A Review of Agricultural Technologies Applicable to Small-Scale Farmers in Fresno, Kings, Madera, Merced, and Tulare Counties

Introduction

Small farms are at the heart of global food security, biodiversity, and rural livelihoods. In regions like California's San Joaquin Valley, where agriculture dominates the landscape, small and mid-scale farms face mounting challenges—from water scarcity and labor shortages to economic precarity and limited access to appropriate technologies. While significant innovation has emerged in agtech, much of it is designed for large-scale, capital-intensive farming, leaving a gap in relevance and accessibility for smaller operations.

In the agriculture technology revolution which focuses on scale and precision as tools for efficient production, small farms are at risk of being left out and eliminated, or worse, exploited in order to enrich technology or data companies. There is an assumption that small farms are inefficient producers of food for the population (Aragón et al. 2022). However, a nuanced perspective on efficiency which considers yields vs. inputs holistically shows that small farms produce more food per acre, are more ecologically sustainable, and strengthen local economies in multiple ways not captured in a typical inputs vs. yields analysis (NIFA 2025; Payen et al. 2022). While large corporate farms hire teams of experts to track and proclaim their positive impacts and mitigate the negative ones, small farms are underrepresented in scholarly and technical publications. This report aims to address the paucity of research on small farms in California's Central San Joaquin Valley by providing a description of technologies currently in use on small farms in the region.

Objectives

This Small Farms Technology Landscape Review looks at which technologies are in use or are under development that meet the needs of small farms in California's Central Valley. The current document is part of a larger technology needs assessment for small farms in Fresno, Kings, Madera, Merced, and Tulare counties, which has a key objective to provide guidance around the development of agricultural technology and policy for the region and for California more broadly in the next five to ten years.
Objectives for this review are:

1) to identify currently available technologies for small-scale farmers in the San Joaquin Valley and

2) to identify technologies that have the potential to support and increase economic viability of small-scale farms in the region.

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Small Farms

Small farms in the San Joaquin Valley are diverse in size, crops grown, income, marketing strategies, and range from monoculture to highly diverse cropping systems. For the purposes of this technology landscape review, the focus will be on farms that grow a diversity of crops on a small acreage (generally under 50 acres) and often do not engage in the commodity market. Many of these farms are operated by black, indigenous and people of color (BIPOC), immigrants and historically underserved farmers and are impacted more acutely by the economic and climate impacts faced by most farms. (Sources: UCANR and University of California Cooperative Extension (UCCE) Fresno/Merced Small Farms Definitions, CAFF's DWR Small Farms Definition Comment Letter, DWR's URCTA Program Eligibility Criteria.)

The USDA's 2022 Census of Agriculture, County Summary Highlights provides the following statistics on average farm size:

Table 1

County	average (mean) acres	median acres
Fresno	375	45
Kings	688	61
Madera	553	80
Merced	426	45
Tulare	353	40

The large difference between average (mean) farm size in this region and the median farm size illustrates that most farms are smaller, and the average is skewed upwards by relatively few large farms.

Additional data from the USDA 2022 Census of Agriculture shows that most farms in each of these counties are less than 180 acres in size. In each county, except for Merced, the largest number of farms are in the category from 10 to 49 acres, as seen in the table below.

Table 2

County	Total farms	Farms of 1-9 acres	**Farms of 10-49 acres**	Farms of 50-179 acres	Farms of 180+ acres
Fresno	4427	646	**1594**	949	1238
Kings	862	155	**249**	149	309
Madera	1255	127	**357**	340	431
Merced	2047	288	**771**	383	605
Tulare	3713	792	**1190**	751	980

Appropriate Technology

Technology is the application of scientific knowledge for practical purposes, or to the practical aims of human life. Thus, technology includes all kinds of applied scientific ideas, and not specifically software, hardware, machines, or tools. The term appropriate technology has a long history of use in the field of sustainable development and refers to tools, practices and ideas that are locally accepted and adapted, and sustainable; sustainability implies that a technology should be locally sourced or maintained and not harmful to the environment (Jurvélius 1997).

Appropriate technology for small farms includes a wide range from simple mechanical tools to innovative methods, to sensors, online technology and software. It is technology that is affordable, right-scale, low-risk, has a clear benefit and learning curve that is justifiable, is flexible and multi-beneficial, doesn't require specialized infrastructure or technical skills, doesn't require English fluency, and is protective of privacy and transparent about data collection and uses. These principles are based on the F3 Commitment to Race Equity that was developed during the grant application process and are currently being expanded into a resource for

evaluating technologies to determine how appropriate they are for small farms (UC Merced 2025).

Cropping systems and tasks for technology

Specified tools and technology that serve a monocrop farm system often do not work well in highly diverse polycrop systems. The following tasks or stages of production will be used to help categorize the different kinds of work that can be addressed by technology for small farms:

1. Nutrient management and soil fertility
2. Field preparation
3. Planting (sowing, transplanting, nursery)
4. Irrigation
5. Spray application (plant health, etc.)
6. Integrated Pest Management (IPM) and weed management
7. Harvest
8. Post-harvest (storage, processing, value added)
9. Sales and marketing
10. Farm management and planning

In the technology profiles section, below, several technologies that each address a particular farm task or stage of production are profiled. These technologies were selected from a large database of existing or currently-under-development tools. They were selected based on farmer priorities as identified through farmer feedback sessions, surveys, and interviews with small farms advisors, carried out by Community Alliance with Family Farmers (CAFF) and University of California, Agriculture and Natural Resources (UCANR). These were identified as common areas of need for tools by small scale farmers: cold storage, weed management, irrigation, and planting or seeding.

Technology profiles

Since small farms tend to have very limited capital, limited human resources, and limited time available for the work of farming, it only makes sense for small farms to use innovative tools or technologies if those work well with their current scale and available capital, labor, and skills. More sophisticated technologies that yield data for decision making or increased crop yields (through the use of technology for various farm tasks) are only helpful if farmers have the capacity to use the data or a market outlet for more volume. To frame it another way, the many facets of production need to be matched in scale to work together in a way that doesn't create wasted time, labor, infrastructure, cost, or produce.

While a few tools, such as a shovel and a rake, are indispensable on most any small farm, the scale and type of crops grown indicate different tools. For example, a mixed vegetable farm on a half an acre or less will likely do well with non-motorized hand tools such as hula hoes, tine weeders, and bed rakes, while a farm on two or more acres would need a walk-behind two wheeled tractor at least, or perhaps a four wheeled tractor with implements. Organized by task or crop stage, technologies of various scale and complexity are profiled below.

Cold storage

From simple crates in the shade to rented cold storage at a warehouse facility, there are a range of technologies that farmers use to keep harvested produce fresh until it reaches its market. The choice of technology is often dictated by its affordability and availability, as well as the scale and timing of the harvest.

For many very small or beginning farmers, ice chests or regular home-use refrigerators are the most appropriate in terms of scale, cost, and ease of use. For a farm with a small amount of produce being direct-marketed, the weekly harvest is often small enough to fit in several ice chests or a few reach-in refrigerators. They can be purchased cheaply on the used marketplace or found and repurposed from household furnishings or purchased new for a relatively low cost. For these options, no specialized infrastructure or equipment is normally required.

Technology	**Ice chests/coolers**
Cost	~$40.00 to $100.00 each
Availability	easy: available at supermarkets and online marketplaces
Requirements	ice or cold packs
Advantages	economical, available, no on-farm electricity required, can also be used for transportation of produce
Disadvantages	small storage capacity, temperature fluctuations, need to have ice or frozen ice packs, hard on body to transport

Technology	**Refrigerator (reach-in or household type)**

Cost	~ $100.00 to $1000.00 each, depending if new/used and specifications
Availability	easy: available at home improvement stores and online marketplaces
Requirements	regular household electricity
Advantages	relatively economical, widely available, maintain even cool temperature, easily turn on/off fridges as needed to adjust to variable capacity needs across a growing season
Disadvantages	small size makes fitting boxes/crates challenging, need for transport containers such as ice chests or crates, in an off-grid location the need for electricity is problematic

A note on electricity usage: while reach-in refrigerators use regular 120 volt electrical connections, the use of several refrigerators on the same circuit can draw too much amperage and result in circuits becoming overloaded, especially if extension cords, small connectors, or long connector lines are being used. In this case, the circuit may need to be upgraded, which can be straight-forward and inexpensive, or complicated and expensive if there is not enough available amperage at the point of use. In many cases, upgrading to a new energy-efficient refrigerator can pay for itself in a few years of energy savings, especially if upgrades to the electrical system can be avoided.

The next section presents options for larger walk-in coolers, which generally use more energy since they are larger, but can be a more efficient choice if the scale is a good fit since they use less energy per unit of space. Some farms use regular refrigerators at the end of the season when the harvest is smaller, and only run the walk-in cooler when the scale of the harvest requires more cold storage space.

If a farm needs more cold storage capacity, an on-farm cold storage room (walk-in refrigerator) or container is a longtime solution. For a traditional walk-in refrigerator, this requires extra electrical capacity and 220/240 volt electrical wiring as well as an insulated room or container. Installation may require hiring an electrician.

Technology	**Walk-in refrigerator**

Cost	~$10,000 to $20,000 (depending on size, new/used components, DIY or professional installation)
Availability	Available online or through local HVAC but requires complex or professional installation/construction
Requirements	Insulated space, 220/240 volt electrical capacity
Advantages	Maintains stable temperature, can be built to (larger) appropriate size, can fit pallets or stacks of crates easily, lifespan of 15 years or more
Disadvantages	Relatively expensive, higher energy use due to size of space being cooled, complex installation and repairs, need for storage and transport containers, permanent and not easily moved (presents problems for tenant farmers who may need landowner's permission or stand to loose investment in infrastructure)

Another option for this scale of cold storage is to use a CoolBot with a window air conditioner to create a cold storage space without the need for specialized electrical capabilities. Compatible window air conditioners are available at local retailers such as hardware stores and home improvement stores. Specialized cold storage containers can be ordered online for delivery, or locally available construction materials can be used to insulate an existing space.
This technology was developed by a farmer who needed a walk-in refrigerator but wanted to avoid the reliance on HVAC professionals, which is a logistical hurdle faced by many small farms, as well as a significant on-going expense. According to independent research by New York State Energy Research and Development Authority, an appropriately installed CoolBot can be up to 40% more energy efficient compared to a traditional refrigerator compressor unit (CDH Energy Corp. 2009).

Technology	**CoolBot controller** (DIY cold storage using window AC and CoolBot controller)
Cost	~$400.00 for CoolBot controller (various models) and ~$300.00 for compatible window AC (depending on size of space to be cooled), CoolBot 8x8 all inclusive turnkey package costs ~$9,000.00 delivered
Availability	CoolBot controller available online or for pick up at home improvement stores, window AC's widely available in stores and online, easy DIY installation instructions/videos available on the CoolBot website, Spanish

	language support available through customer support and user's manual in Spanish
Requirements	Insulated space, regular household electrical wiring and capacity, or depending on the AC unit requirements, possibly 220/240 volt capacity
Advantages	DIY installation and repairs, relatively inexpensive components, up to 40% less energy consumption vs. walk-in refrigerator, can easily fit to existing infrastructure, some versions have wifi capabilities and app based controls, can be built to (larger) appropriate size, can fit pallets or stacks of crates easily, works well between 36 degrees F and
Disadvantages	wear on AC unit/need to replace after 5 years, well-insulated room and correct size AC unit (measured in BTU) for the size of cold storage space are essential to success, not ideal for frequent door openings or rapid cooling, does not work as a freezer

If on-farm cold storage is not a viable option due to space needs or constraints, electrical infrastructure, or timing considerations such as time needed to build out space or crop systems and harvest schedules that include a larger volume of storage at one time, renting space in an industrial cold storage facility is an option.

Technology	**Rented cold storage warehouse space** (off-farm)
Cost	Per month, per unit of space, varies widely
Availability	facilities exist throughout the region but access is usually limited because of high demand at certain seasons and because many warehouses are not willing to work with small farms/small accounts
Requirements	Ability to transport pallets/bins, negotiation of price point for relatively small account
Advantages	Larger capacity, lower cost compared to on-farm cold storage for large volume
Disadvantages	Less control over storage conditions, infrequent access to produce, need for hauling capabilities and hauling time, or need to hire trucking which introduces further costs

Areas of recent and needed innovation

Cold storage has seen recent innovations in technology including the use of trailers as cold storage units because of their mobility and adapting solar power to work with cooling systems for increased access to cold storage in off-grid locations or places with minimal electrical capacity. (See the CoolBot tutorial videos for mobile trailer coolers.)

A recent innovation for cold storage on small farms is the CoolBot controller. This kind of innovation not only saves farmers money upfront in installation savings, and continuously in energy savings, but also increases self-sufficiency by reducing reliance on off-farm expertise. The real value of this increased autonomy is bigger than it appears at first glance because it means that repairs or changes can be made when needed, rather than waiting on the availability of HVAC professionals, thus potentially saving produce, increasing efficiency of work-flow, and reducing stress.

An older solution that is ripe for revisiting is sharing cold storage among multiple small farms that are geographically close to each other. This could be considered a social innovation whereby farms invest together in the infrastructure and share the costs of cold storage as cooperatives or through co-ownership of facilities. This innovation supports and is closely related to shared distribution and marketing and strengthens the connections between nearby farms and builds the local food supply chain. A potential way to support such shared solutions is through access to capital for the purchase and installation of the cold storage infrastructure.

Third party applications that make it easy for consumers to find rides, parking, and other things have become common. A similar application that connects farmers or other users to available cold storage space and provides details such as pricing, temperature options, and other information needed for farmers to find appropriate cold storage would be useful. There is a somewhat similar application for finding warehouse space called WarehouseNow that matches warehouse owners and tenants, and Coldtivate, an application that connects farmers to cold storage and to markets, which is not currently available in the region but something similar would be beneficial.

Weed management

Weed management strategies and practices are diverse and include mechanical tools, grazing animals, mulches and physical barriers, spray applications, and thermal treatments. Mechanical tools for weeding range from hand-held implements, such as hoes, to motorized technologies, such as battery-powered weed wackers, or cultivators pulled behind tractors. The choice of technology for weeding is dependent on many factors such as spacing of crop plants, perennial versus annual crops, field layout and preparation methods, irrigation infrastructure, stage of plant growth, and degree of crop diversity in addition to the scale of planted areas, and the costs of equipment, inputs, and labor for weed management.

For the purposes of this review, the technologies are divided into categories by how they control weeds: 1) mechanical tools, 2) mulches and physical barriers, and 3) treatments or applications. The first category includes mechanical methods: hand tools such as hoes and human-powered implements such as walk-behind cultivators, battery powered tools and attachments for motorized walk-behind tractors such as a BCS, tractor-pulled implements such as cultivators, and grazers. The second category includes various kinds of physical barriers, such as plastic mulches, biodegradable plastic mulches, and plant material mulches and tools that install them. The third category includes herbicide spray applicators and thermal weeding tools. For each of the tools profiled for weed management, the type of crop-system that it is useful for has been added to the description in the tables.

Mechanical tools and methods

The tools in this section range from simple human-powered, hand-held tools to battery powered, fossil fuel powered, walk-behind or ride-on tractors with attachments, as well as things in between. Also included in this section are grazing animals, since they physically remove weeds as they graze.

Technology	**Stirrup hoe, Off-set wire hoe, Collinear hoe, Garden hoe**
Crop-system	Market garden, small scale row crops
Cost	$20.00 to $120.00 depending on style, handle, and width of blade
Availability	Widely available at hardware and home improvement stores or online from garden supply stores
Requirements	Stamina and coordination for repetitive action with tool
Advantages	simple design is human-powered, precise, low cost, no additional inputs, many different implements available for specific tasks, crops, or crop/weed stage
Disadvantages	Physically demanding, labor intensive

Technology	**Weed wacker with tilther or other attachments (gas engine or battery powered)**
Crop-system	Market garden, small scale row crops, small scale orchards

Cost	~$150 for battery or gas engine string trimmer base tool, additional attachments vary ~$100.00 - $200.00
Availability	Widely available at hardware and home improvement stores or online from garden supply stores (power tool brands such as Ryobi, Dewalt, and others). Many universal attachments are available to fit most brands of power tools
Requirements	Stamina and coordination for repetitive action with hand-held tool, gas if gas powered, charging capabilities for battery powered
Advantages	Saves labor, lightweight, battery option creates no exhaust pollution for users (unlike gas engine tools), multi-use since there are many attachments for weed management or other farm applications such as a baby greens harvester or pole saws for pruning using the same base motor system
Disadvantages	Battery power requires frequent charging and/or back-up batteries Batteries wear out and are not cheap to replace Gas engine requires fuel and more maintenance such as oil,

Technology	**Double wheeled hoe with attachments**
Crop-system	Market garden, small scale row crops
Cost	$500.00 for the walk behind implement, ~$200.00 to $500.00 for finger weeders, BioDisc, or other attachments
Availability	Online from Johnny's Selected Seeds and other online retailers focused on small scale vegetable production. Not available for purchase locally.*
Requirements	Ability to push implement and use basic tools for attachments, for use in rows to cultivate around seedlings/plants
Advantages	simple mechanical design is human-powered and easy to fix and understand, relatively low cost, no additional inputs such as power, spray, labor saving over hand-held weeding tools, many available implements for different tasks
Disadvantages	not locally available, somewhat demanding physical work, only works for row crops while plants are small

*However, this tool is available at a publicly funded lending library in Sacramento county, and other kinds of tools maybe available through farmer run tool-shares such as the Plowshare Alliance (which is based on California's Central Coast but transports specialty small scale equipment all over the state, or through individual larger farms such as one in Yolo county that can transport harvest equipment long distances.

Technology	**BCS with cultivator, rotary plow, flail mower, or other attachments**
Crop-system	Market garden, small scale row crops, small orchards
Cost	~$3000.00 for the BCS tractor, V-cultivator attachment ~$500.00, price varies on other implements
Availability	available at several local stores and local BCS dealer delivers parts and accessories
Requirements	Gasoline for engine, use of basic tools to adjust spacing or change implements
Advantages	Local availability and repairs, labor-saving compared to human powered tools, right-scale for many small farms with many available attachments to BCS tractor, sometimes available used at more affordable prices
Disadvantages	can be expensive to repair, may be too small for farms over 2-3 acres, requires walking over uneven ground which can be laborious when preparing an acre or more at once

Technology	**In-row weeders - Flex-tine cultivator for blind cultivation** (such as the Lely Weeder, Tilmore), **finger weeder, and torsion weeder**, each designed to be pulled behind a four wheeled tractor
Crop-system	small scale row crops
Cost	$2,000.00 to $3,000.00 depending on width and new/used condition
Availability	Locally available at agricultural and landscape equipment dealers

Requirements	Four wheeled tractor with PTO for lifting/pulling the weeder, fuel. Leveled and straight rows. Space to turn around.
Advantages	Fast, labor saving, can cover large areas quickly.
Disadvantages	Timing sensitive–blind cultivation is most effective before planting and when weeds are at the white thread stage but crops are slightly bigger. Some crop damage is normal. Requires repeated cultivation to control weeds

Technology	**Grazers (sheep, goats, cattle, poultry, swine)**
Crop-system	Orchards, vineyards, field crops (between harvest and planting)
Cost	Contract grazing cost varies widely (from $0 to several thousand dollars per acre) depending on circumstances, quality of forage, level of infrastructure provided by contract grazer. Cost of maintaining on-farm animals depends upon many factors and capacity to house and feed animals year-round and is not realistic for most small farms in this region
Availability	Contract grazing for small acreage is not widely available, though it is increasing. Keeping on farm animals introduces infrastructure complexities
Requirements	Contract grazer and/or fencing, predation protection, water, suitable forage, livestock, protection for trees or vines and irrigation infrastructure
Advantages	Fast, labor saving, can cover large areas quickly, animals add fertility to the soil while clearing unwanted vegetation.
Disadvantages	Some crop or infrastructure damage possible, complications of adding livestock operation to farm, with contract grazing timing of grazing is not fully in control of farmer, timing constraints related to harvest and food safety regulations

Physical barriers and mulches and mulch layers

Physical barriers and mulches include conventional polyethylene (PE) plastic mulches, soil-biodegradable mulches (BDMs), and wood chip or other plant residue mulches. The tools used for mulch installation range from carts and buckets to spreaders for residue type mulches. For plastic and other manufactured barriers, specialized barrier film laying implements that also sometimes simultaneously form beds, lay irrigation drip tape, or plant seeds are available. The different mulches and tools used to install them in the field are profiled below, along with the plastic mulch retrieval tools available.

Technology	**BCS plastic mulch layer attachment**
Crop-system	small scale row crops, market garden
Cost	$1250.00
Availability	Locally available through BCS dealers
Requirements	BCS tractor 749 or higher capacity with quick hitch attachment, well-worked dry soil and pre-formed, flat beds of standard width and height of no more than 3 inches (which can be formed with a BCS bedformer attachment or other bedformer)
Advantages	Labor saving, can combine with drip irrigation installing attachment to further reduce labor or passes with the tractor, plastic mulch controls weeds while keeping moisture near the surface for crop plants to access
Disadvantages	Adjustments need to be made based on specific soil conditions and bed dimensions, tension may need to be adjusted for PE films versus BDMs, accidental contamination of soils or crops with microplastics is likely

Technology	**Manual mulch layer (various brands)**
Crop-system	small scale row crops, market garden
Cost	$1290.00
Availability	Available online through Dubois Ag, Johnny's Select Seeds

Requirements	Requires two people to pull
Advantages	can combine with multiple lines of drip irrigation installation to reduce labor, fits easily inside high tunnels or small spaces, plastic mulch controls weeds while keeping moisture near the surface for crop plants to access
Disadvantages	Adjustments need to be made based on specific soil conditions and bed dimensions, tension may need to be adjusted for PE films versus BDMs, accidental contamination of soils or crops with microplastics is likely

Technology	**Terrateck brush hoeing machine for weeding edges of plastic mulch (pull-behind attachment for tractor)**
Crop-system	row crops, market garden
Cost	~
Availability	Terrateck website, suppliers online
Requirements	four wheeled tractor with hydraulic lift, second operator to steer hoeing machine, mulched raised beds
Advantages	Works with all kinds of mulch films, reduces labor, reduces passes with the tractor
Disadvantages	Adjustments need to be made based on bed dimensions and shape, second operator on implement

Technology	**Bed former, plastic mulch and drip tape layer attachment for tractor**
Crop-system	row crops, market garden
Cost	~ $3,000.00 - $6,000.00 depending on brand, size, etc.
Availability	Through online farm equipment dealers, several brands/manufacturers
Requirements	A four wheeled tractor, well-prepared soil, plastic mulch roll or weed cloth

Advantages	Works with all kinds of mulch films, reduces labor, reduces passes with the tractor since bed forming, mulch and drip laying can be done in one pass, some are small enough to fit inside high tunnels. Plastic mulch controls weeds while keeping moisture near the surface for crop plants to access
Disadvantages	Adjustments need to be made based on specific soil conditions and bed dimensions, tension may need to be adjusted for PE films versus BDMs, accidental contamination of soils or crops with microplastics is likely

Spray and thermal applications

Several sizes and configurations of thermal weeders are available in the market. Most use propane flames, although laser weeders are also available. In the profiles here, the back-pack torch style, walk behind, and pulled behind tractor versions are described. Flame weeders have the advantage of saving labor over hand weeding and of not using chemical herbicides. However, they all use some kind of fuel for the flame which involves fumes as well as smoke from burning the vegetation.

Technology	**Thermal flame weeder backpack with torch/wand**
Crop-system	small scale row crops, market garden
Cost	~$350.00 depending on accessories
Availability	Available online through retailers such as Neversink Tools and Johnny's Select Seeds
Requirements	ability to carry propane fuel canister on back, propane tank
Advantages	Kills weeds without herbicides or physical implements, complies with organic certification, works best for small weeds, easy to maneuver in small beds such as hoop houses or green houses
Disadvantages	If used on heavy, green growth it creates a lot of smoke which is harmful to the operator's lungs/eyes. Use of propane (fossil) fuel

Technology	Thermal weeder, walk behind
Crop-system	small scale row crops, market garden
Cost	~$250.00 - $1,200.00 depending on size, configuration, brand
Availability	Available online through retailers such as Neversink Tools and Johnny's Select Seeds
Requirements	Propane fuel canister, ability to push/pull weeder
Advantages	Kills weeds without chemicals or physical implements, complies with organic certification, works best for small weeds, easy to maneuver in small beds such as hoop houses or green houses
Disadvantages	If used on heavy, green growth it creates a lot of smoke which is harmful to the operator's lungs/eyes. Use of propane (fossil) fuel

Many other methods of weed control are available and may be appropriate for different cropping systems or stages of weed/crop development. Herbicidal sprays, basket and finger weeders, various harrows, flail mowers and more are available. In addition to these, for orchards and vineyards, grazing animals can be used to remove vegetation.
While perhaps the primary purpose of mulching is to control weeds, they also function to improve soil moisture retention and protect the soil from wind erosion. When tools that simultaneously lay mulch and lay irrigation tape or plant seed are used, there is the potential for significant labor savings. On the other hand, the plastic waste associated with PE mulch, or the microplastics in the soil from either PE or BDM are significant negatives associated with mulch films. Equipment for removing and recycling plastics from farms is an area where more innovation is needed.

Irrigation

In this region, essentially all crops require irrigation since rainfall is below 20 inches annually which is the minimum needed to practice rainfed agriculture. The infrastructure needed for different types of crops varies, but most small farms will use some form of drip irrigation. Depending on the source of the water (pumped from a well, piped from an irrigation district, or accessed from a ditch) a few different pieces of equipment may be required to get the water to the field. These often include booster pumps, filters, valves, pressure regulators, flow meters,

pipe and pipe fittings, and sometimes a water storage tank. While all of these are important, the profiles below will focus on tools that help bring water from the source to the plants efficiently.

Drip irrigation

Drip irrigation involves a lot of plastic parts, some of which can be relatively easily reused and some not. The materials and tools needed to install a drip irrigation system can be bought at irrigation suppliers throughout the region, and those suppliers also work with farmers to design the system. However, these suppliers are primarily set up to service very large farms, so present some challenges to the small scale farmer. However, these stores tend to be focused on large scale crops in the region or alternatively, on home gardens, lawns or landscaping. Some particular parts can be difficult to source locally (specialized emitters and connectors). Online sourcing can be difficult because the parts cannot be compared with the existing system for fit and often involve large minimum orders or expensive shipping costs.
First, they are not set up as stores that one can walk into and buy a few things. They often have no way to accept cash and require setting up an account in order to bill. Additionally, they are warehouses where many parts aren't within reach to look at, and many have to be ordered from another location. This means that if something breaks, a farmer cannot simply buy a replacement right away. For this reason, many small farms purchase drip irrigation pieces from home improvement or garden supply stores instead. These stores are easier to access but often have more limited options. For irrigation, which is the lifeblood of the crop plants, having security in immediate access to the right supplies is essential in order to avoid devastating crop losses.

Technology	**Perforated drip line, perforated drip tape, drip line with emitters, sub-surface or surface options**
Crop-system	
Cost	ranges depending on options chosen and size of irrigated area but is approximately $400 to $1000 per acre.
Availability	Many drip irrigation components are available from local irrigation companies or garden stores and also from online retailers.
Requirements	
Advantages	Highly customizable. Labor reduction once installed. Can (usually) be reused.

Disadvantages	Can get in the way of weed control, field preparation, planting and therefore often need to be removed seasonally. Relatively fragile plastic parts can be damaged by removal/installation, pests, equipment, sun. Creates a lot of plastic trash when no longer usable (usually within X-five years (?) depending on model). Often the valves and connections between lines or lines and emitters are designed to be single-use. Trying to reuse these often results in leaks or clogs. All of these challenges present opportunities for improvement or innovation.

Soil moisture sensors and irrigation automation

Soil moisture sensors have been available commercially for over 70 years. However, they are now easily networked using cellular networks. Most of these run on batteries and some require no power at all. Some have solar panels.

Technology	**Soil moisture sensor (remote sensing, networked, or not) Irrometer or Dynamax, for example.**
Crop-system	
Cost	ranges widely from ~ $50.00 to $2000.00 depending on how many sensors/accessories needed, level of networking.
Availability	Some models available at home improvement or garden stores, more professional models available online and through local irrigation suppliers/dealers.
Requirements	some training involved in knowing where to place and how to read different models, how to track and analyze data, irrigation supply dealers may offer system planning or installation services.
Advantages	allows for remote sensing and can be networked to automate and optimize irrigation from offsite. Helps to ensure efficient use of water and that plants have appropriately moist soil.
Disadvantages	Disadvantages: Can be expensive if many sensors are needed because of variable field conditions (soil type, slope, etc.) or more time is required to use same sensors across multiple beds over multiple seasons. Often

	not more informative than looking at plants/feeling the soil, which is something small scale farmers are usually doing on a daily basis. Networking and real time data option may not work for all locations due to connectivity limitations (but there are options that store data and allow occasional retrieval.)

Technology	**irrigation management software such as Hortau or IoT devices**
Crop-system	
Cost	Hortau complete services and app ~$20/acre, annually (more initially and less after a few years of service). IoT varies, but a smart watering timer by Hub Space is about $70 (one time purchase) and the accompanying app is free.
Availability	Hortau complete irrigation management system and support is available through their advisors, however, the initial cost may be much higher than stated for very small farms. IoT devices are available at local garden supply stores.
Requirements	Use of the Hortau app requires WiFi, smart phone, computer, and some basic computer and data literacy. IoT requires that the smart watering timer is connected to WiFi, as well as a smart phone and ability to DIY the networking of the devices.
Advantages	Remote control of irrigation. Hortau also incorporates sensors, does well testing
Disadvantages	Requires WiFi or cellular service and therefore may not be available for all farm locations/farmers. Data privacy may not be protected, particularly with IoT.

Seeding/planting

Seeding and planting are some of the most labor intensive aspects of farming, and the timing of planting is often challenging since germination depends on soil temperature and moisture and seedling crops are susceptible to damage from extreme weather. As such, efficiencies gained around planting, whether direct seeding, seeding in trays, or transplanting seedlings into the ground can allow a farmer to scale up or have a more successful planting. In this section three

different types of planters/seeders are profiled. These are each appropriate for different crops or types of operations, though some small farms might find them all useful.

Walk behind seeder

A human powered push-seeder is useful in the diversified small farm when direct seeding into prepared soil, up to about two acres at a time. The Jang Seeder and Earthway seeder are two relatively available options.

Technology	**Push-seeder such as the Jang or Earthway, uses rotating plates or wheels and a small shoe or coulter to open the seed bed to insert the seeds at the called-for depth, while a closing mechanism such as a drag chain or tamping wheel covers the seed with soil.**
Crop-system	
Cost	Earthway 1001B ~ $150.00. Jang single row ~ $500.00 up to $2200.00 for a six row version.
Availability	Earthway and Jang seeders available from market garden retailers online such as Johnny's Selected Seeds or Neversink Tools. Earthway available for in store pick up at local Home Depot. Jang, Earthway and others available through regional, though not local, dealers such as Sutton Ag Enterprises.
Requirements	Ability to push the tool over soil, use of basic hand tools to adjust for proper seed depth and to change seed planting wheels and set spacing.
Advantages	Relatively low-cost, can plant many different types of seeds, requires no electricity or fuel to operate, simple mechanical parts are easy to adjust, significantly easier and faster than hand seeding, no need for extra turn-around space at the ends of rows.
Disadvantages	Requires walking and pushing, can be difficult to manage over bumpy soil, cannot plant into hard soil or soil with heavy mulch.

Transplanter

Transplanters for planting seedlings into the field come in many different sizes and can be human-powered, motorized as walk-behind tractors, or pulled behind four wheeled tractors with another operator feeding the seedlings from trays into the coulters.

Technology	**tractor mounted transplanter (such as Checchi & Magli Dual 12 Gold Transplanter)**
Crop-system	
Cost	~$10,000.00
Availability	Regionally available at agricultural equipment dealers, especially those in the industrial scale vegetable growing areas of California such as Sutton Ag.
Requirements	A four-wheeled tractor with PTO and three point hitch. Two people to operate: one for the tractor, one for the transplanter.
Advantages	Labor-saving. Allows for larger scale planting. Estimated 6000 plants per hour. Adjustable for close or wide spacing.
Disadvantages	Expensive. Requires a tractor and minimum of two operators. Is too large-scale for some small farms.

No till seed drill

A no till drill allows seed such as cover crop seed to be planted into untilled, previous crop residue or heavily mulched soil. This has soil health and fertility benefits and requires less labor or passes with the tractor to plant cover crop.

Technology	**No till seed drill such as Tar River Saya drills.**
Crop-system	
Cost	~$7,000.00

Availability	Not local. Closest dealers are out of state. Maybe available in tool lending libraries or tool sharing networks more locally.
Requirements	Four wheeled tractor with three point hitch and PTO.
Advantages	Allows planting of cover crop or grains without tilling. Preserves soil structure, microbiology, maintains soil moisture.
Disadvantages	Expensive. Not locally available.

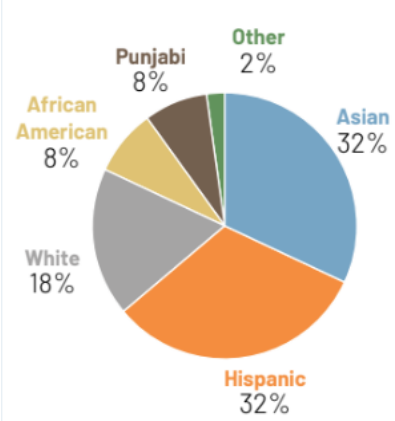
Farmer Input

Several kinds of input from local small scale farmers have contributed to this landscape review and will be used for a Small Farms Technology Needs Assessment report. The farmers who have contributed their input have done so through formal and informal interviews, listening sessions, surveys, and Tech Expo feedback sessions. In addition, several small farms technical assistance providers were interviewed for the report.

Farmer demographics

During the Small Farms Tech Expo on November 8, 2023 in the Kearney Agricultural Research and Extension Center in Parlier, Ca, over 50 farmers filled out surveys about what kinds of equipment they are interested in and what their main challenges are. The field demonstrations and farmer listening sessions were held in four languages, English, Spanish, Hmong, and Punjabi in order to reach as many small farmers as possible in the region. Demographic info: The average age of the farmers is 52, with an average of 13 years of experience. Of the total sample, 37% were women, and 63% were men. The ethnic composition of the sample is 32% Asian, 32% Hispanic, 18% White, 8% Black, 8% Punjabi and 2% others. The average size of the farms is 28 acres, ranging from 0.5 to 300 acres. The main crops of the farmers were vegetables, prunus, and berries. Farmers who attended the expo are from 22 counties along the Central Valley and Central Coast.

The following chart shows the ethnic identity of participants:



Overview of data on technology adoption

Sources of data for this study include surveys, listening sessions, and interviews from Small Farms Tech Expos in 2023 and 2024, farmer listening sessions, and interviews with small farms technical assistance providers.

Surveys from Tech Expo participants: 52 survey responses from Nov. 2023, and 22 survey responses from March 2024. The surveys focused on motivations and challenges for using new equipment, and use of, or barriers to using digital technologies for farm management.

Listening sessions at Tech Expos: At the Nov. 2023 Expo, four groups of farmers (in the four languages mentioned above) were asked discussions about what technologies they would like to test or use on their farms, what tools should be available in an equipment lending library, adapting new or existing technologies to their needs, and what production challenges they would like to use tools to address.

Rise and Restore Listening Session with Central Valley farmers: Spanish language listening session with small scale farmers.

Small Farms TA providers: In-depth open ended interviews with seven UCANR Fresno Small Farms Team technical assistance providers on the topic of technology needs and challenges for small farms in the area.

Themes from farmer input on technology

Several themes emerged through the surveys, interviews, and listening sessions.

1) Motivations for adopting new technologies are reducing labor, increasing yields or crop quality, efficient use of resources, and making heavy tasks easier (on the body) and administrative tasks easier (on the mind).
2) The primary considerations of farmers before trying new technologies are price, cost to operate, and function; in other words, a cost-benefit analysis.
3) The tasks that farmers most often look for equipment or technology to help with are planting/seeding, weed control, irrigation, and cold storage.
4) The barriers to adopting new tools are primarily a lack of knowledge and cost.

Identified technology needs

During listening sessions and through surveys, several types of equipment were identified as needs. These included planters/seeders, weed control, cold storage, irrigation infrastructure and management, tillers, bed formers and plastic mulch layers, compost spreaders, sprayers, mulchers/flail mowers, harvesters, and of course tractors. However, both the price of such

equipment and the training for using it were mentioned as significant barriers to adopting these tools, both digital and mechanical. One way that both cost and training can be addressed is through publicly funded tool lending libraries and on-farm demonstrations of technology. The Kearney Agricultural Research and Extension Center in Parlier, Ca is currently launching such a tool library. The preliminary list of tools that will be available for farmers to borrow or try out (free of charge) is as follows:

a. Compost spreader - Orchards
b. Compost spreader - Beds
c. Front loader
d. Bed maker
e. Flail shredder
f. Seeders
g. Dump trailers
h. Transplanter
i. Sprayers - Crop
j. Sprayers - Orchard Weeder
k. BCS two-wheel tractor
l. BCS attachments
    i. Rollerblade flail mower
    ii. Plastic mulch layer
    iii. Bed shaper
    iv. Pressure washer

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