to produce where you are.

The limit underneath that estimate matters more. Pads are designed to deliver less than the theoretically available cooling, at around 70 to 75 percent efficiency, because taking the air all the way to the wet bulb temperature would deliver it saturated. Air brought in saturated with moisture



Moving Air Helps Birds Shed Heat

Large ventilation fans help move air through the house, carrying heat away from the birds and reducing how much they must rely on panting in hot weather.

Two Different Cooling Jobs

Evaporative pads cool the air before it reaches the birds. Direct surface wetting puts coarse droplets on the birds and lets evaporation carry heat away from their bodies. In humid conditions, that distinction matters because every method that adds moisture also changes what the air can absorb next.

compromises the birds' ability to regulate their own body temperature, and the same guidance states bluntly that this can produce severe heat stress or death even at what would normally be target temperatures.

Foggers and misters work on the same principle and bring a second problem with them. Droplets that evaporate raise the humidity the birds are breathing. Droplets that do not evaporate before they land wet the birds, the litter and the equipment.

There is a local reference point for open-sided housing. The 2021 Trinidad engineering study modeled a redesigned open-ventilated building and found that roof vents alone left most of the structure above the target temperature, which was reached only when a misting system ran alongside them. That result comes from an airflow simulation rather than a working house, the model contained no birds, and in-house humidity was an input to the model rather than a result of it.

Direct surface wetting takes the other approach. Coarse droplets from low-pressure sprinklers, applied intermittently, wet the birds themselves and evaporate off their bodies using the birds' own heat, without deliberately humidifying the incoming air the way a pad does. The method came from the cattle industry, and three conditions carried over with it: intermittent spray rather than continuous, coarse droplets rather than fog or mist, and air movement over the birds. A house cooled this way is also run several degrees warmer than a pad-cooled one, because raising the air temperature without adding moisture lowers its relative humidity and increases how much more water it can take up.

The trial evidence is worth stating precisely. A study on two commercial farms in Queensland, Australia, compared tunnel houses fitted with both sprinklers and pads against controls using pads alone. The sprinklers reduced reliance on the pads rather than replacing them. The combined houses used less water while producing similar litter moisture, live market weight and mortality, and they ran warmer but drier when cooling was called for. Bird comfort was not measured directly; it was inferred from thermal images and from weight and mortality figures.

That work was done in mechanically ventilated houses with cool cells and controllers already installed, so it does not transfer automatically to an open-sided building. In-house humidity still has to stay around or below 70 percent, and the discipline is unforgiving: run sprinklers continuously, or without air movement, or in a house you are holding cool and humid, and the result is wet litter rather than cooler birds.

Measuring Inside the House

All of this depends on knowing what conditions the birds are in, and that capability scales all the way down. A thermometer and hygrometer at bird height, or a small logger of the kind used in the Valsayn houses, will tell you what your afternoons look like inside an open-sided building. Readings taken at the eaves or in the walkway describe somewhere the birds are not.

A controller is the same idea with authority

attached. The same 2021 study also modeled a tunnel house for middle-scale local producers. The design included a control unit governing fan speeds, fogging, air vents and lighting; sensors placed among the birds at 15 centimeters from the floor; and an alarm sending a power-failure alert to a phone.

A controller acts only on what it is told, and a single sensor describes one small area of a building that may vary considerably from end to end. University of Georgia guidance for commercial controlled houses puts the useful number of sensor positions at five or six along the length of the house, on the reasoning that you would need to stand in roughly that many places to know what was happening throughout.

Water supply becomes part of the same system, because the birds are no longer the only ones drawing on it. Broiler water consumption rises about 7 percent for every degree Fahrenheit the temperature climbs and can double or triple under heat stress, so where cooling equipment draws on the same farm supply, both demands peak together. Water quality matters too, because the particulates that cause leaking nipple drinkers also block fogging nozzles.

The Fifteen Minutes After the Power Fails

In a totally enclosed, controlled-environment house, a power failure can produce catastrophic losses in under 15 minutes. Solid sidewalls rule out effective natural ventilation, and in any case there are far too many birds in the building for natural ventilation alone to carry them.

There is no falling back to fresh air at this level of control, so what stands between the flock and the loss is the backup power system. An Alabama Extension analysis of catastrophic losses over two years, across approximately 300 million square feet of housing space, attributed about 45 percent of them to the generator, the automatic transfer switch and the associated switching. Most of those losses



were judged preventable through maintenance.

The principles are unglamorous. A generator has to be sized to handle starting load as well as normal running load, because motors draw several times their running power in the first seconds. It has to be exercised under an actual transfer of power rather than merely started, kept fueled, startable by hand if the electronics fail, and paired with alarms that are tested rather than assumed.

Choosing Your Level

Tunnel-ventilated and climate-controlled poultry housing is being built in several CARICOM states, with investment reported recently in Belize, Guyana, Suriname, and Trinidad and Tobago. Whether it suits a particular operation is a separate question from whether it is the most advanced option available, and the two are easily confused. Each step up removes a physical limit and hands you something new to keep running: power, water, water quality, maintenance, and sensors sitting where the birds actually are.

So for anything that depends on power, water or controls, ask what happens when that supply fails and how quickly the birds can be protected. Passive design carries no such dependence, though it also offers less control when outside conditions turn difficult. Which side of that trade-off suits your operation is the decision, and it is not one the equipment specifications will make for you.





ADVISORY REVIEW

Professor Edwin I. Ekwue

Professor Edwin I. Ekwue is Professor Emeritus in the Mechanical Engineering with Biosystems Programme at The University of the West Indies (UWI), St. Augustine. He served as Dean of the Faculty of Engineering from 2018 to 2023 and previously held leadership roles including Deputy Dean and Head of the Department of Mechanical and Manufacturing Engineering.

He holds a Bachelor of Engineering degree from the University of Nigeria at Nsukka and master's and doctoral degrees in Agricultural Engineering from Cranfield University in the United Kingdom. Before joining UWI in 1992, he was a Senior Lecturer in Agricultural Engineering at the University of Maiduguri, Nigeria.

Professor Ekwue's research has focused on the development and design of agricultural engineering technologies, with work spanning water resources, hydrology, irrigation, drainage, farm structures, environmental engineering, soil erosion, and soil dynamics. He has written or contributed to approximately 127 academic papers, including 80 published in refereed journals, and has supervised more than 190 student projects.

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TECHNOLOGY & INNOVATION

The Machine That Fits the Ground It Has to Work

Advisory Review by **Dr. Jacqueline Bridge**

Choosing farm machinery is about more than horsepower. The job, implement, soil, field shape, slope, traction, power requirements, and available working days all help determine whether a tractor-and-implement combination will actually perform. This article shows how machine capacity, weather risk, soil compaction, and operating constraints can be weighed to find equipment that fits both the work and the ground.

The right tractor and implement are the pair that can finish your job on your ground before the working days run out. Engine power is only one of the measurements that decide which pair that is.

A tractor cannot do field work on its own. What it gets done depends on the implement attached to it and on the ground the two must work. So, the tractor and implement have to be chosen as a pair for a particular job. Engine power alone cannot settle that choice. It tells you what the engine produces, but it does not tell you how much of that power reaches the implement, or whether the pair can finish the job while the ground can still be worked.

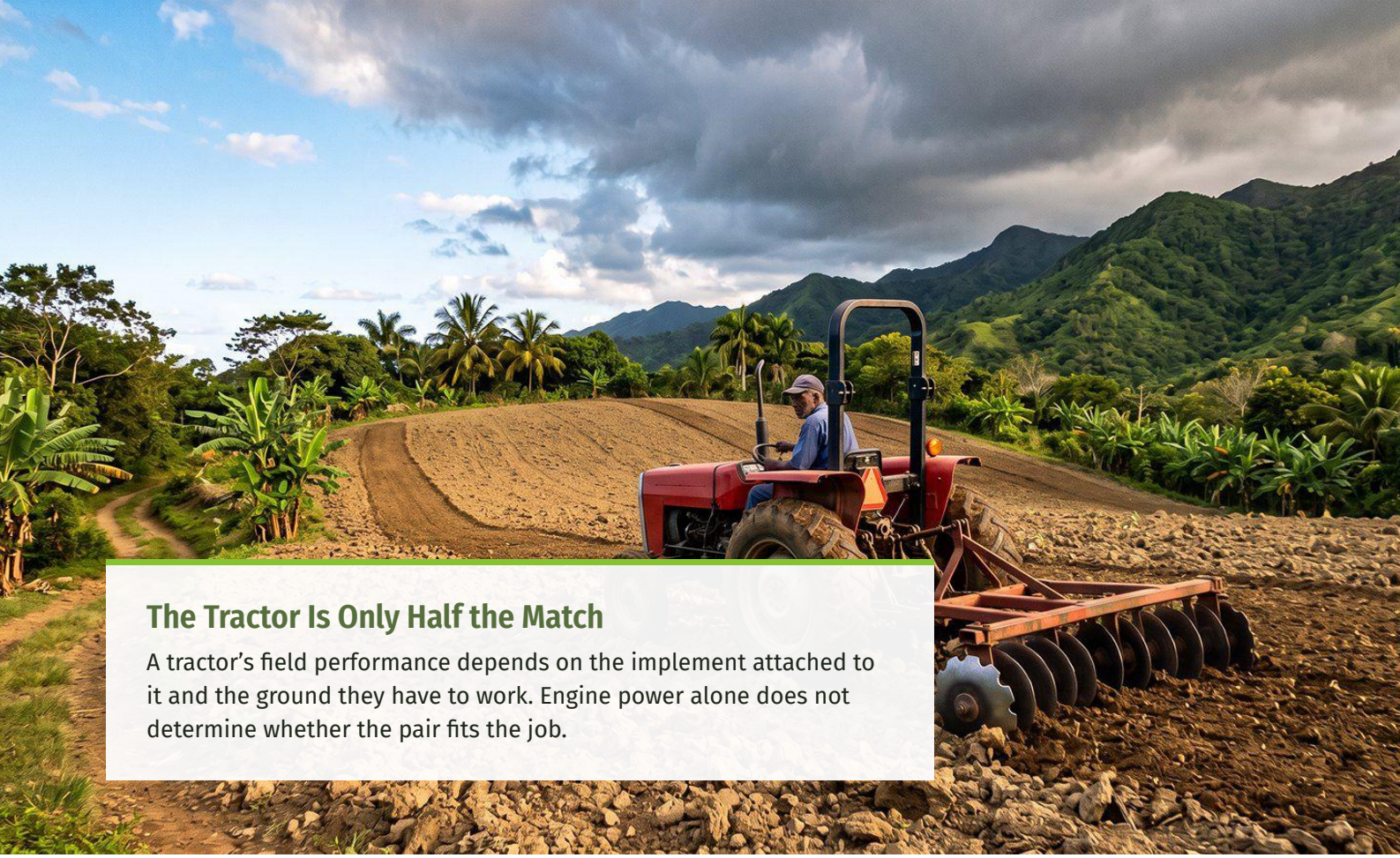
Scale-appropriate mechanization means matching the machine to the size of the farm, instead of reshaping the farm around the machine. But size is only one of the things a machine has to fit. It also has to fit the operation it is meant for, the ground it must work, and the working window. Working window is the term used to describe the number of days on which that operation can be done. Each of these can be measured before you choose a machine.

Each Operation Asks Something Different

The job comes first because it decides what the machine has to supply. Tillage comes down mostly to applying enough force for long enough. The same is true of harvesting a cereal such as rice, and of hauling produce from the field. These are power-intensive operations. Primary tillage, the plowing that first breaks the ground, is among the heaviest work a tractor does. Planting, weeding, and crop protection take power too, but the indicator of success depends on where the machine puts something and when, which makes them control-intensive.

Harvesting sits on both sides of that line. A cereal harvest is mainly a matter of power. Specialty crops such as fruits and vegetables call for careful decision-making, which puts their harvest on the control-intensive side. The distinction also shows up in the order things are mechanized. Power-intensive work such as land preparation usually comes first, and the operations that turn on placement and timing generally follow.

Defining the operation means writing down what it requires before looking at any machine. For an implement pulled through the soil, the working depth, width, and speed set the load. The pull it needs, called its draft, rises with each of them and changes with the soil. For control-intensive work,



The Tractor Is Only Half the Match

A tractor's field performance depends on the implement attached to it and the ground they have to work. Engine power alone does not determine whether the pair fits the job.

the standard is placement and timing: seed placed consistently, and fertilizer or pesticide applied properly and at the right moment. Timing matters for both kinds of work. Planting and harvesting are time-bound, and doing either late can cost yield and quality even when the work itself is done well.

The difference between the two kinds of operation decides which power measurement matters. A power-intensive operation puts sustained load on the drawbar or the shaft, so the tractor's capability figures determine whether it can do the work at all. Until you know which job you are mechanizing, the numbers on a specification sheet have nothing to be measured against.

Power Has More Than One Measure

Tractor tests generally measure four separate capabilities. Two measure power: what the tractor delivers at the power take-off (PTO) shaft and what it delivers at the drawbar. The other two are hydraulic: the weight its three-point hitch can lift, and the pressure and flow the system can supply to cylinders and motors on an implement. Most implements lean on one of these more than the others, and that dominant requirement tells you which tractor figure to read.

Engine power sits behind all four. Some of it is used up before it reaches the PTO shaft, so a tractor's PTO rating is lower than its engine rating. Even less reaches the drawbar when the tractor is pulling a load. Drawbar power combines the pull the machine can exert with the speed it can hold while exerting it. Under field conditions, only about 50 to 65 percent of maximum PTO horsepower converts to drawbar horsepower. The drawbar figures from tractor tests are measured on concrete or asphalt, so they can be well above what the same tractor manages in a field. Overestimating the drawbar side is one of the most common errors in equipment selection; the tractor is paired with an implement that is too big for it.

The single-axle tractor shows the gap between engine power and pull most plainly. This walk-behind machine runs somewhere between 1.5 and 15 kilowatts, and that range says almost nothing about what it will pull. Its pulling force comes from the weight pressing down on its driving wheels. On a machine that size, the weight is not much, so a good team of oxen will usually out-pull it. Its engine does its most useful work spinning an implement rather than dragging one, and a rotovator, or rotary tiller, gets the most out of it.

Hydraulic capacity covers two separate checks. The first is lift. A mounted implement is raised and carried on the three-point hitch, so the hitch's rated lift capacity has to be checked against what the implement requires. The second is flow and pressure, which matter when an implement has hydraulic cylinders or motors of its own and draws its power from the tractor's hydraulic system rather than from the shaft or the drawbar.

The implement itself usually shows which requirement dominates. Anything pulled through the soil, such as a plow, a harrow, or a ridger, leans on the drawbar. At your working speed, its draft sets the drawbar power the tractor has to supply. Anything driven by a shaft from the back of the tractor, such as a rotary tiller or a tractor-mounted brush cutter, leans on the PTO. Anything carried on the hitch or worked by its own cylinders and motors leans on the hydraulics. Some implements draw on two: a PTO-driven harvester is pulled as well as driven, so both figures apply. Planters and sprayers need power too, but placement and timing decide whether they do the job, so for them the specification to read first is the one that describes accuracy.

The Work Has to Fit the Window

An operation’s working window usually holds fewer days than the period in which it must be completed, because only some of those days are fit for fieldwork. The time the window offers is one of the most important inputs to sizing a machine.



Not All Power Reaches the Job the Same Way

A tractor delivers capability through different systems. Hydraulic flow, hitch lift, PTO power, and drawbar pull matter differently depending on the implement and the work it has to do.

Engine power alone cannot settle that choice.

Divide the area the operation has to cover by the number of working days you can expect, and you have the minimum daily capacity the job needs. A tractor and implement combination with at least that capacity can do the job; one with less cannot be relied on to finish on time.

Total farm size is a weaker guide than the area the operation covers, and a field worked twice by the same operation counts twice. Hours count as well as days. The area a machine covers in a working day is the most critical measure of its capacity, more than its width or what it covers in an hour. That daily figure depends on how many hours you can put in. If fieldwork has to fit around other jobs, fewer hours are available on each working day, and the machine has to make up for the difference with a higher hourly rate.

What a machine covers in an hour is its field capacity. It depends on how wide a swath it cuts, how fast it travels, and how much of that hour it spends working rather than turning at the row end, adjusting, refilling, or making minor repairs. That last share is called field efficiency. Field shape acts on it directly: a short or irregular field means more turns for the ground covered, so more of every hour is lost at the headland. Set the machine’s field capacity and the hours you can work against the daily requirement, and whether it can do the job becomes a comparison rather than a guess. Allow for breakdowns as well. When a machine stops during time-bound work, the working days it loses cannot be regained.

The best record of how many working days your land offers is your own. Note each day which fields were worked, which could have been worked but were not, and why. Over a few years, those notes will show how many days each operation can count on and where the wet spots are.

Whether the Implement Will Go On

With the operation defined, the implement's requirement identified, and the required capacity worked out, the tractor and implement can be matched. The tractor is half of that match; the implement is the half that meets the crop and the soil. The checks run in a sensible order: whether the tractor can power the implement, whether it can lift or pull it, whether the two will connect, and whether the pair can work at the right speed.

Power comes first. For an implement driven from the PTO shaft, set its PTO requirement against the tractor's PTO rating. For one worked by hydraulic cylinders or motors, set its flow and pressure needs against what the tractor's hydraulic system can supply. For an implement that is pulled, work out the drawbar power its draft calls for at your working speed. Then compare it with what the tractor can deliver at the drawbar in the field, which is well below its PTO figure.

Lift and pull come next. A mounted implement has to be checked against the hitch's rated lift capacity. An implement pulled through the ground, whether trailed or mounted, depends on traction, the tractor's ability to turn its power into pull without its wheels spinning. Traction comes mostly from the weight over the driving wheels, the same limit that holds back the walk-behind. Ballast reduces wheel slip, but too much of it wastes power in rolling resistance and compacts the soil. The total weight also has to stay within the limits of the tires and the rollover protective structure.

Then comes the connection, which is a matter of fit. A three-point hitch category is a size. It fixes the diameter of the pins and the holes they drop

into. It also corresponds to a range of tractor power: Category 2, for example, is the class for tractors of roughly 40 to 100 hp. Pins and holes have to match, though a bushing will adapt some combinations. PTO speeds are standardized at 540 or 1,000 revolutions per minute (rpm), so the implement and the tractor's shaft have to agree. The driveshaft between them also has to be the right length, and a quick hitch, which speeds up attachment, can change the length the implement needs. A horsepower rating and a working width will not tell you any of this.

The last check costs nothing to run. For many tractor and implement combinations, a correctly sized implement can be pulled at roughly 5 to 13 kilometers an hour, a range more usually published as 3 to 8 miles an hour. A tractor that pulls it comfortably faster than that is probably larger than the implement needs. One that cannot reach the bottom of the range is probably too small. Treat those figures as a rule of thumb and not a specification. An oversized implement forces the tractor to travel slowly, which cuts the pair's field capacity and can compromise the quality of the work.

In Jamaica, a 2024 specification for four tractors and their implements shows how many requirements can sit behind one horsepower figure. Besides a 75 hp engine, the tractors needed a Category 2 three-point linkage, at least 2,000 kg of lift at the hitch points, and a rear PTO turning at 540 rpm or more. The implements carried requirements of their own: the onion and potato harvesters, for instance, were to run from a 540 rpm PTO, work 130 to 200 mm deep, have a field capacity of 0.75 to 1 acre an hour, and need a tractor of at least 60 hp. None of the implement horsepower figures says whether it means engine, PTO, or drawbar power, and that is the first question to ask of any such figure.

What a machine covers in an hour is its field capacity.

The Ground Writes the Specification

None of those checks matters unless the machine can access the fields in which the work is to be done and turn at the end of the row. The gate it comes through, the track it travels, the room at the headland: these are measurements too, and a machine that cannot clear them is out, whatever it can pull.

Slope is a different kind of limit. It makes machinery harder to operate and raises the risk of overturning. The underlying principle is geometry. A tractor stays upright while its center of gravity stays inside the lines joining the points where its tires meet the ground. A slope brings the center of gravity closer to those lines, and the higher it sits, the more easily it crosses them. A mounted implement lifts the center of gravity as it rises, so the same tractor on the same slope is less stable with the implement raised than with it lowered. Wider wheel settings help by moving the lines outward, but no adjustment removes the risk entirely, which is why a rollover protective structure matters on any tractor that works slopes. It does not prevent an overturn, but with the seat belt fastened it keeps the operator inside its protective frame.

Dense concentrations of trees or stumps can stop mechanization altogether, while stumps and stones pose a significant risk of damage to machinery. Small four-wheel and two-wheel tractors can

maneuver around them more easily than a large tractor can.

Field size and shape impose a different type of constraint, since agricultural machinery cannot be readily scaled to match individual plots. A machine's physical dimensions, turning circle, and rated capacity are inherent to its design and may therefore be unsuited to small or awkwardly shaped plots. Consequently, fragmented holdings are at a disadvantage for mechanization, regardless of the quality of the equipment available.

Sized by the Calendar and the Soil

The changing condition of the soil between the wet and dry seasons sets a further constraint. Wet soil is more vulnerable to compaction than dry soil, so the same machine doing the same job leaves a field in a different state depending on when the work is done. Axle load and repeated traffic further influence soil condition, making machine weight on its own an inadequate measure of compaction risk. Compaction in the subsoil is a result of heavy axle loads, especially on wet soil, and is difficult to reverse. Limiting axle loads is therefore important for protecting deeper soil layers.

In addition to increasing compaction risk, wet ground takes working days away. Wet soil affects an implement's draft and the grip the tractor's wheels can find. Additionally, poorly drained fields offer fewer days fit for fieldwork; field drainage may increase the number of suitable days. However, these days are not evenly spread across the year.

Dry soil carries a risk of its own. A rotovator worked in dry soil pulverizes it and breaks down its aggregates, so for that implement, soil moisture sets a limit at both ends of the range.

The number of passes ties the soil back to the calendar. Lighter machines reduce the risk of compaction, but a machine that needs more passes to finish the job runs more traffic over the ground to do the same work, and every extra pass uses time from the same working window. Reducing the number of separate operations, or combining two in one trip, reduces both the traffic and the capacity the job needs.



Case Study: Guyana's Sugar Estates in a Wet Year

Guyana's sugar estates planned to prepare 6,047.4 hectares of land in 2025, but wet conditions severely restricted field operations. Rainfall exceeded the long-term average, and periods of intense rain left fields waterlogged for long spells, limiting field access and disrupting tillage, planting, and harvesting. Of an estimated 75 opportunity days, the estates averaged only 39, with one estate recording just 9 opportunity days. By the end of the year, only 1,446.6 hectares had been prepared, 23.9 percent of the planned amount.

Wet weather was the main cause, but it was not the only one. Labor shortages, machinery availability, and a shortage of land suitable for planting also restricted operations. Tillage equipment availability ranged from 61.3 to 84.5 percent across the estates, and the machinery fleet was not always able to make full use of the opportunity days available. Mechanical harvesting operations were interrupted because transport for the cut cane, within the field and to the factory, was not always available, and trailers on order did not arrive when needed. The ground played its part as well. Field layout was cited as a limit on applying fertilizer by machine; in response, fields are being reshaped with laser-controlled leveling so that machines can work them more readily.

This case highlights the point that capacity on paper does not translate directly into work completed in the field. Productive capacity exists only when the fields can be worked, the machine itself is available, and the labor, transport, and other supporting resources it depends on are available at the same time.

The Case for the Larger Machine

A four-wheel tractor can be the scale-appropriate machine. Where the area, the terrain, and the working window justify its capacity, it is the right technology; a machine rated below that capacity is



Wet Ground Changes the Job

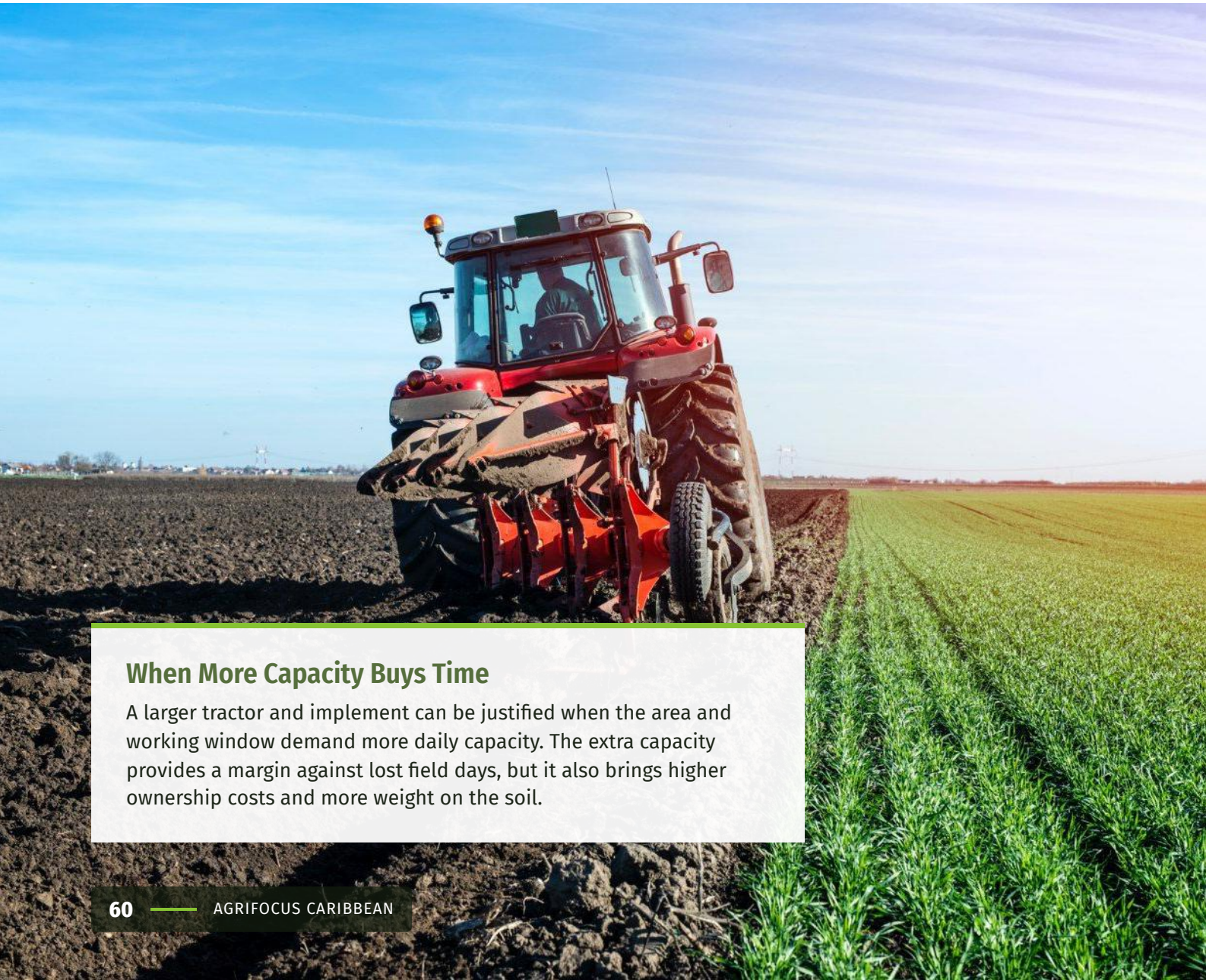
Wet soil can reduce traction, increase the risk of compaction, and take usable field days out of the working window. The same machine can perform very differently as soil conditions change.

as poorly matched as one rated above it. The undersized machine is the harder mismatch to spot because its symptom is an operation that cannot finish within its working window.

Oversizing leaves different signs. A tractor that can pull its implement comfortably faster than the top of the travel-speed range is probably larger than the implement needs. A tractor with more power than the work calls for also costs more to own and to run than it has to.

Between those two mismatches sits a genuine choice about risk. The number of working days changes from year to year, so capacity sized for a year with few of them will be more than the job needs in most others. That spare capacity improves the chance of finishing on time in a bad year. It is the real case for the larger machine: a margin against the weather, paid for in higher ownership costs during the years it goes unused. How much margin is worth having depends on how much a late finish costs the crop.

Sizing comes down to a single test, one that applies to the largest tractor and the smallest walk-behind alike. The right system is the smallest, most suitable tractor and implement combination that can do the required operation properly, on your ground, within the working window you have decided to plan for. A larger machine generally brings more weight on the soil, a higher cost to own, and more room needed to turn, so any size beyond that point has to be justified by the margin it buys against a bad year.



When More Capacity Buys Time

A larger tractor and implement can be justified when the area and working window demand more daily capacity. The extra capacity provides a margin against lost field days, but it also brings higher ownership costs and more weight on the soil.



ADVISORY REVIEW

Dr. Jacqueline Bridge

Jacqueline Bridge is a Senior Lecturer in the Department of Mechanical and Manufacturing Engineering (DMME) at the University of the West Indies, St. Augustine Campus.

She holds a BSc in Mechanical Engineering from UWI-STA and a PhD in Theoretical and Applied Mechanics from Cornell University.

She leads the DMME Applied Mechanics and Design group, and her teaching experience includes mechanical design, engineering dynamics and vibrations, finite element analysis, controls and automation. She has published over 60 peer-reviewed articles in archival journals and conference proceedings in mathematical modelling and analysis of engineering systems, nonlinear dynamics and characterisation of machines using vibration monitoring and machine learning.

Dr. Bridge has academic and professional experience in the Caribbean, Germany, the USA and Canada.

UWI Profile ↗

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TECHNOLOGY & INNOVATION

Choosing the Right Postharvest Technology for Your Crop

Advisory Review by **Dr. Saheeda Mujaffar**

The right postharvest technology depends on where losses actually occur and what the crop must survive before reaching the buyer. Moving through cooling, curing, washing, packaging, handling, temperature, humidity, and monitoring, this article uses Caribbean examples to show why equipment, settings, and methods must be matched to the crop, its journey, and the market rather than simply copied from elsewhere.

What temperature to run it at, how long to leave it, how gently to handle it: postharvest equipment does not arrive with any of those answers in it, and where they come from is your crop, the journey it has to make and the buyer waiting at the end of it.

Suppose you have money for one piece of equipment this year, and you want it to be the one that stops you losing your crop between the field and the buyer. Which one should it be?

Nobody can answer that for you yet, because the question is missing three pieces of information: what you grow, how far it has to travel, and what the buyer expects when it arrives. Until those are settled, any recommendation is a guess.

The reason is that none of this equipment arrives with your crop's settings already in it. A cold room does not know what you plan to store in it, and a box does not know what it will be asked to carry or how far. Somebody has to decide the temperature, the timing and the handling in every case, and those decisions shift with the crop and with the journey it has to survive.

So the more useful question, and the one to work through before you spend anything, is what your crop needs done to it, and what it has to come through before somebody pays for it.

Which Jobs Your Crop Needs

Start by ruling things out, because not every crop needs every operation, and equipment bought for a job your crop does not require is money gone before it has done anything.

Some roots and tubers, sweet potato and yam among them, keep far better if they are cured before going into storage. Curing gives the cuts and scrapes from digging a chance to seal over, and a root that has sealed holds its condition much longer than one that went into the bag with the damage still open. A lettuce cannot do that, which is why the equipment for curing would sit idle on a holding that grows leaves.

Washing works the same way. Some crops need it and some do not, and the timing matters as much as the washing itself: sweet potato is cured first and washed afterward, if it needs washing at all.

The other half of the question is what is actually taking your crop, and that is not always what you would assume. When hot peppers were followed through the roadside trade in Trinidad, from the field to the person who bought them, almost a third of the crop was lost in the dry season, rising to almost 39% in the wet season, and the biggest single cause was not rot or heat but bruising. A cold room would have done nothing about bruising. Better containers and gentler handling are what answer that.



So it is worth following one of your own crops the whole way before you price anything. Watch it come out of the ground, into the container, through the shed, onto the vehicle and into the buyer's hands, noting as you go where it stands in the sun, where it gets dropped and where it waits. Twenty-five farmers, processors and extension officers spent a week on this ground in Roseau in January 2025, working through loss measurement, quality, packaging, cooling, temperature and transport.

Colder Is Not Automatically Better

Suppose cooling is the answer for your crop. The next question is how cold, and that is where money gets wasted.

Those same hot peppers were held in storage at between two and four degrees, which sounds like a sensible setting for a cold room and was the wrong one for them. The low temperature injured them (a condition known as chilling injury), and the expensive part was where that damage showed up, which was later at the roadside stall, in front of the customer.

Curing has its own settings, and what makes it awkward is that all of them have to hold at once. The crop needs warmth, it needs air that is damp but with no water sitting on its surface, and it needs enough air moving through to keep oxygen around it without drying it out. Get two of those right and the third badly wrong, and the curing suffers for it.

For sweet potato, none of that necessarily requires a machine. Crates or small heaps kept off the ground, in shade, sheltered and with air moving through them for a few days, will hold those conditions. What will not hold them is roots bagged straight out of wet soil into something that cannot breathe.

Water needs managing rather than simply running, because water that stands, or gets used over and over with nobody watching it, can carry rot from one batch of produce into the next. Chlorine does not solve that either, because it reacts with the dirt and debris in the tank and stops



working, and a dirty tank with chlorine in it is still a dirty tank.

Borrowing Somebody Else's Method

This is the question that catches most people out. Somebody tells you how they handle their crop, or you come across the numbers written down somewhere, and it all looks sensible enough. Can you simply use them?

Mangoes going to export markets have long been dipped in hot water, mainly to deal with the fruit fly, and work done in Dominica on Julie mangoes tested a range of water temperatures and dipping times to see what the treatment could and could not achieve. The dip accepted for the fruit fly at the time did control the fly, but it did not adequately control the rot that develops after harvest. Hotter water for a shorter period controlled the fly and cut back the rot as well, without harming the fruit's color, texture or sweetness. The same tank of hot water answered one problem and left the other standing, and which of those you ended up with depended on the numbers you ran it at.

That is what a proven method is: proven against something in particular, under conditions somebody wrote down at the time. Change the pest, the disease, the variety, the growing area or the time of year the fruit came off the tree, and you cannot assume those numbers still hold. They are research conditions rather than a recipe, and anyone dipping fruit commercially should be working to a schedule validated for that fruit and



that market.

The equipment follows from how tight the margins are. The water has to be held at the temperature the treatment calls for and the fruit taken out on time, which means a thermometer you can trust and a reliable way of timing the dip. There is very little room for error, which is why somebody stands and watches rather than setting it going and walking away.

What the Box Is Holding Up

A box looks like the least technical thing on the list, and it is doing more than it looks. Three parts of that work matter here: one person has to be able to lift and carry it without dropping it, it has to take the weight of everything stacked above it, and it has to let the heat coming off the crop escape.

Ventilation is where the design shows itself. Guidance written for Eastern Caribbean fiberboard produce boxes recommends ventilation openings covering at least 5 percent of the total box surface, which is advice rather than a rule anybody enforces, but a sound figure to work to. The complication is that every hole you cut weakens the box, which is why a long narrow slot running up and down works better than a round hole of the same area: part of an upright slot stays clear even when a telescoping lid has not been pushed fully down over it.

How you fill the box matters as much as how it is made. Overfill it and the lid has to be forced, at which point the box starts crushing the crop you bought it to protect; underfill it and everything inside shifts and rubs for the whole journey. Keep the loaded weight under fifty kilograms and preferably under twenty-five, with handles built in so that it can be lifted properly.

Cartons also soften in damp air, so dry washed produce before it goes in and keep your empties dry and flat until you need them. And when you stack, line the vent holes up with one another, because a box stacked so that its openings are covered has lost you the airway you paid for.

Reusable crates earn their money over a number of trips rather than on the first. A collapsible wooden crate developed for Dominica was built to survive at least eight return journeys, and with careful use and occasional repair a good many ran to twenty and more.

Knowing Whether It Worked

The temperature you set and the temperature your crop reaches are two different numbers, and it is worth having a way of telling them apart. A maximum and minimum thermometer left in a store will tell you how hot and how cold the air got while nobody was watching, and if those figures sit outside what you were expecting, something in the store has gone wrong. What it will not tell you is when that happened, why, or what the crop itself reached inside the box.

For that you need a probe pushed into the flesh, either a pulp thermometer or a thermistor probe on a meter. The probe is worth having for a second reason, which is that the same instrument reads the temperature of the produce, the dip tank and the air in the store, so a single purchase covers everything above. One probe reads one fruit, though, so take your readings in a few places rather than trusting whichever one happened to be nearest.

Humidity is the measurement that turns curing from something you hope went right into something you managed. A whirling hygrometer is cheap and quick and works where a fixed wet and dry bulb is too slow to be any use, while a simple digital hygrometer is even easier to use and gives you a direct reading. The caution with the inexpensive digital ones is that they can lose their accuracy over time, so check them against known conditions every so often rather than trusting the same instrument for years.

None of this will win you an argument with a buyer. What it gives you is something worth writing down, so that when a load arrives in poor condition you have somewhere to start looking.



A Box Does More Than Carry Produce

Good packaging must protect the crop, carry the weight stacked above it, remain manageable to lift, and still allow heat to escape through properly placed ventilation openings.



Making the Purchase Pay

The last questions are about money, and these are the ones you can answer without help, because they depend on things only you know: how much you handle, what you grow, how far it travels, what your buyer insists on, whether the power holds where you are, and who will repair the thing when it breaks.

Packaging guidance suggests working the cost out per use rather than against the price on the label, and that is a fair way to look at most of this equipment. A crate used twice in a season and a crate used every week are not the same purchase even at the same price, because one is spreading its cost over far more produce than the other. A useful test for anything you are considering is whether it comes back to you as fewer losses, a better price or less handling, and if you cannot see which of those three it is meant to deliver, you have your answer.

It is also worth remembering that you do not have to own any of it alone. A shared shed, or a cold room owned between several growers, can put equipment within reach that none of you would buy on your own.

All of which brings the question back to where it started. The piece of equipment worth buying this year is the one that does the job your crop and your buyer actually need doing, and the way to find that out is to follow a single crop from the field to the buyer and watch what it has to come through.

Measure the Crop, Not Just the Setting

The temperature set on equipment is not necessarily the temperature inside the produce. A probe thermometer and humidity measurements show what the crop is actually experiencing.

How you fill the box matters as much as how it is made.



ADVISORY REVIEW

Dr. Saheeda Mujaffar

Dr. Saheeda Mujaffar is a Senior Lecturer in Food Science and Technology in the Department of Chemical Engineering at The University of the West Indies, St. Augustine Campus.

She holds M.Phil. and Ph.D. degrees in Agricultural Engineering, specializing in Crop Processing and Postharvest Technology. Her research spans the postharvest handling, preservation and processing of tropical agricultural commodities, with particular emphasis on fruits and vegetables, drying technologies, quality preservation and value addition.

She has extensive experience in postgraduate teaching and research supervision in food processing, food packaging and food quality assurance, as well as professional experience as a Food Technologist in industry.

Her current research interests include sustainable food systems, circularity, food waste utilization, and the use of locally available and underutilized food resources.

LinkedIn ↗ ResearchGate ↗ Google Scholar ↗

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TECHNOLOGY & INNOVATION

How Agri-Food Traceability Follows One Lot

Advisory Review by **Professor Neela Badrie**

Digital traceability is more than placing a QR code on a product. This article follows one lot through identification, record capture, linking, exchange, transformation, and retrieval, showing how lot size and record structure determine what a business can trace when something goes wrong. It also examines practical weaknesses in Caribbean agri-food chains and how businesses can test their records before investing in software.

Digital traceability means giving one batch of food a single identity, then recording every event in that batch's life in a form you can search for later. It is what allows a business to say, quickly and with evidence, where a particular lot came from, what went into it, what it became, and who received it.

A buyer calls about one case of your pepper sauce. How long would it take you to say which batch it came from, what went into that batch, and where the rest of that batch went?

The answer depends less on the digital traceability software you use than on an operational decision most businesses make without much thought: how much product you put under a single lot number.

A lot number, sometimes called a batch number, is the reference you assign to a quantity of product that was grown, harvested, packed or made under the same conditions. Its job is to separate one production run from the next, so that a question about one of them does not become a question about all of them.

The size of that quantity matters more than it looks. Whatever you group under one lot number becomes the smallest quantity your records can isolate and therefore, that minimum quantity you must treat as one unit if that lot ever had to be held, checked or withdrawn from sale.

A lot can be a full day's production at one facility, but only if that day's output really was one uniform batch made from the same input under the same conditions. It can equally be the output of a single hour on one packing line, or one run of a recipe.

That is the trade-off. If lots are defined broadly, you keep fewer records, but you tie a much larger quantity to a single lot number. However, should a problem arise anywhere inside a lot, it puts the whole lot in question, because nothing in your records separates the good part from the suspect part. If lots are defined narrowly then you gain that separation, at the cost of more numbers to assign and more entries to keep.

Drawing the Lot

Before deciding how big a lot should be, you should settle what exactly is being traced.

FAO's *Food Traceability Guidance* (2017), written for food businesses in Antigua and Barbuda, Barbados, Dominica and Grenada, calls that unit the traceable item. A traceable item is whatever physical unit of food your records treat as a single thing that can be followed and, if necessary, called back. In practice it can be a



Where One Lot Ends

Products grouped under the same lot number are treated as one traceable batch, making the lot boundary an important operational decision.

packaged product such as a case of bottled sauce or a consumer pack, a logistic unit such as a crate, bin or shipping container, or an entire shipment.

The choice is yours to make, but it cannot be made in isolation. The businesses on either side of a handover must be tracking the same defined unit. If your packhouse traces by crate and your buyer traces by pallet, the chain breaks at that handover no matter how carefully either of you have recorded your own side of it.

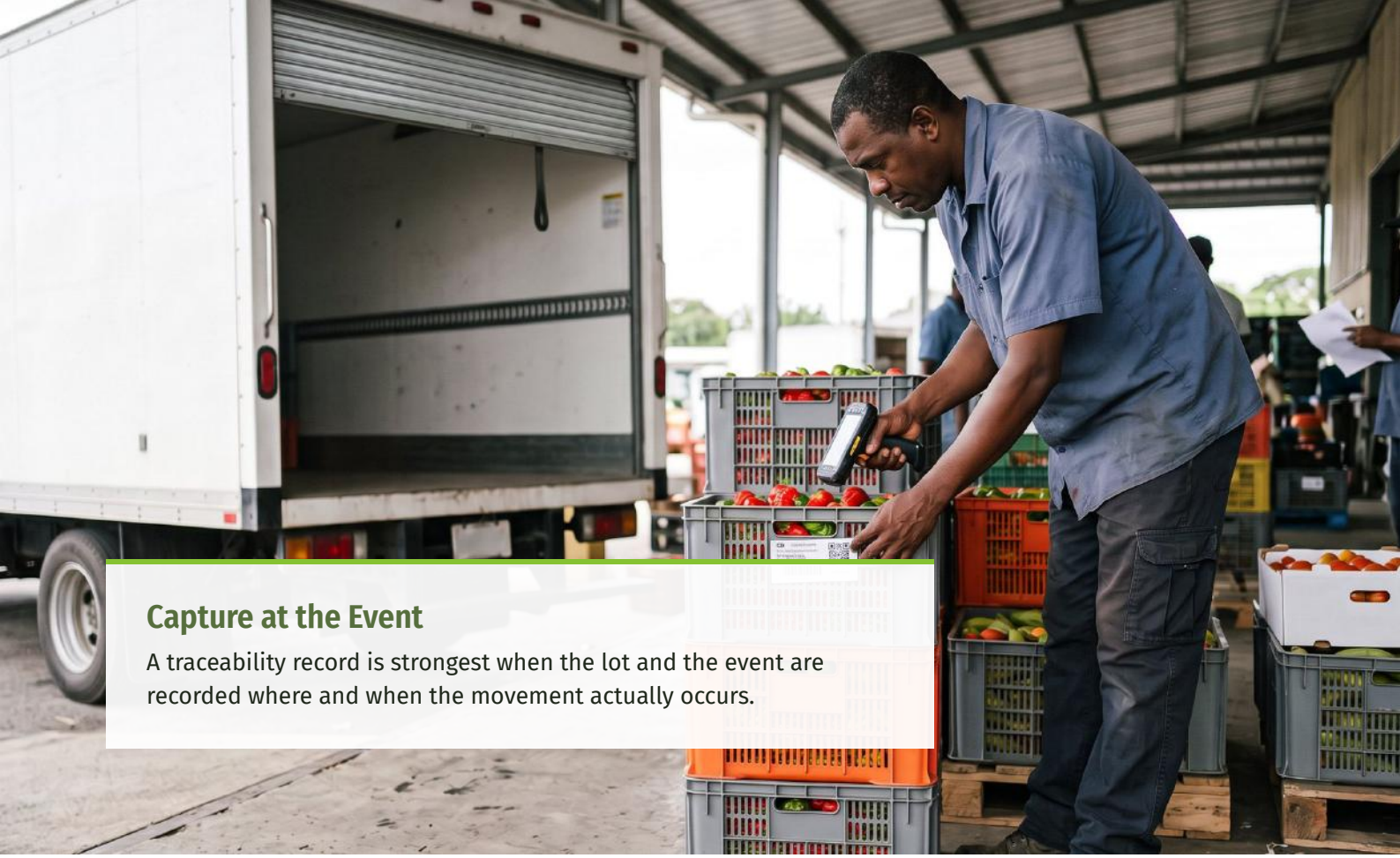
Once the unit is settled, the lot number is what distinguishes one batch of those units from another. For crops it is commonly denoted by the harvest date, which gives every crate filled on a given day the same reference.

Two different identifiers are at work here. The first identifies the product: a product name, a product code, or a Global Trade Item Number (GTIN), the standard number used on retail barcodes. It answers the question "what is this?" and stays the same from one batch to the next. The second is the lot number. It answers the question "which batch is this?" and changes with every production run. A buyer who quotes only the product code has told you what was bought. The lot number tells you from which batch the product came, and the records linked to that number tell you when it was made and what went into it.

The format of the lot number is yours to choose, and it does not need to be elaborate. But if a lot number is designed to carry several pieces of information that software must parse separately, the internal structure of the code has to stay the same from one lot to the next so those parts can be interpreted reliably. What matters is applying it consistently and making sure the next business in the chain knows what it refers to.

Six Jobs a Digital System Does

A digital traceability system does several distinct jobs. The printed code on the label is the only one you can see, which is why it is easily mistaken for the whole thing.



Capture at the Event

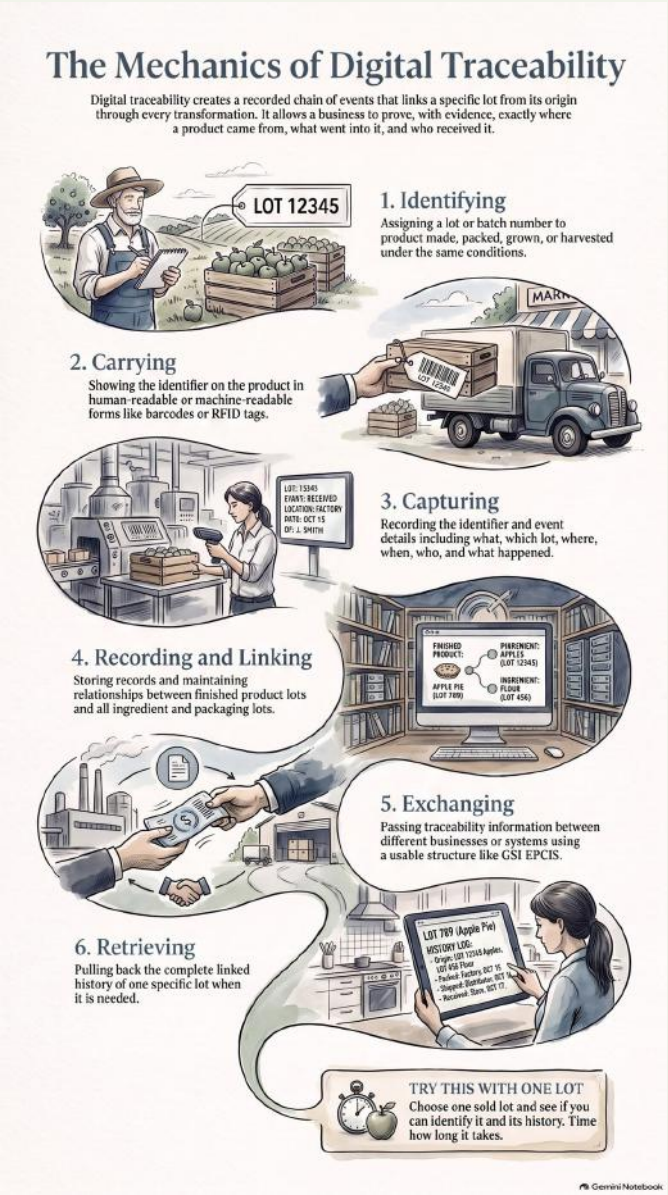
A traceability record is strongest when the lot and the event are recorded where and when the movement actually occurs.

1. **Identifying** is assigning the lot number, and you have already done it.

2. **Carrying** is presenting that identifier where the product is, so that whoever handles the crate can tell which lot it belongs to. Printed text carries it in a form a person reads. A barcode, a Quick Response (QR) code or a Radio-Frequency Identification (RFID) tag carries it in a form a machine reads. A QR code is worth using because it holds an identifier cheaply and can be read with a phone camera, not because it looks modern.

3. **Capturing** is getting that identifier, and whatever has just happened to the product, into a record. Typing, a phone camera, a barcode scanner and an RFID reader differ in speed, cost and how much of the work can be automated. The harder question is whether the record gets captured at the time of the event, because capture happens at a loading bay, a drying floor or the tailgate of a truck, not at a desk. Every event needs to leave behind six things: what the product was, which lot it belonged to, where it was, when it was there, who supplied or received it, and what was done to it. The guidance asks that the movement of the goods and the movement of information stay linked, recorded on the business documents you already use, including sales receipts.

4. **Recording and linking** is the part the software has to get right, and it covers two separate obligations. Recording is storing what happened, which is the easy half. Linking is holding the relationships between records: a finished product's lot number is tied to the lot numbers of every ingredient, raw material and packaging item that was in direct contact with the food. Neither recording nor linking is worth much unless the system also stores that information in a structured form that can be searched, since that is what makes retrieval fast and reliable rather than a matter of hunting through files. Where product moves through nested units — bottles into cases, cases onto pallets, pallets into containers — those



relationships may also need to be captured, otherwise a trace runs backward only as far as the pallet and stops there.

5. **Exchanging** matters the moment information must cross into somebody else's system instead of moving around inside your own. GS1's EPCIS standard, short for Electronic Product Code Information Services, exists for exactly this: a shared structure that lets two businesses using different software pass on what happened, when, where and why, without either having to adopt the other's system.

6. **Retrieving** is the output of everything above it, and the part a buyer or an inspector puts to the test. To retrieve is to pull the complete, linked history of one lot back out of the system: every event, every movement, every transformation, and every consignment into which it was divided. The five jobs before retrieval exist so that a question asked on a Tuesday afternoon can be answered with that history, through every stage of processing to the suppliers, and forward again to everyone who has received part of it.

The dependence of retrieval on the five traceability jobs is why a printed code on its own settles nothing. A printed code cannot create records that were never made, and it cannot connect records which were never linked to each other. A QR code that opens a page about your farm is a marketing tool. It does not tell a shopper or you which batch a complaint refers to, because the records behind it were never built to support lot-level traceability.

The Link Has to Be Written Down

The link is what holds the chain together. It is the recorded connection between the lot you have assigned, the product that lot became, and the crate, pallet or container that carried it out of your gate. Where that connection exists only in somebody's memory or in the order things happened to be stacked, there is no chain, only a collection of separate records.

The link is what holds the chain together.

The connection matters because food does not always leave a business in the form or the grouping in which it has arrived, and each way of changing it does something different to the identity you have assigned. FAO's Caribbean guidance treats four common cases in this way, summarized in Table 1.

(i) Dividing a lot across several consignments need not change anything, provided the system keeps the lot intact as the traceable unit. The lot keeps its number, and each consignment travels under it. The FDA's Food Traceability Rule takes a similar approach for the foods on its Food Traceability List. The assignment of a traceability lot code occurs when a raw agricultural commodity is initially packed, when food from a fishing vessel is first received on land, and when a food is transformed, and no new code is established for other activities such as shipping.

(ii) Repackaging or reconfiguration creates a new product. A product that has been repacked or reconfigured must be given a new unique product identifier, and the linkage between that new product and its original inputs must be maintained. Separately, packers and re-packers assign a batch or lot number to the products they create, which may cover a day's packing or the output of a single packing line, and the lot number must be internally linked back to the original grower and the harvest information. Both identifiers are therefore in play at once. Take a packhouse that receives field crates and sends out graded cartons. The cartons are a new product, so they carry a product identifier of their own, and the packing run that produced them carries its own lot number. What makes the cartons traceable is the record tying that lot number back to the crates that came in.

(iii) Combining one lot with others is harder, because it is the point where several separate identities become one. Two or more lots are brought together into a single quantity that can no longer be taken apart, so the output needs an identity of its own and a record of everything that went into it.

The nutmeg drying operation which is described in the guidance shows how this works in practice. Deliveries arrive from several growers and are separated by product, and each product is mixed into one batch on a drying shelf. When the drying period ends, that shelf is closed to new deliveries and the next arrivals begin a fresh shelf. Closing the shelf is what fixes the boundary of the lot: everything on it is now one batch and cannot be separated back into individual growers' deliveries. What keeps it traceable is a written record listing every delivery that goes onto that shelf before it is closed.

(iv) Transformation goes a step further, because the food itself becomes something different. In the condiment example, ingredients, packaging and raw material, mainly pepper, arrive under several different lot numbers and go into one production batch. The batch emerges with a single new identity of its own, and the only link back to its inputs is the record that documents them.

Purchase and sales records will not make those connections on their own. They show who supplied an input and who bought an output and can carry lot numbers, but unless they also link specific input lots to the specific batch that was produced, they will not tell you which peppers ended up in which bottles.

Table 1. How the FAO Caribbean guidance treats a lot's identity when the product changes hands or form

What happens to the lot	The identifier	What has to be recorded
Divided across several consignments	Unchanged identifier. It travels under the number it already has	Which consignment carried which lot, and who received it
Repacked or reconfigured	New identifier for the repacked product	The link from the new identifier back to the original inputs
Combined with other lots into one output	New identifier for the output	Every input lot that went into it
Transformed into a different product	New identifier for the production batch	Every ingredient, raw material and packaging lot in that batch

Source: Summarized from FAO, *Food Traceability Guidance* (2017).

The Obstacles in Caribbean Agri-Food Chains

You do not need a computer to follow a batch of food through your business. Records can sit in a copybook, and the guidance accepts a copybook as perfectly legitimate. What digital systems change is how information is captured, linked, exchanged, and retrieved, and each of those four steps faces a particular difficulty in this region.

When records are kept by hand, whatever is written stays wherever it was written, so the information cannot easily be searched or shared. Digital records can have the same problem if they are stored in formats that the next business cannot open or use. Information may exist inside a business and still be disconnected from the lot it describes. Processing raises the stakes, because the link between input lots and an output batch must be captured at the moment the batch is made. If that link is missed, reconstructing it later may be difficult or impossible. And all of this depends on people, training and coordination between businesses just as much as on equipment.

In April 2026, the Caribbean Agricultural Health and Food Safety Agency (CAHFSA) reported that the same difficulties were appearing across the region. It highlighted four main obstacles: limited digitalization of traceability systems, gaps in data management and recordkeeping, capacity constraints among food business operators, and the need for stronger coordination among national food-safety authorities. Earlier, in January 2026, a regional project had called for food-safety gap analyses—including traceability assessments in at least twenty agro-processing businesses in the roots, tubers, and vegetables value chains across the Caribbean Forum of African, Caribbean and Pacific States (CARIFORUM)—to be carried out over eighteen months from April 2026. That call tells us what is being examined, not what the examinations found.

None of these obstacles suggests that businesses should buy the largest system available. The Codex Alimentarius holds that traceability must be practical, technically feasible, and economically viable, and that its application must reflect the capabilities of developing countries. The system worth having is the one that fits your operation, the businesses you trade with, and the information you will need to retrieve.

Reconstruct One Lot

Before considering software, start with one exercise that costs nothing. Reconstructing a lot means retrieving its entire history from your own records: every event, every movement, every transformation, every consignment it was divided into, every sale, and every receiving record attached to it, from where it started to where each part of it ended.

Take one lot your business has already sold and try the exercise. Identify which inputs went into that lot and which records identify them, what identifier was assigned to it and when, note whether the lot was divided, combined, or transformed along the way, and trace who received each resulting lot.

Then compare what you found with the six jobs a digital system performs. The exercise may reveal more than one weak point. If nobody can say which lot a delivery belonged to, the issue is identification. If the information exists but was never written down at the loading bay, the issue is capture. If every record exists separately and nothing ties the inputs to the output, the issue is linking. If your buyer's system cannot use the information you produce, the issue is exchange.

Then measure how long the entire exercise took. That is the same amount of time a buyer would be waiting for an answer, and the duration will point directly to the places where the links between your records were missing.

> **Purchase and sales records will not make those connections on their own.**





Traceability Depends on the Record

The challenge is not only collecting information, but keeping it connected across handwritten notes, business documents, and digital records so one lot can be followed reliably.



ADVISORY REVIEW

Professor Neela Badrie

Professor Neela Badrie is a professor of food microbiology and agri/food safety at The University of the West Indies in Trinidad and Tobago. Her areas of expertise span food science and technology, epidemiology, food-borne diseases, international trade, and agri/food legislation. She is also an Attorney-at-Law and practises in Trinidad and Tobago with Thompson, Badrie-Maharaj & Associates.

Professor Badrie is a Fellow of the Caribbean Academy of Sciences and The World Academy of Sciences, and a U.S. Fulbright Researcher. Her professional and academic distinctions include the National Institute for Higher Education in Science and Technology Rudranath Capildeo Gold Medal for Applied Science and Technology, recognition as an Outstanding UWI Woman Graduate in Applied Science and Technology, the European Union Lomé IV-CULP-UWI Fellowship, and the United Nations University UNU/CFNI/PAHO/WHO Fellowship.

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TECHNOLOGY & INNOVATION

What AI Can Do for Your Farm Business and What It Must Not Decide

Advisory Review by **Dr. Priscilla Bahaw**

Generative AI can save time on the paperwork surrounding a farm business, but it should not be treated as an expert on the farm itself. This article shows where AI can help with drafting, summarizing, organizing, and preparing for decisions, while examining unreliable information, missing local context, privacy concerns, and the decisions that still require professional or official expertise.

It is unusually good with words, and it knows only what you tell it about your farm. What it is good for, and what it must not decide, follows from that.

Fourteen pages of funding guidance with a closing date, and the eligibility rules somewhere around page nine. Sales figures spread across a notebook, a stack of receipts and a WhatsApp thread. A buyer who has been waiting two days for a reply that needs to read professionally. None of it grows anything, all of it has to be done, and it gets done at night by whoever was in the field at six.

This is the work generative AI is built for. It is the kind of artificial intelligence you talk to in plain language, and it answers in plain language: drafting, summarizing, reorganizing, explaining. It runs on a phone or a computer, with nothing to install.

What it does not have is your farm. It cannot see the block that is worrying you, it holds no reading from your soil, and it knows nothing about what was planted there last season unless you tell it. Upload a photograph and it can analyze the image, which is a different thing from reliably identifying what is wrong with the crop.

So the useful question is a narrow one. Which jobs do you hand it, and which do you keep?

Start With the Paperwork

In a controlled study of professional writing tasks, people using generative AI finished 40 percent faster and produced work rated 18 percent better. The largest gains went to those who had found the writing hardest to begin with, and the shape of the work changed: less effort spent getting a rough draft onto the page, more spent on ideas and on editing.

Across six Caribbean small island developing states, owners of small and medium businesses using generative AI reported wider access to knowledge, time saved on the tasks that take the longest, and in some cases lower costs where it stood in for services they would otherwise have paid for. The word reported is carrying weight there. Those are the owners' own accounts, given in interviews, and the researchers are explicit that they reflect perceptions rather than measured outcomes.

Agriculture was in that group. Among the businesses interviewed were a poultry producer in Trinidad and Tobago who used it to work up a model for turning waste into animal feed, and an agricultural retailer who used it to prepare workshop material for local farmers at low cost.

Worth knowing as well: a third of the owners



surveyed had never used it at all.

The First Draft Is the Hard Part

A business plan, a grant application, a price quotation, an inquiry to a new buyer, a set of written procedures for a packing shed, copy for a product post. Every one of them is easier to correct than to start.

So start it with the tool. Give it what you actually have, your volumes, your costs, your buyers, your constraints, and ask for a draft you intend to take apart.

The limit here is specific. It cannot know the facts of your operation that you have not given it, and asked to fill a gap it may produce something that reads convincingly and is invented. It will also not turn a weak proposition into a viable one. It can make a weak proposition read more smoothly, which is worse. The finished document has to be yours. What you are buying is the hour that would have gone on the first paragraph.

Making a Long Document Manageable

The same tools will summarize a long document, find the eligibility criteria buried on page nine, or restate a technical passage in language you can act on. Paste in your own scattered notes and ask for them back as a table, sorted by crop, by week, by customer.

One distinction is worth holding on to. Asking it to work on a document you have supplied is a different kind of request from asking it to tell you something out of its own memory. In the first case the material is in front of it and you can check the summary against the source. In the second you are relying on what it absorbed during training, and that is where the trouble sits.

Why It Guesses

These systems produce what is statistically likely to come next, and they do it extremely well. Likely and true are not the same thing.

The Farm Generates More Than Crops

Records, quotations, applications, procedures, and buyer communication are part of running the business. AI can help organize and draft that work, but the facts still have to come from the farm.

Research published by OpenAI explains the behavior bluntly. The systems guess when they are uncertain because the way they are trained and scored rewards a guess over an admission of ignorance. A wrong answer and an honest "I don't know" both score nothing, so a plausible guess is the better bet. In the researchers' own demonstration, a widely used chatbot asked for the title of one author's doctoral dissertation produced three different answers, none of them correct, then produced three different birth dates for him, also all wrong. The United States National Institute of Standards and Technology gives the behavior a name in its generative AI risk profile: confabulation, content stated confidently and wrong.

The practical difficulty is that the writing gives you no warning. The invented figure and the correct one arrive in the same calm, well organized prose. Connecting a model to web search does not remove the problem either, and the same research notes that some questions stay unanswerable whatever search and reasoning are added.

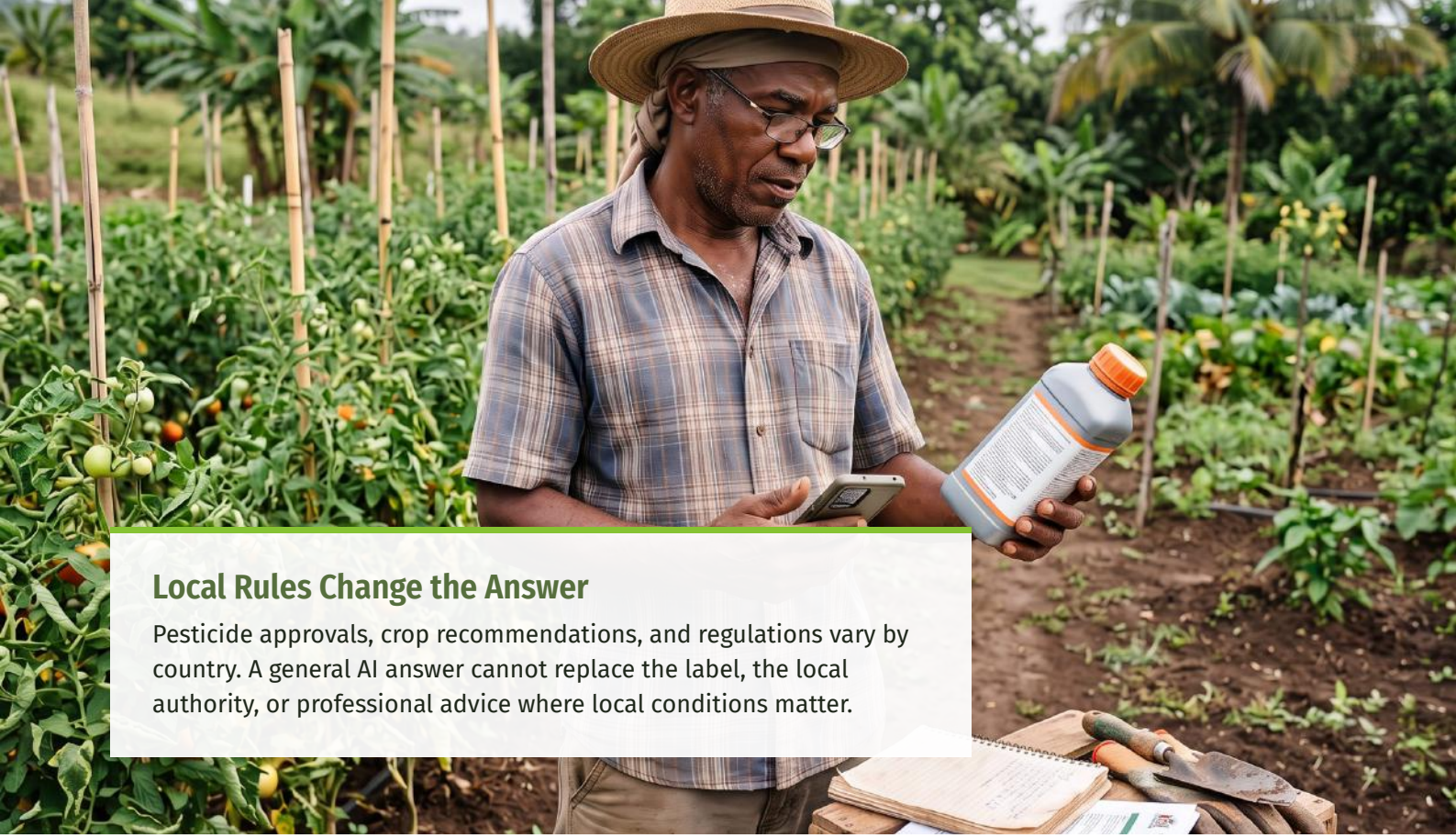
Owners in Trinidad and Tobago already using generative AI in their businesses listed unreliable information among their own concerns, alongside the security of what they upload and the risk of leaning on it hard enough to lose skills. None of that stopped them using it.

Local Context Breaks a General Answer

For Caribbean agriculture there is a second problem, and it is the more expensive one, because an answer can be accurate somewhere else and still be wrong on your holding.

Pesticide registration is national. The international code of conduct on pesticide management, the voluntary framework agreed through FAO and WHO, places registration and label approval with national authorities, so a label carries what that country approved. In Trinidad and Tobago, pesticides are registered by the Pesticides





Local Rules Change the Answer

Pesticide approvals, crop recommendations, and regulations vary by country. A general AI answer cannot replace the label, the local authority, or professional advice where local conditions matter.

and Toxic Chemicals Control Board, and importing one requires a license, under the Pesticides and Toxic Chemicals Act and its regulations. The Ministry of Health publishes the current registration status. Ask a general purpose chatbot what to spray and you may be told about a product that is not registered where you farm, at a rate approved for a different crop, against a pest that behaves differently here.

The same weakness runs through variety recommendations, planting calendars built around temperate seasons, soil advice, veterinary rules, food safety requirements and grade specifications. An answer that does not know which island you are on cannot settle any decision where the island matters.

The Questions Before the Appointment

The most valuable habit in all of this is a change of job description. Generative AI is far stronger preparing you for a decision than making one.

Take a recurring problem in a tomato block. The weak use is to describe the symptoms and ask what to spray. The strong use is to ask for help assembling what an agronomist will want: when the symptoms first showed, which part of the field, how the pattern has moved since, recent rain and temperature, what was applied and when, what grew there before, what has already been tried, which photographs to take and from what distance. Then a list of questions worth asking during the visit.

The specialist still makes the call. You arrive with the information already gathered, which is not a small thing when a visit is hard to arrange.

Task	Where it sits	What that means in practice
Organizing notes, records and rough figures	Good fit	Check the numbers came across correctly
Drafting a letter, quotation or inquiry to a buyer	Good fit	Read it aloud and make it sound like you
Writing procedures and task lists	Good fit	Have someone who does the job confirm every step
Drafting marketing copy	Good fit	Each product claim has to be one you can stand behind
Summarizing a document you supply	Check carefully	Read the source itself for anything you will rely on
Putting a technical passage into plainer language	Check carefully	Confirm the meaning has not been simplified away
Working out figures from your own records	Check carefully	Arithmetic errors arrive as confidently as correct answers
Interpreting a regulation, standard or grade specification	Professional or official verification needed	Wording and version both matter, and both come from the issuing body
Pesticide choice, rate, interval or withholding period	Professional or official verification needed	Follow the label registered in your country
Veterinary treatment and animal health	Professional or official verification needed	A veterinarian, not a chatbot
Identifying what is wrong with a crop	Professional or official verification needed	Use it to prepare for the diagnosis, not to make it
Food safety compliance, contracts, major financial commitments	Professional or official verification needed	The cost of a wrong answer sets the standard of proof

What Not to Type In

Anything you paste into one of these online services is being sent to an outside company. Treat the box the way you would treat a document handed to somebody outside the business.

That means keeping out customer lists and contact details, staff records, bank and payment details, passwords, signed contracts and supplier terms, unpublished accounts, and pricing you would not want a competitor to see. If you need help with a document containing any of it, take the identifying details out first. A pricing structure can be worked on without the customer's name attached to it.

Whether your conversations are used to improve a service, or read by a human reviewer, depends on the service, the account type and the settings you have, and it changes over time. Open the privacy and data settings of the service you actually use,

read what is there, and look again from time to time. The working rule in between is simple enough: do not type anything you would not want a person to read.

There may be a legal dimension too, and it differs sharply across the region. Jamaica's Data Protection Act has been fully in force since December 2023, with a public register of data controllers. Trinidad and Tobago's Data Protection Act of 2011 remains only partly proclaimed. If you hold personal information about customers, staff or members, find out what applies where you operate before any of it goes near an outside system.

Keep the Decisions

There is no position to take on artificial intelligence. Its competence is narrow and specific: unusually good with words, and entirely dependent on what you tell it.

Used inside its limits, organizing, drafting, summarizing, preparing, questioning, it gives back hours that were never productive to begin with. Pushed outside them it may answer anyway, in the same confident prose, and the loss is yours to carry.

Start with one job. The one you have been avoiding.





ADVISORY REVIEW

Dr. Priscilla Bahaw

Dr. Priscilla Bahaw is a Lecturer in Entrepreneurship and Agri-business Management at The University of the West Indies, Trinidad and Tobago. She serves as Caribbean Chair of the Academy of Latin America Business and Sustainability Studies and co-chairs the ONE UWI regional research cluster on entrepreneurship.

Her work focuses on developmental entrepreneurship, with particular emphasis on agripreneurship, entrepreneurship education, and support systems for underrepresented and disadvantaged groups. Her research intersects with climate resilience, digital technology adoption, and entrepreneurial ecosystems in developing contexts.

Dr. Bahaw has published in internationally recognized journals and is committed to advancing inclusive, impact-driven entrepreneurship research.

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