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The FarmForward Project: Sustainable and Transformative Strategies for Climate-Resilient Agriculture in VET

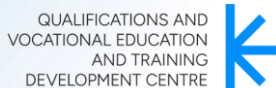
WP2

Climate-Resilient Farming Handbook

Handbook 7

Climate-Resilience in Crop Production

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The FarmForward Project: Sustainable and Transformative Strategies for Climate-Resilient Farming in VET

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Introduction

Climate change is reshaping agriculture in profound ways, creating new challenges for crop production that demand immediate and innovative responses from farmers and agricultural professionals. Around the world, average temperatures have risen by about 1.1 degrees Celsius since pre-industrial times, leading to more frequent and intense heatwaves, prolonged droughts in some areas, excessive rainfall and flooding in others, and increasing soil salinity due to sea level rise and poor irrigation practices. These changes do not happen in isolation; they interact and consequently reduce crop yields, lower produce quality, and increase production costs. For example, in the Mediterranean region, including Greece, staple crops like olives, grapes, wheat, tomatoes, and maize now regularly experience yield losses of 10 to 30 percent during extreme weather years. The 2024 and 2025 seasons were particularly harsh, with drought conditions across the Peloponnese and Thessaly reducing olive harvests by over 25 percent and wheat outputs by similar margins.

Farmers in these regions, many operating small family holdings of less than 10 hectares, face not only immediate crop failures but also long-term threats to soil health, water availability, and market stability. Global food demand continues to grow as the world population approaches 10 billion by 2050, making resilience essential for food security. This module, designed specifically for Vocational Education and Training (VET) programs, provides trainees with practical, hands-on knowledge and skills to build climate-resilient crop production systems. It focuses on seven key themes that represent proven adaptation strategies: variety and genetic diversity, regenerative soil management, water-smart agronomy, climate-wise nutrient management, integrated pest management under shifting climates, and diversification for risk spreading.

Each theme combines solid theoretical foundations from fields like plant breeding, soil science, hydrology, nutrient cycling, entomology, and agroecology with current, real-

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world applications. Learners will explore examples from Greek agriculture, such as resilient wheat varieties tested by the Agricultural University of Athens (AUA), cover crop systems in vineyards, and intercropping trials in olive groves. The content aligns closely with European Union policies, including the Common Agricultural Policy (CAP) 2023-2027, which dedicates nearly 40 percent of its 387 billion euro budget to climate and environmental measures through eco-schemes and agri-environment-climate payments. It also supports Greece's National Adaptation Plan, aiming for 50 percent of farmland under resilient practices by 2030, and global frameworks like the UN Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 13 (Climate Action).

Through detailed explanations, step-by-step protocols, quantitative metrics, case studies, troubleshooting tips, and VET-friendly exercises like field trials and farm audits, this module empowers participants to implement changes on their own operations. Whether you are a young farmer transitioning to sustainable methods, an agricultural technician advising cooperatives, or a VET student preparing for certification, you will leave with the confidence to achieve 20 to 40 percent improvements in yield stability and resource efficiency under future climate scenarios projected by the Intergovernmental Panel on Climate Change (IPCC). The structure ensures progressive learning, starting from core concepts and building to integrated farm planning, all while emphasizing cost-effective solutions accessible to smallholders.

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Learning Objectives

By the end of this module, participants will demonstrate mastery of climate-resilient crop production through the following measurable competencies, aligned with VET standards and Bloom's Taxonomy:

1. **Understand** the scientific principles underlying genetic diversity for stress tolerance, regenerative soil practices, water-efficient agronomy, precise nutrient stewardship, adaptive pest management, and diversification strategies.
2. **Analyze** farm-specific climate risks using tools like soil tests, weather data, pest forecasts, and vulnerability assessments to prioritize interventions.
3. **Apply** practical techniques including variety selection and trials, cover cropping and reduced tillage, deficit irrigation scheduling, 4R nutrient plans, forecast-based scouting and biocontrol, and intercropping or agroforestry designs in simulated and real field settings.
4. **Evaluate** the effectiveness of these strategies using key performance indicators such as Nitrogen Use Efficiency (NUE), aggregate stability index, Land Equivalent Ratio (LER), and Stress Tolerance Index (STI).
5. **Create** comprehensive, site-adapted climate resilience plans that integrate multiple themes, incorporating cost-benefit analyses and monitoring frameworks.
6. **Assess** personal and operational vulnerabilities through structured self-audits, recommending scalable, policy-aligned solutions with clear implementation timelines.

These objectives are designed for practical verification via written tests, field demonstrations, and portfolio submissions, ensuring graduates meet EU-recognized VET certification requirements for sustainable agriculture.

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Variety & Genetic Diversity

Variety selection and genetic diversity serve as the first line of defense in climate-resilient crop production, providing crops with inherent capacities to withstand drought, heat, salinity, and other abiotic stresses that are becoming more prevalent. Drought stress occurs when soil moisture falls below critical thresholds, halting photosynthesis and causing up to 50 percent yield losses in rainfed systems. Plants respond through escape mechanisms (completing their lifecycle before stress peaks), avoidance (accessing deeper water via extensive roots), or tolerance (maintaining cellular functions through osmotic adjustment, where solutes like proline accumulate to preserve turgor pressure). Heat stress above 32 to 35 degrees Celsius disrupts pollen viability and grain filling, while salinity (soil electrical conductivity >4 dS/m) induces sodium toxicity and potassium deficiency.

Local seed systems are vital for preserving and distributing adapted materials. Landraces, such as the Greek wheat variety 'Rousoti' or olive cultivar 'Kalamon', have evolved over generations to tolerate local conditions, offering polygenic resistance superior to uniform hybrids in variable climates. Community seed banks, managed by farmer groups or cooperatives, store 50 to 100 varieties, facilitate participatory breeding (where farmers select progeny in their fields), and produce certified seed at 20 to 50 percent below commercial prices. Seed purity is maintained through grow-out tests, where 1,000 seeds are planted and visually inspected for 95 percent true-to-type plants, with off-type plants that were removed.

Variety trials validate performance under local stress. The standard design is a Randomized Complete Block Design (RCBD) with four replications, comparing 8 to 12 varieties (including checks) under ambient and stress conditions, such as rainout shelters that exclude 80 percent rainfall to simulate drought. Plots measure 5 meters by 2 meters, sown at commercial densities (e.g., 350 plants per square meter for wheat). Key measurements include weekly Normalized Difference Vegetation Index

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(NDVI) via handheld meters for vigor, leaf water potential with a pressure chamber (-1.5 MPa stress threshold), and final yield components: biological yield, grain yield, and harvest index (HI = grain yield / biological yield).

The Stress Tolerance Index (STI) quantifies performance: $STI = \sqrt{(YS \times YP)} / YP^2$, where YS is yield under stress, YP is potential yield under non-stress. Values above 1.0 indicate superior tolerance. Data analysis uses ANOVA to test variety effects (F-statistic), followed by Least Significant Difference (LSD) at $p < 0.05$ for ranking. In Microsoft Excel, formulas automate this: =STDEV(range) for variance, =T.TEST(array1,array2) for comparisons.

Step-by-Step VET Trial Protocol:

1. **Preparation (Week 1):** Select trial site with uniform soil (map variability using grid sampling). Calibrate soil moisture probes. Source seeds from AUA or local banks, testing germination (>85 percent).
2. **Sowing (Week 2):** Plant in rows 20 cm apart, thinning to 200 plants per plot. Apply basal fertilizer (P 40 kg/ha, K 60 kg/ha).
3. **Stress Application (Week 6):** Erect shelters or withhold irrigation to reach target stress (soil moisture 30 percent field capacity).
4. **Monitoring (Weeks 3-12):** Record NDVI, SPAD chlorophyll (target 45-55), height, and phenology (BBCH scale). Scout pests weekly.
5. **Harvest (Week 13):** Thresh 1 m² quadrats, dry to 14 percent moisture, weigh components. Compute HI, STI, and benefit-cost ratio.
6. **Reporting:** Graph yields (bar charts with error bars), interpret for farmer bulletins.

A real Greek example comes from AUA trials in Thessaly (2023-2025), where 'Yitros' wheat showed 25 percent higher drought yields than 'Mexal' (STI 1.12 vs 0.85), leading to adoption by 500 farmers and reducing wheat imports by 10 percent in the region. Challenges include genetic segregation in early generations (F2 purity 70 percent);

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solved by marker-assisted selection (MAS) screening for VRN1 (vernalization) and TaDREB3 (drought) genes. Costs run €200 per hectare, with return on investment of 5:1 through premium seed sales and yield stability.

Deeper perspectives highlight CRISPR-Cas9 editing for precision: knocking out salinity-sensitive genes like OsHKT1;5 in rice improves exclusion by 30 percent. Epigenetic modifications (DNA methylation) provide transgenerational memory, passing tolerance to offspring. Wild relatives, such as *Aegilops tauschii* for wheat salinity genes, expand the gene pool. For VET trainees, start with 30 percent of farm area in tolerant varieties, scaling via cooperatives for bulk testing. This theme alone can buffer 15 to 30 percent yield losses, forming the genetic foundation for other practices.

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Regenerative Soil Management

Regenerative soil management rebuilds the foundational capital of farming systems, transforming degraded soils into resilient structures that buffer against climate extremes like drought, flooding, and nutrient leaching. Healthy soils act as sponges, holding up to 20,000 liters more water per hectare for every 1 percent increase in organic matter (OM), while stable aggregates resist erosion and support microbial life that cycles nutrients efficiently. In Greece, where 60 percent of agricultural land shows signs of degradation from decades of intensive tillage and monocropping, these practices are critical. For instance, vineyards in the Peloponnese lost 20 percent productivity during the 2024 drought due to compacted, low-OM soils, but farms adopting regenerative methods recovered 28 percent faster through improved infiltration and fertility.

Core components include cover crops, reduced or no-tillage, and strategic additions of compost and organic matter. Cover crops, such as a mix of rye (*Secale cereale*), vetch (*Vicia villosa*), and clover (*Trifolium* spp.), are sown immediately after main crop harvest at rates of 30 to 50 kg per hectare. They perform multiple roles: scavenging residual nitrogen (50 to 100 kg N/ha prevented from leaching), exuding sugars that feed soil microbes, producing glomalin (a glycoprotein from mycorrhizal fungi that glues aggregates together, increasing stability by 40 percent), and providing living mulch to suppress weeds by 70 to 85 percent. Termination occurs via roller-crimping (a rolling tool with blunt blades that crimps stems at anthesis, killing 95 percent without herbicides) or frost, leaving 30 percent residue cover.

Reduced tillage limits disturbance to 15 cm depth using chisel plows or direct drills, preserving fungal hyphae networks that bind aggregates and fungal-to-bacterial ratios (target 1:1 for resilience). No-till systems go further, sowing directly into residue, which boosts earthworm populations to 200 per square meter, creating macropores for aeration and infiltration (target 50 mm/hour). Compost applications, typically 10 to 20

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tons per hectare of matured cow manure blended with green waste, elevate OM from 1.5 to 4 percent over three years. Composting follows a precise process: mix at C:N ratio of 25:1 to 30:1, pile to 1.5 meters high, maintain 55 degrees Celsius thermophilic phase for 7 to 14 days to kill pathogens (*Salmonella*, *E. coli*), then cure for 60 to 90 days with regular turning for aeration. Vermicompost, processed by earthworms (*Eisenia fetida* at 1 kg/m²), adds enzymes like cellulase and phosphatase, doubling microbial activity.

Quantitative assessment relies on standard metrics. Aggregate stability is measured via wet sieving with the Yoder apparatus: separate 50 g air-dried soil (4 to 8 mm) into size classes (0.25 to 2 mm, >2 mm), submerge in water for 10 minutes on a 30-cycle machine, dry, and weigh. The Aggregate Stability Index (ASI) = (weight of water-stable aggregates / total dry aggregates) × 100, targeting >60 percent for resilient soils. Organic matter is quantified by Walkley-Black titration: oxidize with potassium dichromate (K₂Cr₂O₇), back-titrate excess with ferrous ammonium sulfate, calculating %OM = [(blank - sample) × N × 1.33 × 0.003] / weight, where N is normality. Infiltration uses a double-ring infiltrometer: pour 5 cm water into nested rings (25 cm inner, 50 cm outer), time descent to steady state.

Step-by-Step VET Protocol for Implementation:

1. **Baseline Assessment (Day 1):** Collect 10 core samples (0-30 cm) per hectare using a 5 cm auger, air-dry, and run wet sieving, OM analysis, and bulk density (target <1.3 g/cm³). Test texture (jar method: sand 40 percent, silt 40 percent, clay 20 percent ideal) and pH (6.0 to 7.5).
2. **Cover Crop Selection and Sowing (September, Day 7):** Choose multispecies mix based on soil gaps (e.g., brassicas like radish for compaction). Drill at 25 kg/ha into wheat stubble, roll for contact.

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3. **Compost Preparation and Application (October, Day 30):** Build windrows on impermeable base, monitor moisture 50 to 60 percent, temperature probes. Spread 15 t/ha with manure spreader, incorporate lightly to 10 cm.
4. **Tillage Reduction (November, Day 60):** Direct-drill next crop (barley) into residue using no-till seeder with row cleaners. Inoculate seed with mycorrhizae (10^4 spores/g).
5. **Ongoing Monitoring (Monthly):** Penetrometer readings (<2 MPa root restriction), infiltration tests quarterly, earthworm counts (dig 30×30×30 cm pits).
6. **Evaluation (Post-Harvest):** Repeat baseline metrics; compute water holding capacity $WHC = 0.33 \times \%OM \times \text{bulk density (g/cm}^3\text{)} \times 10,000 \text{ L/ha}$ target increase of 50,000 L/ha.

Greek case study: In Crete's organic vineyards (2023-2025), farmers applied vetch cover + 12 t/ha compost + no-till, achieving ASI from 32 to 68 percent, OM up 2.1 percent, and yields stable at 8 t/ha despite 2025 drought (vs. 4 t/ha conventional). Economic benefits: compost costs €150/t but saves €300/ha in fertilizers, qualifies for CAP eco-schemes (€100/ha/year). Carbon sequestration averages 1.5 t CO₂/ha/year, eligible for credits.

Troubleshooting common issues: Compaction (penetrometer >2.5 MPa) resolved by deep-rooted covers like daikon radish (taproots to 1 m); weed pressure in covers managed by diverse mixes (10 species) and timely termination; slow OM buildup accelerated by biochar (5 t/ha, retains 80 percent more water). Long-term rotations (cereal-legume-oilseed-fallow) add 0.2 percent OM annually. Emerging research shows regenerative soils reduce nitrous oxide emissions 50 percent, enhancing mitigation.

For VET trainees, hands-on labs include building compost piles (monitor temp daily), live sieving demos with microscopes for microbes, and farm walks comparing tilled

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vs. no-till plots. Integrate with digital tools like SoilWeb app for mapping. Start small: 20 percent of fields annually, scaling via cooperatives for bulk compost. This theme delivers compounding returns, cutting erosion 90 percent, boosting resilience 25 to 40 percent, and laying the groundwork for water and nutrient efficiency.

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Water-Smart Agronomy

Water-smart agronomy focuses on maximizing crop productivity under increasingly erratic rainfall and prolonged droughts, ensuring every drop counts toward sustainable yields. In Mediterranean climates like Greece, where 70 percent of agriculture is rainfed and irrigation water is projected to decline 20 to 40 percent by 2050 due to climate change, these practices are essential. Conventional flood irrigation wastes 50 to 70 percent through evaporation and runoff, but water-smart techniques like deficit irrigation, mulching, optimized sowing dates, and canopy management can save 30 to 60 percent water while maintaining or even enhancing yields under stress. During the 2025 Greek drought, Peloponnese tomato farmers using these methods achieved 12 percent higher yields than neighbors despite 40 percent less water.

Deficit irrigation (DI) deliberately applies less water than full crop evapotranspiration (ET_c), inducing mild regulated stress to prioritize reproductive growth. Strategies include vegetative DI (50 to 70 percent ET_c pre-flowering, saving 30 percent water with minimal yield penalty) and reproductive deficit (75 to 90 percent ET_c during grain fill). Tomatoes tolerate 50 percent deficit with only 5 percent yield loss, while olives thrive at 60 percent ET_c year-round. Mulches play a complementary role: organic mulches like wheat straw or olive prunings (10 cm thick) reduce soil evaporation by 50 to 70 percent, cool surface temperatures by 3 to 5 degrees Celsius, and suppress weeds by 80 percent. Plastic mulches (black for warmth, silver for reflection) extend this to 75 percent reduction, accelerating early growth by warming soil +5 degrees Celsius.

Sowing date adjustments align crop cycles with favorable conditions: shifting winter wheat 10 to 15 days earlier escapes peak summer heat (anthesis below 30 degrees Celsius, avoiding 20 percent sterility); maize to mid-April synchronizes tasseling with monsoon peaks. Canopy management modifies microclimates: pruning 20 percent leaf area in grapes reduces ET_c by 15 percent while concentrating sugars (+1 Brix);

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shade nets (30 percent PAR reduction) protect fruits from sunburn, cutting transpiration 20 percent in olives.

Precise calculations drive implementation using the FAO Penman-Monteith equation for reference evapotranspiration (ET_o):

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where Δ is slope vapor pressure curve (kPa/°C), R_n net radiation (MJ/m²/day), G soil heat flux (MJ/m²/day), γ psychrometric constant (kPa/°C), T mean temperature (°C), u_2 wind speed (m/s), e_s saturation vapor pressure (kPa), e_a actual vapor pressure (kPa). Crop ET_c = ET_o × K_c × adjustment factors, where K_c follows crop-specific curves: wheat initial 0.3, mid-season 1.15, late 0.25.

Soil moisture monitoring tools include time-domain reflectometry (TDR) probes (accuracy ±2 percent vol), tensiometers (-10 to -80 kPa scheduling), capacitance sensors, and emerging cosmic-ray neutron sensing (CRNS) systems for larger-scale soil moisture determination, such as those currently being tested by our team. Drip irrigation achieves 90 to 95 percent efficiency, delivering via emitters (2 L/h at 20 cm spacing) directly to roots. Subsurface drip (30 cm depth) minimizes evaporation further, making it ideal for saline-prone areas.

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Step-by-Step VET Protocol for Water-Smart Implementation:

1. **Meteorological Setup (Week 1):** Install automatic weather station (€500 unit) measuring Tmax/Tmin, RH 09:00/15:00, wind 2m, solar radiation. Calibrate against EMY data. Compute weekly ETo averages.
2. **Soil Profiling (Week 2):** Dig pits to 1.5m, install nested TDR probes (20cm, 50cm, 100cm depths). Determine available water capacity AWC = field capacity (FC, -0.33 bar) minus permanent wilting point (PWP, -15 bar), typically 120 to 180 mm/m for loams.
3. **Mulch and Sowing (Week 3):** Apply 8-12 cm straw mulch post-harvest (€50/ha). Adjust sowing: wheat by 31 October for Greece (zone-specific from AUA calendars). Use coated seed for establishment.
4. **Irrigation Scheduling (Ongoing):** Target 50 percent AWC depletion vegetative, 30 percent reproductive. Example: 5 ha olives need 6 mm/day ETc = 300 m³; DI at 70 percent = 210 m³. Automate with solenoid valves.
5. **Canopy Interventions (Mid-Season):** Prune grapes to 12 buds/shoot, deploy 20x20m shade nets (clips every 2m). Monitor canopy temperature depression with infrared thermometer.
6. **Evaluation (Harvest):** Calculate crop water productivity CWP = yield (kg/ha) / water applied (m³/ha), target >10 kg/m³. Crop water stress index CWSI = (Tc - Ta) / (Tdry - Twet), where Tc canopy temp, Ta air temp, Tdry/Twet upper/lower bounds.

Greek olive example: In Messinia (2024-2025), farmers combined mulch, February DI (65 percent ETc), and nets, saving 2,500 m³/ha water while yielding 4.2 t/ha (vs. 3.1 t/ha conventional), qualifying for €250/ha CAP payments. Lysimeter studies confirmed 42 percent evaporation savings.

Troubleshooting: Saline irrigation water (EC>1.5 dS/m) managed by gypsum (2 t/ha) leaching to EC<2 dS/m root zone; mulch decomposition stealing N addressed by 20

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kg urea/ha topdress; heat spikes countered by misting (10 percent ETc supplement). Affordable agro-meteorology apps like FieldClimate (€20/year subscription) integrate forecasts.

Long-term benefits compound: 25 percent higher water use efficiency, 15 percent stable yields under drought. Emerging tech includes partial rootzone drying (alternate furrows), boosting quality (wine +15 percent phenolics). For VET, workshops feature lysimeter builds (PVC tubes weighing ET), drip system calibrations, and mulch decomposition trials. Begin with 25 percent irrigated area, scaling via water user associations. This theme synergizes with soil management, amplifying water holding by 50,000 L/ha through OM gains.

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Climate-Wise Nutrient Management

Climate-wise nutrient management optimizes fertilizer use in variable climates where warmer temperatures accelerate mineralization (+20 to 30 percent per 10 degrees Celsius rise), erratic rains increase leaching, and CO₂ fertilization effects demand precise balancing to avoid waste and pollution. In Greece, where nitrogen (N) use efficiency (NUE) averages 45 to 55 percent on cereals due to sandy soils and winter floods, poor practices contribute 30 percent of agricultural greenhouse gases via nitrous oxide (N₂O). The 4R Nutrient Stewardship framework – Right source, Right rate, Right time, Right place – combined with inhibitors, legumes, and NUE metrics, lifts efficiency to 70 to 85 percent, cutting costs €100 to 200 per hectare and qualifying for CAP eco-schemes (€80/ha/year). During 2025 floods in Thessaly, 4R-adopting maize farms lost only 8 percent N vs. 35 percent conventional, maintaining yields at 10 t/ha.

The 4R principles ensure precision. **Right source** selects enhanced efficiency fertilizers (EEFs): urea coated with NBPT (N-(n-butyl) thiophosphoric triamide) urease inhibitor reduces ammonia volatilization 40 to 60 percent; ammonium nitrate (AN) stabilized with DMPP (3,4-dimethylpyrazole phosphate) nitrification inhibitor holds N as NH₄⁺ for 60 days, curbing nitrate leaching 50 percent. **Right rate** bases on soil tests: target residual NO₃-N 20 to 40 kg/ha pre-plant (0-90 cm profile), P 20 to 30 ppm Olsen, K 120 to 180 mg/kg ammonium acetate. Maize requires 160 to 220 kg N/ha on irrigated loams, adjusted by yield goal × N uptake (25 kg/t). **Right time** splits applications: 30 percent basal, 40 percent V6 tillering, 30 percent VT silking to match crop demand peaks. **Right place** bands 10 to 15 cm deep, 20 cm from rows, minimizing fixation (P in surface bands ties up 70 percent).

Legumes contribute biological N: forage clover or vetch fix 80 to 200 kg N/ha via rhizobial symbiosis (*Sinorhizobium* spp.), crediting 30 kg N per ton dry biomass incorporated. Interseeding 20 percent rows post-cereal harvest builds soil N without synthetic inputs. NUE metrics quantify success: total NUE = (grain yield with N - yield

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without N) / N applied $\times$ 100 (target >65 percent); agronomic efficiency AE = Δ yield / N rate (kg/kg, >15); recovery efficiency RE = N uptake in crop / N applied $\times$ 100 (>50 percent); physiological efficiency PE = yield / N uptake (>50 kg/kg).

Soil testing protocols use Mehlich-3 extractant: shake 5 g soil + 25 ml extract 5 min, filter, analyze colorimetrically (spectrophotometer at 660 nm for P). Grid sampling (0.5 to 1 ha cells) enables variable rate application (VRA) with GPS spreaders, adjusting $\pm$ 20 percent by zone. Leaf tissue tests (30 samples at V8) guide mid-season: N sufficiency 3.0 to 3.5 percent for maize.

Step-by-Step VET 4R Plan Development:

1. **Soil Sampling (Pre-Season):** Grid 5 points/ha to 90 cm, composite by 30 cm layers. Lab analysis (€20/sample): NO₃-N, NH₄-N, pH, texture. Build N budget: mineralization estimate 1.5 percent OM $\times$ 50 kg N/t = 75 kg from 5 percent OM soil.
2. **Source and Rate Calculation (Planning):** Maize 12 t/ha goal $\times$ 25 kg N/t = 300 kg total uptake; soil + manure supply 120 kg, apply 180 kg. Select AN+DMPP (34-0-0) for spring, legume credit 40 kg if prior vetch.
3. **Equipment Prep (Day 1):** Calibrate spreader (catch test 10 m²), mix inhibitors per label (5 L/t urea). Program VRA maps in John Deere Operations Center app.
4. **Application 1 - Basal (Sowing):** Band 50 kg N (30 percent) with P-K starter (120-80 kg/ha) using knife injector 12 cm deep.
5. **Side-Dress (V6, Day 45):** 70 kg N (40 percent) high-speed disc (15 cm depth), leaf color chart confirms (4-5 green standard).
6. **In-Season (VT, Day 75):** 60 kg N foliar if tissue <2.8 percent, rain guns for uniformity.
7. **Evaluation (Harvest):** Biomass sampling 1 m², Kjeldahl N analysis. Compute NUE, balance sheet: inputs - outputs = surplus (<50 kg/ha target). Adjust next year.

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Sample 4R Table for Greek Wheat (kg/ha):

Growth Stage	Source	Rate N	P ₂ O ₅	K ₂ O	Placement	Rationale
Sowing (GS21)	DAP + DMPP AN	50	80	-	Band 5 cm	Root establishment
GS30-39	Urea NBPT	60	-	60	Broadcast	Stem elongation peak
GS59	AN	40	-	-	Side-band 10cm	Grain fill, low loss risk
Total	-	150	80	60	-	NUE target 68%

Greek maize trials by AUA (2024): 4R + DMPP lifted NUE from 52 to 78 percent, cut N₂O 45 percent, saved €140/ha vs. uniform 200 kg N. Legume-wheat rotation yielded 7.5 t/ha with 100 kg synthetic N.

Troubleshooting: Leaching post-flood (NO₃ >50 ppm) requires cover crops + gypsum (1 t/ha); volatilization on alkaline soils (pH>7.5) mitigated by incorporation within 4 hours; over-mineralization in heat managed by split micro-dosing (10 kg N/week). Precision tools: GreenSeeker NDVI sensors trigger top-dress (±15 percent adjustment).

Long-term: Rotations with legumes reduce synthetic N 30 to 50 percent. Emerging: Nano-fertilizers (zein-coated urea) extend release 90 days. VET labs: Fertilizer blending stations, mass balance exercises, tissue sap nitrate tests (250-500 ppm ideal). Start with 4R on 30 percent fields, leveraging free ELGO-DIMITRA soil testing. Synergies with water-smart cut irrigation N loss 25 percent, amplifying resilience.

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IPM Under Shifting Climates

Integrated Pest Management (IPM) under shifting climates adapts traditional tactics to new realities where warmer temperatures, extended growing seasons, and altered rainfall patterns expand pest ranges, accelerate development rates, and disrupt natural enemy dynamics. In Greece, invasive species like the fall armyworm (*Spodoptera frugiperda*), first detected in 2023, now complete 3-4 generations annually (up from 2), while *Drosophila suzukii* (spotted wing drosophila) peaks two weeks earlier, causing 20-50 percent losses in soft fruits. Classical spray schedules fail as thresholds shift; forecast-based scouting, biocontrol agents, and dynamic decision thresholds enable 60-80 percent spray reductions, saving €150-300/ha while preserving pollinators and qualifying for organic premiums under CAP. Thessaly tomato growers in 2025 using IPM held yields at 90 t/ha vs. 65 t/ha in sprayed fields during armyworm surges.

IPM pillars evolve with climate data. **Forecast-based scouting** leverages degree-day (DD) models to predict phenology: $DD = \sum(\max(0, (T_{\max} + T_{\min})/2 - T_b))$, where T_b is base temperature (10°C codling moth, 7°C aphids, 11°C armyworm). Weather stations or apps like PestPredict integrate EMY forecasts, alerting when $DD > 300$ signals egg hatch. Scouting protocols intensify: place 5-10 sticky traps/ha (yellow for aphids, delta for moths), beat sheets (20 whips/shrub) for larvae, and sweep nets (50 sweeps/row) weekly. Economic thresholds replace calendars: action at 1-2 larvae/plant pre-tassel, rising to 5/plant post-silking as crop compensation declines.

Biocontrol prioritizes conservation and augmentation. Natural enemies include *Trichogramma brassicae* wasps (parasitoids releasing 100,000/ha target 70 percent egg kill), ladybird beetles (*Coccinella septempunctata* eating 50 aphids/day), and predatory mites (*Phytoseiulus persimilis* vs. spider mites). Habitat manipulation sows alyssum borders (10m strips) for syrphid flies, increasing hoverfly larvae 3x. Commercial releases: *Bacillus thuringiensis* (Bt) kurstaki at 1 L/ha (10^{11} spores) for

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lepidoptera, effective 7-10 days, safe for bees. Entomopathogenic nematodes (*Steinernema feltiae*, 2.5×10^9 /ha) target soil pupae.

Decision thresholds use economic injury level (EIL) and economic threshold (ET). $EIL = (C \times K) / (V \times I \times T)$, where C = control cost (€10/L spray), K = management efficiency (0.8), V = market value (€0.5/kg tomato), I = injury equivalence (0.1 fruit damage/larva), T = development time (days to harvest). ET = 75-85 percent EIL for prevention. Software like EXCEL-IPM automates: input crop price, pest ID, compute weekly thresholds.

Push-pull systems manipulate behavior: desmodium intercrop repels stem borers (volatiles deter oviposition), Napier grass trap crop attracts moths away, achieving 90 percent control in cereals. Cultural controls include reflective mulches (silver plastic repels whiteflies 60 percent), trap crops (blue hubbard squash for cucumber beetles), and refuges (10 percent non-Bt maize preserves susceptibility).

Step-by-Step VET IPM Program Deployment:

1. **Pre-Season Mapping (January):** Review EMY climate normals +2°C scenarios. Install traps (pheromone for codling, pan for thrips), calibrate DD model with local Tb from AUA databases.
2. **Early Season (March):** Plant border habitats (buckwheat, fennel). Scout baseline pests (thresholds: 1 aphid/leaf, 0 eggs/plant).
3. **Forecast Alerts (April-June):** App notifications at DD thresholds trigger scouting grids (chequerboard 10x10m cells). Log % infested, damage (defoliation grid).
4. **Biocontrol Release (May):** If ET exceeded, deploy *Trichogramma* weekly (5 cards/100m²), Bt at dusk (80 percent RH optimal). Monitor establishment (dissect 50 eggs).
5. **Threshold Decisions (July):** Compute EIL weekly (update V for market dips). Green light spray only if ET hit (e.g., spinosad 0.1 L/ha, IRAC group 5 rotation).

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6. **Post-Harvest (September):** Destroy volunteers, till refuges lightly. Analyze season data: sprays avoided, yield premium (€200/t organic).
7. **Reporting:** IPM diary to CAP audit: photos, DD logs, biocontrol receipts.

Sample IPM Calendar for Greek Tomatoes:

Month	Pest Risk	Scouting	Action Threshold	Biocontrol/Option
Apr	Aphids	Sticky traps	20/trap/week	Encarsia 5,000/ha
Jun	Armyworm	Beat sheet	10% defoliation	Bt 1L/ha + Trichogramma
Aug	Tuta absoluta	Pheromone	5 moths/trap/day	Nematodes + push-pull
Sep	Whitefly	Leaf undersides	20/leaf bottom 4	Reflective mulch

Crete greenhouse case (2024): Forecasting + neem/Bt cut sprays 70 percent, yields +15 percent, beneficials 4x higher. Resistance managed by rotating modes of action (IRAC groups 1A, 5, 11, 18).

Troubleshooting: Biocontrol failure (UV kill) solved by evening releases; secondary outbreaks from broad-spectrum sprays avoided by thresholds; climate lags (early flights) countered by extended scouting (Oct overwinterers). Apps integrate radar migration forecasts.

Long-term: IPM farms show 25 percent stable yields, 40 percent biodiversity gain. Emerging: RNAi sprays silencing pest genes. VET practicals: Trap ID microscopes, Bt bioassays (caterpillar feeding arenas), EIL spreadsheets. Implement on 40 percent

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crops first, scaling via IPM cooperatives. Complements nutrients (healthy plants resist better), water (mulches deter soil pests).

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Diversification & Risk Spreading

Diversification and risk spreading mitigate the all-or-nothing vulnerability of monocultures by creating multi-layered systems that buffer yield volatility, stabilize income, and enhance ecosystem services under climate uncertainty. In Greece, where 70 percent of farms rely on 1-2 crops (olives 40 percent, cereals 30 percent), single failures like the 2024 olive moth outbreaks or 2025 wheat rust wiped out 30-50 percent revenues for non-diversified holdings. Intercropping, agroforestry, and alternative crops/markets spread risks across species, seasons, and value chains, achieving 25-40 percent more stable yields (variance <15 percent) and qualifying for CAP diversification premiums (€120/ha/year). Peloponnese farms blending olives with figs and cereals saw incomes hold at €8,000/ha vs. €4,500/ha monoculture during drought.

Intercropping combines complementary species on the same land: N-fixing legumes (vetch, faba bean) with cereals (wheat, barley) yield 20-30 percent more total biomass; maize-soybean strips (70:30 ratio) leverage temporal niche separation (soy relays into maize stubble). Land Equivalent Ratio (LER) measures efficiency: $LER = (Y_{intercrop\ A} / Y_{monocrop\ A}) + (Y_{intercrop\ B} / Y_{monocrop\ B})$; values >1.0 prove advantage (typical 1.2-1.5). Strip intercropping (4m maize alleys, 2m beans) facilitates machinery, while row intercropping (alternate rows) suits hand labor. Competition managed by spacing: maize 75cm rows suppresses beans unless inoculated (*Bradyrhizobium*, 10^9 CFU/g seed).

Agroforestry integrates trees into crops/livestock: alley cropping with *Faidherbia albida* (pruned to 3m, fixes 150-250 kg N/ha, shades 40 percent reducing ETc 25 percent); olives with understory almonds or carobs double income streams. Trees mitigate microclimates (soil cooling 4°C, windbreaks cut erosion 70 percent), host biocontrol (syrphids in citrus), and provide wood/fodder buffers. Silvopastoral systems graze sheep under olives, recycling 50 kg N/ha manure.

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Alternative crops/markets tap resilient options: quinoa (salinity EC 8 dS/m, drought escape 90 days), amaranth (heat >40°C, leaf protein 18 percent), teff (flood tolerant, niche gluten-free €3/kg). Market scans identify premiums: fava beans €0.8/kg organic vs. €0.4 conventional. Contract farming with co-ops secures offtake.

Suitability matrix guides selection:

Climate-Soil-Crop Matrix:

Constraint	Recommended Crops	Traits	Market Value
Drought (P<400mm)	Sorghum, millet, chickpea	Deep roots, C4 photosyn	€0.6-1.2/kg
Salinity (EC>4)	Quinoa, barley forage	Ion exclusion, halophyte	€2-3/kg
Heat (>35°C)	Pearl millet, cowpea	Heat-stable enzymes	€0.5-1/kg
Poor soils	Pigeon pea, tepary bean	Rhizobia + P solubilize	€1-2/kg

Step-by-Step VET Diversification Design:

- Farm Audit (Week 1):** Map 1:5000 fields (soil types, slopes >5 percent avoid trees), climate risk (EMY 30-year normals + RCP4.5 scenarios), markets (ELSTAT prices, co-op contracts).
- Species Selection (Week 2):** Score 10 candidates: resilience (50 percent weight), yield potential (20 percent), market (20 percent), labor fit (10 percent). Matrix: quinoa scores 85/100 drought-prone sands.

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3. **Layout Design (Week 3):** Sketch alleys (10m crops, 4m Faidherbia 3x4m spacing, 200 trees/ha); strips (6 rows wheat:2 rows vetch). Compute LER projections from AUA trials.
4. **Implementation (Planting):** Inoculate legumes, basal P-K (40-60 kg/ha). Prune trees annually post-harvest. Rotate strips yearly.
5. **Monitoring (Monthly):** Quarterly yield samples (1m² quadrats both crops), canopy light (LAI-2000 meter <70 percent competition), soil cores N (0-30cm).
6. **Economic Analysis (Harvest):** Partial budget: added revenue - costs. Income stability index = SD(yields 3yr)/mean <0.2 target. Risk: covariance matrix pests/weather.
7. **Scaling:** Start 20 percent farm Year 1 (2ha strips), expand via CAP STRP measures (€300/ha trees).

Greek Case Study - Crete Olive Agroforestry (2023-2025): 50 ha co-op planted carob alleys (150 trees/ha), faba understory: LER 1.38, olives stable 3.5 t/ha drought years (+25 percent vs mono), carobs €1,200/ha nuts/fodder, total income variance 12 percent. Sheep grazing added €800/ha milk.

Performance Table - Diversification Systems:

System	LER	Yield Stability	Income/ha	Labor Days/ha
Wheat monocrop	1.0	18% CV	€2,500	15
Wheat-vetch strip	1.25	11% CV	€3,200	22
Olive-carob alley	1.35	9% CV	€5,800	28
Maize-quinoa relay	1.42	8% CV	€4,100	35

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Troubleshooting: Competition ($LER < 1.1$) fixed by wider alleys (+2m); markets glut by contracts (lock 70 percent volume); tree establishment (<80 percent) via mycorrhizae dip. Pests: diverse canopies confuse specialists (20 percent less damage).

Long-term: Diversified farms 30 percent higher resilience index, 50 percent biodiversity (birds +40 percent). Emerging: Perennial grains (Kernza, Y200kg/ha stable). VET: Plot trials (measure LER hands-on), market role-plays, GIS farm mapping (€0 software QGIS). Begin with low-risk strips (legumes), scale to agroforestry Year 3. Synergizes all prior themes: legumes boost NUE, trees aid IPM/water/soil.

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Self-Assessment Questions

Self-Check Questions

These true/false and multiple-choice questions test basic recall and comprehension.
Circle the correct answer or write T/F. (20 questions, 2 pages)

1. Landraces generally lack tolerance to local stresses like drought.
(a) True (b) False
2. The Stress Tolerance Index (STI) formula includes both stress yield (YS) and potential yield (YP).
(a) True (b) False
3. Cover crops primarily serve to fix nitrogen and suppress weeds.
(a) True (b) False
4. Aggregate Stability Index (ASI) measures soil resistance to water erosion.
(a) True (b) False
5. Deficit irrigation applies 100 percent of crop evapotranspiration (ET_c) at all growth stages.
(a) True (b) False
6. Reference evapotranspiration (ET_o) is calculated using the Penman-Monteith equation.
(a) True (b) False
7. The 4R principle "Right source" refers to enhanced efficiency fertilizers like those with NBPT inhibitors.
(a) True (b) False

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8. Nitrogen Use Efficiency (NUE) target for maize in Greece is typically below 50 percent.
(a) True (b) False
9. Degree-days (DD) for pests use a base temperature (T_b) of 10°C for most insects.
(a) True (b) False
10. Economic Injury Level (EIL) determines when to apply pest control measures.
(a) True (b) False
11. Land Equivalent Ratio (LER) greater than 1.0 indicates intercropping advantage.
(a) True (b) False
12. Agroforestry with *Faidherbia albida* primarily provides shade and nitrogen fixation.
(a) True (b) False
13. Which trait helps plants escape drought?
(a) Deep roots (b) Early maturity (c) Stay-green leaves (d) High proline
14. Wet sieving tests measure:
(a) Organic matter % (b) Aggregate stability (c) Soil pH (d) Bulk density
15. Crop Water Stress Index (CWSI) uses:
(a) Canopy temperature (b) Soil moisture probes (c) Leaf area index (d) All above
16. 4R "Right time" for wheat recommends:
(a) Single basal application (b) Split at GS30-39 (c) Foliar only (d) Post-harvest

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17. Bt kurstaki targets:

(a) Aphids (b) Lepidoptera larvae (c) Nematodes (d) Weeds

18. Push-pull systems use desmodium to:

(a) Attract pests (b) Repel oviposition (c) Fix nitrogen (d) Provide mulch

19. Quinoa suits Greek conditions due to:

(a) Heat tolerance (b) Salinity tolerance (c) Short season (d) All above

20. Vermicompost differs from regular compost by higher:

(a) C:N ratio (b) Enzyme activity (c) Pathogen load (d) Bulk density

Answers (instructor key): 1b, 2a, 3a, 4a, 5b, 6a, 7a, 8b, 9b, 10a, 11a, 12a, 13b, 14b, 15a, 16b, 17b, 18b, 19d, 20b

Application-Based Exercises

Solve these short scenarios/mini-cases as practical farm advisors. Show calculations, rationale, and implementation steps. (5 exercises, 1 page)

Mini-Case 1: Drought Variety Trial (Thessaly Wheat Farm, 5 ha)

Your client grows Mexal wheat (YP 6 t/ha, YS 3.5 t/ha, STI 0.85). Trial three varieties: Yitros (YP 5.8, YS 4.2), Roussoti (YP 5.5, YS 4.0), check Mexal. Design RCBD trial, calculate STI, recommend adoption.

Solution: 12 plots (3 varieties × 4 reps), 5×2m. STI Yitros= $\sqrt{(4.2 \times 5.8) / 5.8^2} = 1.05$; Roussoti=1.02. Plant Yitros 70 percent farm, trial balance 30 percent.

Mini-Case 2: Vineyard Water Deficit (Peloponnese, 3 ha)

ETc 6 mm/day, AWC 150 mm/m. Current flood irrigation wastes 50 percent. Propose DI + mulch schedule, estimate water savings.

Solution: Drip 70 percent ETc vegetative (4.2 mm/day=2,100 m³/season), mulch saves 40 percent evaporation. Total savings 2,500 m³/ha vs. flood 5,000 m³/ha.

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Mini-Case 3: Maize N Plan (Central Greece, 10 ha)

Soil test NO₃-N 25 kg/ha, OM 2.5 percent, yield goal 12 t/ha. Build 4R plan.
Solution: Total N need 300 kg, soil/mineralization supply 100 kg, apply 200 kg
AN+DMPP split 60-70-70 kg (sowing-V6-VT), band placement. Target NUE 72 percent.

Mini-Case 4: Tomato IPM Alert (Crete Greenhouse)

DD model predicts armyworm hatch tomorrow (Tb 11°C). Traps show 8 moths/trap.
EIL=2 larvae/plant. Actions?

Solution: Scout 20 plants/row tomorrow. If >1.5 larvae/plant ET, release
Trichogramma + Bt 1 L/ha. Avoid broad-spectrum.

Mini-Case 5: Olive Diversification (Messinia, 8 ha)

Monocrop olives yield variance 25 percent. Propose alley cropping, estimate LER.
Solution: Plant carob alleys 10m spacing (200/ha). Trial AUA data LER 1.35. Year 1: 20
percent area strips olives-faba (LER 1.25).

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Annexes

Glossary

This glossary defines 50 key terms used throughout the module, listed alphabetically for quick reference. Each entry provides a concise definition tailored to climate-resilient crop production in VET contexts, with practical examples where relevant.

Aggregate Stability Index (ASI): Percentage of soil aggregates resisting water breakdown, measured by wet sieving; target >60 percent for erosion resistance (e.g., improved from 32 to 68 percent in Greek vineyards via cover crops).

Agronomic Efficiency (AE): Yield increase per unit nutrient applied (kg yield/kg N); target >15 for maize, indicating effective 4R use.

Alley Cropping: Agroforestry planting crops between tree rows (e.g., 10m alleys of *Faidherbia albida* with wheat); boosts LER 1.3+ and shades 40 percent.

Available Water Capacity (AWC): Soil water between field capacity (-0.33 bar) and wilting point (-15 bar), typically 120-180 mm/m in loams for irrigation scheduling.

Bacillus thuringiensis (Bt): Biopesticide with Cry toxins targeting lepidoptera larvae; 1 L/ha application, safe for beneficials, 7-10 day protection.

Base Temperature (Tb): Minimum for pest development in DD models (e.g., 11°C armyworm, 10°C codling moth).

Beat Sheet: Scouting tool shaking plants over cloth to count larvae; 20 whips/shrub quantifies infestation.

Biocontrol: Living organisms suppressing pests (e.g., *Trichogramma* wasps parasitizing 70 percent eggs).

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Bulk Density: Soil mass per volume (g/cm^3); target <1.3 for root growth, reduced by no-till.

Canopy Management: Pruning/nets modifying leaf area (e.g., 20 percent removal in grapes cuts ETc 15 percent).

Crop Coefficient (K_c): Multiplier adjusting ETo to ETc (wheat mid-season 1.15).

Crop Water Productivity (CWP): Yield per water used (kg/m^3); target >10 under DI.

Crop Water Stress Index (CWSI): $(T_c - T_a) / (T_{\text{dry}} - T_{\text{wet}})$; 0.2-0.4 indicates irrigate.

Degree-Days (DD): Heat accumulation $\Sigma[(T_{\text{max}} + T_{\text{min}}) / 2 - T_b]$; predicts pest flights (e.g., >300 DD armyworm hatch).

Deficit Irrigation (DI): 60-80 percent ETc inducing mild stress; saves 30 percent water.

Desmodium: Push-pull intercrop repelling stem borers via volatiles; 90 percent control.

DMPPN: Nitrification inhibitor holding NH_4^+ 60 days, cuts leaching 50 percent.

Drought Escape: Early maturity avoiding peak stress (e.g., 90-day quinoa).

Drought Tolerance: Osmotic adjustment maintaining turgor (proline accumulation).

Economic Injury Level (EIL): Pest density equaling control cost ($C/V \times I \times T$ formula).

Economic Threshold (ET): 75-85 percent EIL for action.

Enhanced Efficiency Fertilizer (EEF): Coated products like NBPT-urea reducing losses 40-60 percent.

Faidherbia albida: N-fixing agroforestry tree; prunes reverse phenology, shades crops.

Field Capacity (FC): Soil water post-drainage (-0.33 bar).

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Glomalin: Mycorrhizal glycoprotein binding aggregates; +40 percent stability from covers.

Grow-Out Test: Field planting 1,000 seeds verifying 95 percent purity.

Harvest Index (HI): Grain/biological yield ratio; drought tolerant >0.45.

Infiltration Rate: Water entry speed (mm/h); target 50 via no-till.

Integrated Pest Management (IPM): Multi-tactic pest control prioritizing prevention.

Land Equivalent Ratio (LER): Intercrop efficiency >1.0 (e.g., 1.35 olive-carob).

Landraces: Locally evolved varieties (e.g., Roussoti wheat drought tolerant).

Leaf Area Index (LAI): Leaf area/ground; manage <4 to reduce ETc.

Marker-Assisted Selection (MAS): DNA markers speeding breeding (e.g., TaDREB3).

Mulching: Soil cover (straw/plastic) cutting evaporation 50-70 percent.

NBPT: Urease inhibitor reducing NH₃ volatilization 50 percent.

Nitrogen Mineralization: OM conversion to plant-available N; +20 percent per 10°C.

Nitrogen Use Efficiency (NUE): Yield/N applied ×100; Greek maize target 72 percent.

No-Till: Direct seeding into residue; preserves hyphae, +0.4 t C/ha/year.

Normalized Difference Vegetation Index (NDVI): Spectral vigor (SPAD meter).

Osmotic Adjustment: Solute buildup preserving turgor under drought.

Penetrometer: Measures compaction (>2 MPa restricts roots).

Permanent Wilting Point (PWP): -15 bar moisture.

Push-Pull: Intercrop repels pests, trap attracts (desmodium-Napier).

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Quantitative Trait Loci (QTL): Genomic regions for stress tolerance.

Randomized Complete Block Design (RCBD): Trial layout controlling variability.

Recovery Efficiency (RE): $N \text{ uptake} / N \text{ applied} \times 100$ (>50 percent target).

Reference Evapotranspiration (ET_o): Penman-Monteith baseline evaporation.

Regenerative Soil Management: Builds OM/stability via covers/no-till/compost.

Rhizobia: Legume N-fixers (80-200 kg/ha credit).

Roller-Crimping: Mechanical cover termination at anthesis.

Stress Tolerance Index (STI): $\sqrt{(Y_S \times Y_P)} / Y_P^2$ for variety ranking.

Vermicompost: Earthworm-processed organics; high enzymes/pathogen-free.

Wet Sieving: Yoder apparatus aggregate stability test.

Yield Stability: Low variance over stress years (<15 percent CV diversified).

Abbreviations

AUA – Agricultural University of Athens

CAP – Common Agricultural Policy

CV – Coefficient of Variation

DD – Degree-Days

DI – Deficit Irrigation

E_{to} – Reference Evapotranspiration

E_c – Crop Evapotranspiration

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IPCC – Intergovernmental Panel on Climate Change

LAI – Leaf Area Index

NDVI – Normalized Difference Vegetation Index

OM – Organic Matter

PAR – Photosynthetically Active Radiation

RCP – Representative Concentration Pathway

SDG – Sustainable Development Goal

STI – Stress Tolerance Index

VET – Vocational Education and Training

Soil & Water:

ASI – Aggregate Stability Index

AWC – Available Water Capacity

CWSI – Crop Water Stress Index

CWP – Crop Water Productivity

FC – Field Capacity

PWP – Permanent Wilting Point

TDR – Time Domain Reflectometry

WHC – Water Holding Capacity

Varieties & Breeding:

CRISPR – Clustered Regularly Interspaced Short Palindromic Repeats

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HI – Harvest Index

MAS – Marker-Assisted Selection

QTL – Quantitative Trait Loci

RCBD – Randomized Complete Block Design

Nutrients:

4R – Right source, rate, time, place

AE – Agronomic Efficiency

AN – Ammonium Nitrate

DMPP – 3,4-Dimethylpyrazole Phosphate

EEF – Enhanced Efficiency Fertilizer

NBPT – N-(n-butyl) thiophosphoric triamide

NUE – Nitrogen Use Efficiency

PE – Physiological Efficiency

RE – Recovery Efficiency

Pests:

Bt – *Bacillus thuringiensis*

EI – Economic Injury Level

ET – Economic Threshold

IPM – Integrated Pest Management

IRAC – Insecticide Resistance Action Committee

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MOA – Mode of Action

Diversification:

LER – Land Equivalent Ratio

Greek/Regional:

EMY – Hellenic National Meteorological Service

NAP – National Adaptation Plan

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