Landscape Review, Level II: International Tools and Technologies for Small Farms

Executive Summary

Small farms are at the heart of global food security, biodiversity, and rural livelihoods (FAO 2014). Yet, while agricultural technology has advanced rapidly in recent decades, much of this innovation targets large-scale, capital-intensive operations, leaving a significant gap in accessibility and relevance for smaller-scale farms (Lowder, Skoet, and Raney 2016).

This Level II Landscape Review is part of the F3 Local Initiative, which aims to increase the viability and resilience of small farms in Fresno, Kings, Merced, Madera, and Tulare counties in California. It builds on Landscape Review Level I, which profiled tools and technologies already in use or available in the region. Both reviews served to inform the final needs assessment report "Small Farms And The Future Of AgTech".

The intended audiences for this report are farmer support organizations, policy researchers and lawmakers, and technology developers. This review aims to inform these stakeholders about globally available technologies that have the potential to increase the viability of small farms in the San Joaquin Valley.

By looking outward—at what smallholder farms are adopting successfully in other parts of the world—this review identifies promising technologies that are not yet available or used locally, but that could be adapted for small-scale farms in the region. Special attention is given to countries with similar climatic conditions, arid or semi-arid environments, and a predominance of small holdings, as these share critical structural similarities with California's San Joaquin Valley.

The primary objective of this review is to identify international technologies already in use by smallholder farmers elsewhere that can be feasibly introduced, adapted, and scaled in the San Joaquin Valley.

Topics include:

- Smart irrigation systems
- Soil health technologies
- Theft prevention and security tools
- Crop protection and pest control
- Farm management and reporting software

Technologies already in use or available in the region are not addressed here, as they are covered in Landscape Review I. Similarly, tools still under development or designed for large-scale use are excluded from the scope of this report.

1. Introduction

Small farms in the Fresno, California (F3) region are a vital part of the state's diverse agricultural landscape. These farms contribute significantly to local food systems, specialty crop production, and community resilience. However, smallholder farmers face mounting pressures: rising input costs, labor shortages, regulatory compliance burdens, extreme weather patterns, and resource constraints, especially related to water. To remain viable, these farms need access to appropriate, affordable, and scalable tools and technologies that improve efficiency, resilience, and profitability.

This Landscape Review (Level II) is part of the F3 Local Initiative, which seeks to increase the viability and resilience of small farms across Fresno, Kings, Merced, Madera, and Tulare counties in California's San Joaquin Valley. It builds upon Landscape Review Level I, which profiled tools and technologies currently in use or available in the region. In contrast, this Level II review looks beyond California's borders to examine international innovations in smallholder agriculture that could hold promise for adaptation and adoption locally.

This review explores a wide range of internationally developed tools and technologies tailored to smallholder agriculture, assessing their relevance and potential application to small farms in the counties surrounding Fresno and the greater San Joaquin Valley. The analysis covers both field-level innovations—such as irrigation systems, pest control methods, and post-harvest technologies—and broader management tools, including digital recordkeeping, security solutions, and cooperative infrastructure models.

By examining examples from regions with similar constraints—such as drought-prone areas in Israel and Australia, labor-scarce zones in Sub-Saharan Africa, and fragmented smallholder systems in South and Southeast Asia—this review aims to identify technologies that could be adapted for local conditions in the F3 region. Special attention is given to solutions that are low-cost, low-energy, labor-saving, and compatible with diversified cropping systems.

Ultimately, this review seeks to inform policy-makers, agricultural support organizations, and growers themselves about practical innovations from around the world that could support a more sustainable and secure future for the Fresno region's small-scale farms.

Scope and Objectives

The primary objective of this review is to identify international technologies already in use by smallholder farmers elsewhere that are feasible to introduce, adapt, and scale within the San

Joaquin Valley. By looking outward—toward successful smallholder strategies in other parts of the world—this review spotlights technologies not yet widely available or used locally, but which may address critical local needs based on structural similarities.

Special emphasis is given to:

- Countries with arid or semi-arid climates
- Regions dominated by small farms
- Technologies that are affordable, scalable, and low-barrier for adoption (World Bank 2021)

This review focuses on practical, real-world tools—especially digital technologies—that address core farm challenges identified by growers in the region (UC SAREP 2023). Thematic areas include:

- Water efficiency and irrigation management
- Theft prevention and farm security
- Crop protection and pest control
- Farm activity management and reporting

Technologies already available and in use locally are not included, as these are covered in Landscape Review I. Similarly, tools still under development or intended solely for large-scale, high-capital operations are outside the scope of this report.

Ultimately, this review seeks to equip stakeholders with insight into promising, field-tested innovations from around the world that can help small-scale farms in California thrive amid changing environmental, regulatory, and market conditions (Deininger and Byerlee 2011; CCAFS 2020).

2. Methodology

This review draws on a diverse set of data sources to identify, evaluate, and contextualize internationally used tools and technologies relevant to small-scale farms in California's San Joaquin Valley. The methodology is rooted in applied research and community-driven insights, emphasizing both expert analysis and local relevance.

This review draws on a diverse set of data sources to identify, evaluate, and contextualize internationally used tools and technologies relevant to small-scale farms in California's San Joaquin Valley. The methodology combines applied research with farmer-grounded insights, emphasizing both technical credibility and local relevance (Snapp and Pound 2017; UC SAREP 2023).

Sources of Information

The data and information for this report come from the following sources:

- **Published literature and reports** from international organizations focused on smallholder agriculture, including the Food and Agriculture Organization (FAO), CGIAR, World Bank, and regional agricultural research institutions.**Published literature and international reports**, including those from the Food and Agriculture Organization (FAO), the CGIAR network, the World Bank, and other organizations focusing on smallholder agriculture and rural innovation (FAO 2014; World Bank 2021).

- **Subject matter experts**, including members of the University of California Agriculture and Natural Resources (UCANR) Small Farms Team in Fresno, as well as technical assistance providers who support small-scale farmers in the region.**Subject matter experts**, particularly members of the University of California Agriculture and Natural Resources (UCANR) Small Farms Team in Fresno, along with other local technical assistance providers who support small-scale farms in the region.

- **Primary observations and interviews** conducted with technology developers and service providers at three Tech Expos hosted by CAFF in the F3 region during 2023 and 2024 and at 2025 World Ag Expo in Tulare, California, offering real-time insights into tools made and marketed for smallholder and mid-scale producers.**Primary observations and interviews** at the 2025 World Ag Expo in Tulare, California, offering insight into technologies marketed for smallholder or mid-scale producers and their accessibility in U.S. markets.

- **Direct input from farmers**, gathered through structured farmer listening sessions and in-depth interviews with growers in Fresno and surrounding counties. These interactions prioritized understanding unmet needs, adoption barriers, and farmer-defined priorities for innovation.**Direct farmer input**, gathered through structured listening sessions and in-depth interviews with small-scale farmers in Fresno and neighboring counties. These consultations highlighted local needs, constraints, and opportunities for technological adaptation.

Analytical Framework

Each tool, technology, or insight gathered was evaluated according to the following guiding questions:

1. **How does this information frame the search for appropriate tools?**
   – Does it highlight a specific need or opportunity that could be addressed by technology or innovation?

2. **How can this information or technology increase the viability of small farms?**
   – Is the technology affordable, labor-saving, water-efficient, or capable of expanding market access?

3. **If the technology is available globally but not locally, why?**
   – Are there barriers such as cost, language, supply chains, or regulatory issues preventing adoption in the region?

4. **Is the tool appropriate for the scale and circumstances of small farms in the Fresno region?**
   – Can it function in diversified cropping systems, on small acreage, or with minimal mechanization?

5. **How could the technology be brought into use in the region?**
   – What forms of support (training, financing, policy, cooperative models) would be necessary for successful adoption?

This layered approach allows the review to move beyond simply listing technologies to instead critically assessing their fit, accessibility, and adaptability for small farms in the San Joaquin Valley. It also centers farmer knowledge and local context as core criteria for relevance.

Analytical Framework

To ensure relevance and actionability, each source of information—whether a technology, concept, or policy model—was examined using the following guiding questions:

Evaluation Question	Purpose
1. How does this information frame the search for appropriate tools?	Identifies the problem space or specific farm need (e.g., irrigation inefficiency, pest control gaps)

2. How can this information or technology increase the viability of small farms?	Assesses potential benefits like cost savings, productivity, labor efficiency, or compliance aid
3. If the technology is available globally but not locally, why?	Identifies barriers to adoption such as cost, infrastructure, regulation, or cultural mismatch
4. Is it appropriate for the scale and context of small farms in the Fresno region?	Evaluates compatibility with regional crops, acreage sizes, labor systems, and environmental constraints
5. How can this technology be brought into use in the region?	Considers enabling strategies like financial incentives, training programs, cooperative use, or localization

This framework centers real-world utility over theoretical potential and places farmer voice at the center of the technology assessment process (Altieri 2018). It also supports alignment with the F3 Local Initiative's goals of resilience, equity, and practical implementation.

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3. International Technology Initiatives

3A. Smart Irrigation Systems

Water availability and efficient irrigation are critical challenges for small farms in California's San Joaquin Valley, a region marked by semi-arid climate and increasing water scarcity. Globally, smallholder farmers have adopted diverse technologies and practices to optimize water use, reduce waste, and maintain crop health. This section highlights relevant innovations in irrigation technology, water monitoring, and management systems with potential for adaptation in Fresno's small farms.

Water scarcity is one of the most urgent challenges facing small farms in California's San Joaquin Valley. The implementation of the Sustainable Groundwater Management Act (SGMA), combined with prolonged drought cycles and rising temperatures, has intensified pressure on farmers to maximize water-use efficiency. Internationally, many smallholder farmers in arid and semi-arid regions face similar conditions and have developed or adopted cost-effective, scalable smart irrigation systems to adapt.

This section reviews leading small-scale irrigation technologies from regions such as Israel, India, and Australia, where innovation has targeted water conservation at farm scale. These systems combine physical hardware—such as drip lines and soil moisture sensors—with digital controls, mobile alerts, and climate-responsive scheduling.

International Technologies of Note

- **Israel: Netafim Drip Irrigation + Digital Control Units**
  Israel's Netafim pioneered pressure-compensated drip systems designed to deliver precise water and nutrient levels directly to plant roots, even on uneven terrain. Their newer models integrate with digital platforms (e.g., NetBeat) for remote monitoring and fertigation scheduling via mobile apps (Kibbutz Hatzerim 2021).

- **India: Jain Irrigation Micro-Irrigation + Solar Pumping**
  Jain Irrigation has deployed over 6 million hectares of micro-irrigation systems, often in combination with low-energy solar pumps for off-grid farms. Their systems emphasize affordability and modular design, with bundled technical training (Jain Irrigation 2020).

- **Australia: Soil Moisture Sensor Networks and Climate-Smart Scheduling**
  In Australia, small farms have adopted simple but powerful sensor-based irrigation systems that rely on soil moisture probes, evapotranspiration data, and real-time weather forecasts to automate irrigation. Startups like SWAN Systems and AgLogic offer open-platform software compatible with various hardware brands (Charlesworth and Baldwin 2022).

International Technologies of Note

- **Drip Irrigation Systems**
  Widely adopted in arid and semi-arid regions such as Israel, India, and parts of Africa, drip irrigation delivers water directly to plant roots, minimizing evaporation and runoff. Low-cost drip kits and modular systems have expanded access to smallholders, improving yields and water use efficiency (Postel et al. 2020; Kisekka et al. 2019).

- **Smart Irrigation Controllers and Sensors**
  Technologies integrating soil moisture sensors, weather data, and automated valves allow precise irrigation scheduling. Examples from Israel and Australia include sensor-based irrigation controllers that adjust water delivery in real time, conserving water and reducing labor (Shani et al. 2019; Smith and Jones 2021).

- **Water Harvesting and Storage Innovations**
  Smallholder farmers in Ethiopia and Mexico use micro-catchments, rainwater harvesting tanks, and underground storage to capture and store water for irrigation during dry periods. These low-tech but effective solutions improve resilience to drought and water

variability (Gebremariam et al. 2021; López-Gunn and Llamas 2018).

Relevance to Fresno Region Farms

Fresno-area small farms—many of which grow high-value but water-intensive crops like vegetables, stone fruit, and berries—face similar climate and regulatory pressures. Yet many growers continue to rely on flood irrigation or manually controlled drip systems. Barriers to upgrading include cost, lack of technical training, and perceived complexity.

The reviewed international tools offer several advantages:

- **Water efficiency** (up to 60% savings vs. flood)
- **Improved yield and quality** due to consistent moisture levels
- **Labor savings** through automation and remote alerts
- **Potential eligibility** for NRCS EQIP and CDFA SWEEP grant programs when adopted

At the same time, successful adaptation in the San Joaquin Valley will require:

- **Subsidized pilots** to demonstrate viability on diversified small farms
- **Multilingual training** and mobile-friendly user interfaces
- **Technical support networks** and local distributors

Comparison Table: Smart Irrigation Systems

System / Country	Core Features	Cost Range	Requirements	Advantages	Challenges / Gaps
Netafim (Israel)	Drip + fertigation + mobile scheduling	$$$	Pressure pump, app, filters	High efficiency, commercial-grade, long lifespan	High upfront cost; complex install

Jain (India)	Drip + solar pump, modular kits	$$	Solar access, basic training	Affordable, scalable, local training model	Limited U.S. availability
SWAN Systems (Australia)	Moisture sensor + weather-based software	$$	Sensor probes, internet access	Real-time adaptation, integrates with existing systems	Requires connectivity, software literacy

Summary

Smart irrigation tools developed for international smallholder use offer tested, cost-effective strategies for improving water efficiency and productivity on small farms in the Fresno region. With targeted support and localized training, these tools could play a vital role in helping small-scale farmers meet both environmental mandates and economic goals.

Relevance to Fresno Small Farms

Fresno's small farms rely heavily on groundwater, facing challenges from regulatory restrictions and drought. Adopting efficient irrigation technologies can:

- Reduce water consumption and pumping costs
- Improve crop water status and yields
- Support compliance with regional water regulations and sustainability goals

Limitations include upfront costs, system maintenance, and technical knowledge requirements. Programs combining technology access with farmer training have shown success in overcoming these barriers.

Summary

Water-efficient irrigation technologies and water management strategies from global smallholder contexts offer viable options to enhance Fresno's farm water sustainability. Integration with local extension services and incentive programs will be crucial for adoption.

3A. Smart Irrigation Technologies

Water scarcity and efficiency are critical issues for small farms in Fresno's semi-arid climate. Smart irrigation technologies integrate sensors, data analytics, and automation to optimize water use, reduce waste, and improve crop health. These tools are increasingly accessible to smallholder farmers globally and have promising applications for Fresno's agricultural community.

International Technologies of Note

- **Soil Moisture Sensors and Automated Controllers**
  Widely used in Israel and Australia, these systems monitor real-time soil moisture levels and automatically adjust irrigation schedules to meet crop needs without overwatering (Shani et al. 2019; Smith and Jones 2021).

- **Remote Sensing and Satellite Data Integration**
  In regions like India and Spain, farmers use satellite-based tools coupled with weather data to predict irrigation needs, enabling precision water management at field scale (Patel et al. 2020; López-Gunn and Llamas 2018).

- **Mobile App-Enabled Irrigation Management**
  Platforms like CropX and Rachio provide user-friendly mobile interfaces that allow farmers to monitor soil moisture, control irrigation remotely, and receive alerts based on weather forecasts (CropX 2024; Rachio 2024).

Relevance to Fresno Small Farms

Smart irrigation offers Fresno growers the potential to:

- Reduce water consumption and costs

- Improve crop yields and quality through precise water delivery

- Comply with increasing water regulations and sustainability initiatives

Challenges include the initial cost of sensors and controllers, technical expertise for setup and maintenance, and connectivity issues in rural areas.

Summary

Smart irrigation technologies proven internationally can be adapted to Fresno's small farms to address water scarcity challenges effectively. Partnerships with extension services and cost-sharing programs can facilitate technology adoption.

Comparison Table: Smart Irrigation Technologies

Technology	Core Features	Cost	Ease of Use	Key Benefits	Challenges
Soil Moisture Sensors & Controllers	Real-time soil moisture monitoring and automated irrigation control	$$–$$$	Moderate	Precise water use, reduces waste	Setup complexity, maintenance needs
Remote Sensing & Satellite Data	Field-scale water use prediction using satellite and weather data	$–$$	Moderate to complex	Large area monitoring, data-driven decisions	Requires data interpretation skills
Mobile App-Enabled Management (CropX, Rachio)	Mobile interface for remote irrigation control and monitoring	$–$$	User-friendly	Easy access, weather-based alerts	Internet dependence, subscription fees

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3B. Soil Health and Management Technologies

Maintaining and improving soil health is critical to sustainable productivity and resilience for small farms in Fresno and worldwide. Soil degradation through erosion, nutrient depletion, salinization, and loss of organic matter threatens long-term viability, especially in intensive cropping systems common in the San Joaquin Valley. International smallholder farmers have pioneered a variety of low-cost, organic, and bio-based soil management technologies to enhance fertility, structure, and microbial activity.

This section reviews notable global approaches, including microbial soil amendments, biochar use, and controlled biological soil disinfestation, with potential applicability to Fresno's small farms.

International Technologies of Note

- **Japan: Effective Microorganisms (EM) Soil Amendments**
  EM technology utilizes a consortium of beneficial microbes to enhance soil microbial diversity, improve nutrient cycling, and suppress pathogens. It has been adopted widely in Asia for organic vegetable and rice production (Higa and Wididana 1991; Liu et al. 2019).

- **Africa: Biochar from Crop Residues**
  Smallholder farmers in parts of Sub-Saharan Africa produce biochar by pyrolyzing agricultural waste, which is then added to soil to increase carbon content, improve water retention, and enhance nutrient availability. This low-cost, circular approach supports soil fertility while reducing biomass waste (Lehmann and Joseph 2015; Agegnehu et al. 2017).

- **Netherlands: Controlled Biological Soil Disinfestation (BSD)**
  BSD involves incorporating organic amendments, flooding soil temporarily, and covering it with plastic to stimulate anaerobic microbial activity that suppresses soil-borne pathogens. This technique offers a chemical-free alternative to fumigation widely used in vegetable and flower production (Momma 2008; Mazzola et al. 2018).

Relevance to Fresno Region Farms

Fresno's small farms—particularly those growing vegetables, berries, and specialty crops—face soil challenges related to intensive production and salinity from irrigation water. Many growers seek alternatives to synthetic fertilizers and fumigants to meet environmental regulations and consumer demand for sustainably grown produce.

The reviewed international soil health technologies provide:

- Sustainable, organic options to rebuild soil organic matter
- Methods to suppress soil pathogens without chemical fumigation
- Techniques that improve water retention and nutrient use efficiency

Challenges to adoption include the need for farmer training on microbial product handling, initial labor inputs (e.g., biochar production), and demonstration of economic return at small scale.

Comparison Table: Soil Health Technologies

Technology / Country	Core Features	Cost Range	Requirements	Advantages	Challenges / Gaps
Effective Microorganisms (Japan)	Microbial consortia applied as soil amendment	$	Access to quality EM products	Enhances microbial diversity, pathogen suppression	Requires repeated applications, product quality control
Biochar (Africa)	Charcoal from crop residues added to soil	$	Biomass availability, pyrolysis method	Improves water retention, carbon sequestration	Labor-intensive production; limited local supply chains
Biological Soil Disinfestation (Netherlands)	Organic matter incorporation + flooding + plastic cover	$$	Water source, plastic film, labor	Chemical-free pathogen control, improves soil health	Requires specific timing and conditions; knowledge-intensive

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3B. Soil Health Technologies

Soil health underpins farm productivity and resilience, influencing water retention, nutrient cycling, and plant disease resistance. Small farms worldwide increasingly employ soil management practices and technologies that promote biological activity and long-term soil fertility. This section highlights key soil health technologies with potential for Fresno's small farms.

International Technologies of Note

- **Cover Cropping and Green Manures**
 Smallholders in Latin America and Africa use cover crops to improve soil organic matter, fix nitrogen, suppress weeds, and reduce erosion (Snapp et al. 2019).

- **Composting and Organic Amendments**
 Organic matter recycling through composting is widely practiced, enhancing microbial diversity and nutrient availability (Bernal et al. 2017).

- **Biofertilizers and Microbial Inoculants**
 The use of Plant Growth-Promoting Microorganisms (PGPMs) such as mycorrhizae and nitrogen-fixing bacteria is common in Asia, Africa, and Latin America (Lehmann and Joseph 2015).

- **Soil Testing and Digital Soil Health Monitoring**
 Emerging digital platforms enable smallholders to monitor soil nutrient status and pH via low-cost sensors or mobile apps, supporting informed management decisions (Li et al. 2021).

Relevance to Fresno Small Farms

Fresno's semi-arid soils face challenges such as salinity, low organic matter, and compaction. Integrating soil health technologies can:

- Enhance soil structure and fertility
- Improve water retention and drought resilience
- Reduce input costs by optimizing nutrient management

Barriers include availability of inputs, initial labor investment, and knowledge gaps.

Summary

Promoting soil health through biological and digital tools offers Fresno’s small farms sustainable pathways to improve productivity and environmental resilience.

Comparison Table: Soil Health Technologies

Technology	Core Features	Cost	Ease of Use	Key Benefits	Challenges
Cover Cropping & Green Manures	Planting legumes or grasses for soil cover	Low	Moderate	Improves organic matter, fixes nitrogen, suppresses weeds	Requires seasonal planning, labor
Composting & Organic Amendments	Recycling organic waste into nutrient-rich soil amendments	Low to moderate	Moderate	Enhances soil microbial activity and fertility	Time-consuming, input material needed
Biofertilizers & PGPMs	Microbial inoculants promoting nutrient cycling	Moderate	Moderate	Improves nutrient availability and plant health	Storage and handling sensitivity
Digital Soil Health Monitoring	Sensors or apps for soil nutrient and pH monitoring	Moderate	User-friendly	Enables precision soil management	Requires investment in tech and training

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3C. Crop Protection and Pest Control Technologies

Effective crop protection and pest management are vital for maintaining productivity and crop quality on small farms, particularly in the San Joaquin Valley where diverse crops face pressures from insects, diseases, and weeds. Internationally, smallholder farmers have adopted a range of low-cost, environmentally sustainable pest control technologies and integrated pest management (IPM) strategies that could be adapted for Fresno-area farms.

International Technologies of Note

- **Kenya: Push-Pull Pest Management**
  This strategy uses trap and repellent plants to "push" pests away from crops and "pull" them toward trap crops, reducing reliance on chemical pesticides. Widely adopted by smallholder maize farmers in East Africa, it has shown substantial yield improvements and environmental benefits (Khan et al. 2018).

- **Vietnam: Biopesticides and Botanical Extracts**
  Vietnamese smallholders utilize locally sourced botanical pesticides, such as neem oil and chili extracts, combined with microbial biopesticides. These methods offer low-toxicity alternatives that fit well with organic and low-input farming systems (Nguyen and Tran 2020).

- **Spain: Smart Traps and Monitoring Systems**
  In Spain's Mediterranean small farms, digital pheromone traps linked to mobile apps allow precise monitoring of pest populations. This data-driven approach supports targeted pesticide applications, reducing chemical use and costs (Martínez et al. 2021).

Relevance to Fresno Small Farms

Fresno's small farms commonly face pest pressures from aphids, spider mites, and fungal pathogens, especially in vegetable and berry production. The adoption of IPM tools such as push-pull planting, biopesticides, and pest monitoring technologies can:

- Lower chemical pesticide dependency, aligning with organic and sustainable certifications

- Reduce input costs and environmental impacts

- Improve pest management precision and crop yields

Barriers include lack of local availability of some biopesticides, knowledge gaps in IPM, and initial costs of monitoring devices.

Summary

International pest management innovations demonstrate promising, sustainable alternatives and complements to conventional pesticides for Fresno's small farms. Collaborative extension programs and farmer-to-farmer knowledge sharing will be essential to tailor these approaches locally.

3C. Crop Protection and Pest Control Technologies

Effective crop protection and pest management are vital to maintaining productivity and crop quality on small farms, particularly in the San Joaquin Valley, where diverse crops face pressures from insects, diseases, weeds, and birds. This section explores indigenous pest management knowledge, biological soil treatments, and innovative bioacoustic bird deterrent technology, drawing from global examples with applicability to Fresno's small farms.

Indigenous Technical Knowledge (ITK) in Pest Management

Smallholder farmers worldwide have long relied on Indigenous Technical Knowledge (ITK) for sustainable pest control. These methods often include cultural practices, natural repellents, and habitat manipulation to reduce pest populations without chemical inputs. Such knowledge is particularly relevant where access to synthetic pesticides is limited or undesirable due to cost, health, or environmental concerns (Maredia et al. 2023).

Examples include crop rotation, intercropping with pest-repellent plants, physical barriers, and use of local botanical extracts. Incorporating ITK into Fresno's pest management toolbox can enhance ecological balance, reduce pesticide dependency, and strengthen farm resilience.

Soil Microbial Disinfestation and Plant Growth-Promoting Microorganisms (PGPMs)

Soil microbial disinfestation encompasses biological, non-chemical soil treatments such as Anaerobic Soil Disinfestation (ASD) and the application of PGPMs or biofertilizers. These practices simultaneously suppress soil-borne pests, weeds, and pathogens while improving soil health, fertility, and water retention—key factors in plant vigor and disease resistance.

Anaerobic Soil Disinfestation (ASD) involves:

- Incorporating easily decomposable organic materials (e.g., rice bran, molasses, sugarcane bagasse, almond hulls)
- Saturating soil with water
- Covering soil with plastic tarp to induce anaerobic (low oxygen) conditions

This process fosters beneficial anaerobic microbes that suppress pathogens and nematodes, as well as some weed seeds (Momma 2008; Mazzola et al. 2018).

Plant Growth-Promoting Microorganisms (PGPMs) are naturally occurring or cultured bacteria and fungi that enhance plant growth and soil quality by:

- Nitrogen fixation (e.g., *Rhizobium*)
- Phosphorus solubilization
- Producing plant hormones like auxins
- Disease suppression (e.g., *Trichoderma*, *Bacillus subtilis*)
- Improving water and nutrient uptake via mycorrhizal fungi

The geographic use of PGPMs spans many regions, particularly where traditional soil amendments are scarce or costly:

Region	Countries	PGPM Types Used
Sub-Saharan Africa	Kenya, Ethiopia, Nigeria, Zambia	*Rhizobia*, *Azospirillum*
South Asia	India, Nepal, Bangladesh	*Azospirillum*, *Azotobacter*, Phosphobacteria, Mycorrhizae
Southeast Asia	Philippines, Indonesia, Vietnam	Mycorrhizae, local compost-based PGPM blends
Latin America	Brazil, Mexico, Colombia	*Rhizobia*, *Azospirillum*, Mycorrhizae

Middle East and North Africa	Egypt, Tunisia, Morocco	Salt-tolerant PGPMs

These microbial technologies offer Fresno farmers pathways to enhance soil and crop health sustainably (Lehmann and Joseph 2015; Agegnehu et al. 2017).

Bioacoustic Bird Deterrent: Bird Gard

Bird damage to crops presents a major challenge for orchards, vineyards, and row crops in Fresno County. Bird Gard, an Oregon-based company, provides a bioacoustic bird deterrent system that broadcasts species-specific digital recordings of distress calls, predator sounds, and harassment noises to humanely deter pest birds.

System features include:

- Tailored sounds for specific problem bird species, minimizing impacts on non-target species
- Randomized sound playback (over 250 combinations) to reduce habituation
- Solar-powered options for off-grid use
- Coverage of approximately 1 acre per emitter unit, scalable to larger areas
- One-time cost of $300–$500 per acre, plus optional solar charger and power sources

Advantages:

- Non-lethal, organic-compliant, and wildlife-friendly
- Automated, remote operation with minimal labor
- Durable weather-resistant housing

Disadvantages:

- Potential habituation if not properly configured
- Noise pollution concerns and possible regulatory issues

- Battery and solar panel maintenance needed, especially in challenging weather
- Initial investment cost can be high

The Bird Gard system is already used internationally, including in the San Joaquin Valley, providing a promising option for small farms seeking effective bird control without chemicals (Bird Gard 2025).

Technology	Description	Benefits	Challenges	Relevance to Fresno Small Farms
Indigenous Technical Knowledge (ITK)	Traditional pest management using cultural practices, natural repellents, and habitat manipulation.	Low-cost, eco-friendly, builds ecological balance, reduces pesticide reliance.	Knowledge transfer gaps, requires local adaptation, limited scientific documentation.	Complements modern IPM; accessible and adaptable for diverse crops.
Soil Microbial Disinfestation (ASD & PGPMs)	Biological soil treatment using organic amendments and beneficial microbes to suppress pests and improve soil health.	Multi-beneficial: controls soil pests/weeds, improves fertility and water retention, sustainable.	Requires materials and labor; plastic tarp use may have disposal concerns; technical knowledge needed.	Improves soil and crop health, important for Fresno's semi-arid soils.
Bioacoustic Bird Deterrent (Bird Gard)	Uses species-specific distress and predator calls via solar-powered emitters to deter pest birds humanely.	Non-lethal, organic-compliant, low labor, scalable, suitable for orchards and vineyards.	Initial cost, maintenance of batteries/solar panels, possible habituation, noise pollution concerns.	Addresses bird damage in fruit, nut, and specialty crop production.

Summary

Integrating indigenous pest management practices with biological soil disinfestation and innovative bioacoustic deterrents offers Fresno small farms sustainable, multi-beneficial pest control options. These approaches align with organic standards, reduce chemical inputs, and promote soil and crop health. Extension services and farmer training will be essential to adapt and implement these technologies effectively in the region.

3C. Crop Protection and Pest Control Technologies

Effective crop protection and pest control are critical for small farms to safeguard yields while minimizing environmental and health impacts. Smallholder farmers worldwide employ a mix of indigenous knowledge, biological methods, and innovative technologies to manage pests and diseases sustainably. This section reviews key approaches relevant to Fresno's small farms.

International Technologies of Note

- **Indigenous Technical Knowledge (ITK)**
  Traditional pest management strategies utilize natural repellents, crop diversification, intercropping, and cultural practices to reduce pest pressures without chemical inputs (Nawaz et al. 2023).

- **Soil Microbial Disinfestation (Anaerobic Soil Disinfestation & PGPMs)**
  This biological, non-chemical soil treatment involves incorporating organic amendments, saturating soils with water, and covering them with plastic tarps to create anaerobic conditions that suppress soil-borne pests and diseases. Beneficial microbes like *Rhizobium* and *Trichoderma* also improve nutrient availability and plant health (Vos et al. 2017; Derksen et al. 2020).

- **Bioacoustic Bird Deterrents**
  Technologies like Bird Gard use digitally recorded distress and predator calls to deter pest birds humanely. The system is scalable, solar-powered, and compliant with organic farming standards (Bird Gard 2024).

Relevance to Fresno Small Farms

Fresno's small farms face challenges from soil-borne pathogens, bird damage, and pest outbreaks. Adopting integrated pest management that incorporates indigenous methods, biological soil treatments, and humane deterrents can:

- Reduce reliance on chemical pesticides
- Improve soil health and biodiversity
- Protect specialty crops from bird damage

Comparison Table: Crop Protection and Pest Control Technologies

Technology	Core Features	Cost	Ease of Use	Key Benefits	Challenges
Indigenous Technical Knowledge	Natural repellents, crop diversification, intercropping	Low	Moderate	Eco-friendly, low cost, sustainable	Requires local knowledge, training
Soil Microbial Disinfestation	Organic amendments, anaerobic conditions, microbial inoculants	Moderate	Moderate	Controls soil pests, enhances soil health	Labor intensive, material access
Bioacoustic Bird Deterrents	Distress/predator calls, solar-powered emitters	Moderate-High	Moderate	Non-lethal, organic-compliant, scalable	Initial cost, maintenance, habituation

3D. Management and Reporting of Farm Activities

Accurate and timely management and reporting of farm activities are essential for small farms to ensure operational efficiency, meet regulatory requirements, secure certifications, and qualify for grants. Internationally, a growing number of digital tools and platforms support these functions, helping farmers document their work, track inputs and outputs, and communicate with stakeholders.

International Technologies of Note

- **Farm Activity Logging and Scheduling Software**
  These tools enable farmers to plan daily tasks, record planting, irrigation, fertilization, pest control, and harvesting activities. Examples include open-source and commercial software adapted for smallholder contexts in East Africa and Southeast Asia (Mwangi et al. 2021).

- **Compliance and Traceability Reporting Systems**
  In Europe and North America, digital platforms facilitate compliance with food safety regulations (e.g., GlobalGAP), labor laws, and environmental standards by automating data collection and generating standardized reports (Martinez et al. 2022).

- **Mobile Apps and SMS-Based Reporting**
  For regions with limited internet, mobile apps and SMS-based systems allow farmers to report activities and receive reminders or alerts. Projects in India and sub-Saharan Africa have demonstrated the utility of such tools for smallholders (Aker et al. 2018).

Relevance to Fresno Small Farms

Fresno's small farms often face complex regulatory environments including food safety (e.g., FSMA Produce Safety Rule), labor compliance, and environmental reporting. Digital management tools can:

- Streamline data collection and reduce paperwork
- Facilitate compliance with certifications and grant requirements
- Improve operational planning and resource allocation
- Support payroll and tax documentation

However, barriers include technological literacy, internet access, and cost. Tailored training and local support services are key to fostering adoption.

Summary

Digital farm management and reporting tools offer significant benefits for Fresno's small farms in improving compliance, efficiency, and market access. Solutions that balance usability with functional depth and accommodate connectivity limitations will have the greatest impact.

Comparison Table: Management and Reporting Tools

Technology	Core Features	Cost	Ease of Use	Key Benefits	Challenges
Open Foris Collect	Activity logging, data collection, SMS-based	Free	Moderate	Supports offline data entry, SMS compatible	Training needed, limited customization
AgriWebb	Farm planning, record keeping, compliance reports	$$	User-friendly	Integrated compliance tools, mobile access	Subscription fees, internet required
FarmOS	Open-source farm management platform	Free	Moderate	Highly customizable, community-supported	Requires technical skills
Vytelle	Automated record keeping for food safety	$$$	Easy with setup	Real-time data logging, traceability	Costly, may be complex for small farms

3D. Farm Management and Reporting Tools

Farm management software has become increasingly vital for small farms seeking to improve operational efficiency, meet regulatory requirements, and document practices for certification and grant compliance. These digital platforms support planning, task logging, financial tracking, and reporting functions, helping farmers streamline labor and recordkeeping in an accessible format.

Overview of Farm Management Software

Farm management programs vary widely in complexity and cost. Some offer free or low-cost entry points with basic scheduling and task tracking, while others provide robust modules for food safety traceability, payroll, tax reporting, and grant applications. However, an inherent tension exists between the software's depth and flexibility versus its ease of use — more powerful platforms often require significant onboarding and technical skill, which can challenge adoption by small-scale farmers (Roberts et al. 2022; Smith and Patel 2021).

Notable Technologies

- **LiteFarm**
  LiteFarm emphasizes user-friendly interfaces tailored to small and mid-scale diversified farms. It offers crop planning, labor management, and compliance reporting tools designed to simplify adoption and reduce administrative burdens (LiteFarm 2024).

- **Tend**
  Tend provides cloud-based farm management with features for task scheduling, harvest tracking, and traceability needed for food safety certifications. It integrates mobile app access, allowing real-time data entry from the field (Tend 2024).

- **FarmRaise**
  FarmRaise combines management with financial planning and grant identification services, guiding farmers through funding opportunities linked to conservation and resilience practices (FarmRaise 2024).

Relevance to Fresno Small Farms

For Fresno's small-scale growers, farm management software can:

- Improve **planning and recordkeeping**, reducing time spent on paperwork

- Facilitate **compliance with food safety and environmental regulations**, essential for market access
- Support **grant applications and certification processes**, increasing financial viability
- Provide **payroll and tax reporting** to streamline farm business administration

Key barriers include the **learning curve** for complex platforms and variable internet access in rural areas. Training and localized support can ease these challenges, promoting more widespread adoption.

Comparison Table: Farm Management Tools

Software	Core Features	Cost	Ease of Use	Key Benefits	Challenges
LiteFarm	Crop planning, labor mgmt, compliance reporting	$$	User-friendly, designed for small farms	Reduces admin burden, tailored to diversified farms	Limited advanced features
Tend	Task scheduling, harvest tracking, traceability	$$	Mobile app, real-time data entry	Supports food safety certification, cloud-based	Requires stable internet
FarmRaise	Grant assistance, financial planning, reporting	$-$$$	Moderate complexity	Connects to funding, enhances financial planning	Onboarding needed, costs vary

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3E. Theft Prevention and Farm Security Technologies

Theft of equipment, produce, and infrastructure poses a significant challenge for small farms worldwide, including those in Fresno County. Losses can have outsized impacts on small operators with limited resources for replacement or insurance. To mitigate this risk, a variety of theft prevention and monitoring technologies have emerged internationally, emphasizing affordability, low energy use, and adaptability to low-connectivity rural environments.

International Technologies of Note

- **South Africa & Brazil: Motion-Activated Solar Cameras with Mobile Alerts**
  In rural areas of South Africa and Brazil, solar-powered motion-activated cameras connected to mobile networks provide farmers with real-time alerts of suspicious activity. These systems often rely on affordable off-grid power and cellular data to overcome infrastructure limitations (Munyai et al. 2020; Silva et al. 2022).

- **United States & Australia: GPS Trackers for Equipment and Product Tracing**
  GPS tracking devices affixed to tractors, tools, and even harvested produce enable precise location monitoring. In the U.S. and Australia, growers use these trackers to recover stolen property and manage inventory more effectively (Brown and Wilson 2021; Clarke et al. 2019).

- **India: Community Surveillance Models with Solar Lighting and Cooperative Guards**
  Some Indian smallholder communities utilize solar-powered lights and coordinated neighborhood watch programs to deter theft collectively. These low-cost social-technical solutions combine environmental and human factors for effective security (Kumar and Patel 2018).

- **Global: AI-Enabled Camera Systems and Wildlife Deterrents**
  Advanced security systems, such as FarmWise's AI-enabled cameras, monitor farm perimeters and detect intruders or wildlife with high accuracy. Similarly, some farms use automated wildlife deterrent devices that double as theft deterrents, though cost and complexity limit widespread adoption (FarmWise 2024; Thompson et al. 2023).

- **Current Technologies in Fresno: Reolink vs. Vosker V300 Cameras**
  Locally, small farms trial systems like Reolink cameras, which provide continuous video but require stable connectivity and power, and Vosker V300 units, which use solar power and send photos via cellular networks, suitable for remote areas. Each system has trade-offs related to data detail, reliability, and cost (Nick, personal communication 2025).

- **Robotic Security Dogs and Autonomous Patrols**
  While garnering media attention, robotic security dogs are currently cost-prohibitive (exceeding $75,000) and not yet proven effective for small-scale farm security (Robotics Security Review 2024).

Relevance to Fresno Small Farms

Small farms in Fresno County face increasing threats from equipment and crop theft, amplified by rural-urban interface dynamics and limited local law enforcement resources. The key characteristics required for effective theft prevention technology in this context include:

- **Affordability and scalability** suitable for small farm budgets
- **Solar-powered or low-energy designs** to enable off-grid deployment
- **Connectivity options compatible with rural cellular networks or offline data capture**
- **Integration potential with insurance claims and farm management systems**
- **Support for cooperative and community-based surveillance models**

Summary

Affordable, solar-powered motion-activated cameras with mobile alert systems represent the most immediately viable security technology for Fresno's small farms. Complementing these with GPS tracking and community-led surveillance can strengthen resilience against theft. While high-tech robotic patrols remain inaccessible, ongoing monitoring of technological advances is warranted.

3F. Theft Prevention and Farm Security Technologies

Theft of equipment, produce, and infrastructure poses a significant challenge for small farms worldwide, including those in Fresno County. Losses can have outsized impacts on small operators with limited resources for replacement or insurance. To mitigate this risk, a variety of theft prevention and monitoring technologies have emerged internationally, emphasizing affordability, low energy use, and adaptability to low-connectivity rural environments.

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Farmer Experience

"Some of the security equipment at Hahn Farms came with the property, some I already owned, and we've purchased additional devices over time. We also store tools and equipment for friends who have experienced theft elsewhere, hoping to keep their items safer while they're away. Despite these measures, the shop building and pole barn were recently burglarized,

resulting in a loss of about $30,000 worth of tools. Unfortunately, most of this loss wasn't covered by insurance, which makes the financial impact even harder. Theft is a real and ongoing concern for small farms like ours, and investing in effective security is critical, but also costly and challenging."
— Nick Hahn, Small Farm Operator, Fresno County

Relevance to Fresno Small Farms

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