

CHALLENGES AND OPPORTUNITIES FOR IRRIGATION MANAGEMENT TECHNOLOGY IN CALIFORNIAN SMALL FARMS

DEFIS ET OPPORTUNITES LIES AUX TECHNOLOGIES DE GESTION DE L'IRRIGATION POUR LES PETITES EXPLOITATIONS AGRICOLES CALIFORNIENNES

G. Ingersoll^{1,2}, M. Fairbairn^{2,3}, C. Leauthaud^{1,2,3}

ABSTRACT

This study investigates the extent to which the irrigation needs of small farmers are met by currently available technology by examining irrigation sensing and management technology extension efforts in California's central coast. This was accomplished through open-ended interviews with small farmers, extension professionals and technology developers from the public and private sectors. These data were then subjected to a coding analysis informed by a theoretical framework of critical agricultural technology literature focusing on digital agriculture and sensing technology. The study begins with an examination of the methodologies and goals of precision irrigation and the critical perspective of critical agricultural studies. Next, the technologies utilized by extension professionals are described and analyzed. These are then contrasted to the ways in which small farmers practice irrigation and utilize technology. Finally, the possible reasons for limited success in technology extension efforts are discussed. These findings suggest that currently available sensing and management technologies have limited applications in small farmer systems due to the marginal status of most small farmer systems, as well as the political economic context in which technological development and extension takes place. However, these findings are limited by the size and scope of the data currently collected and thus is a preliminary analysis.

Keywords: irrigation management technology; small farmers; private sectors; political economic context.

RESUME

Cette étude examine la mesure dans laquelle les besoins en irrigation des petits exploitants sont satisfaits par les technologies actuellement disponibles, en examinant les efforts de vulgarisation des technologies de détection et de gestion de l'irrigation sur la côte centrale de la Californie. Ce travail s'est appuyé sur des entretiens ouverts menés auprès de petits exploitants, des professionnels de la vulgarisation et des développeurs de technologies des secteurs public et privé. Les données recueillies ont ensuite été soumises à une analyse de codage fondée sur un cadre théorique issu de la littérature critique sur la technologie agricole, axée sur l'agriculture numérique et les technologies de détection.

L'étude commence par un examen des méthodologies et des objectifs de l'irrigation de précision et la perspective critique des études agricoles critiques. Ensuite, les technologies utilisées par les professionnels de la vulgarisation sont décrites et analysées. Celles-ci sont ensuite contrastées avec la façon dont les petits exploitants pratiquent l'irrigation et utilisent la technologie. Enfin, les raisons possibles du succès limité des efforts de vulgarisation des technologies sont discutées. Ces résultats proposent que les technologies de détection et de gestion actuellement disponibles ont moindre

1 University of California, Center for Agroecology, Santa Cruz, United States

2 University of California Agriculture and Natural Resources (ANR), Davis, United States

3 University of California, Santa Cruz, Environmental Studies Department, Santa Cruz, United States Corresponding author : G. Ingersoll, UC Santa Cruz, Department of Environmental Studies, 1156 High Street, Santa Cruz, CA 95064, USA. e-mail: gringers@ucanr.edu

application dans les systèmes de petits exploitants en raison du statut marginal de la plupart des systèmes de petits exploitants, ainsi que du contexte politique et économique dans lequel se déroulent le développement et la vulgarisation des technologies. Cependant, ces conclusions sont limitées par l'ampleur et la portée des données actuellement recueillies et constituent donc une analyse préliminaire.

Mots-clés : Technologies de gestion de l'irrigation; Petits exploitants; Secteur privé; Contexte politico-économique.

INTRODUCTION

California agriculture is adapting to increased precarity of its water resources. Politically, the state has attempted to stabilize the future of its water through strict regulatory mechanisms such as the Sustainable Groundwater Management Act (SGMA) and Irrigated Lands Regulatory Program (ILRP). Furthermore, increasing water prices across the state mean farmers must manage their water resources more efficiently in order to maintain their profit margins. While these natural, political and economic factors present challenges for all of Californian agriculture, the future of small farmers – defined by the University of California's extension arm as those whose "needs for research and extension are outside of traditional commodity-based extension programs, such as highly diversified farms...and limited-resource, beginning, and socially disadvantaged farmers" (UC ANR, n.d.) – are particularly at risk because of their marginal status.

Many extension professionals see the adoption of irrigation sensing and management technology – proximate, remote or weather based sensing and information platforms or variable rate irrigation systems – as necessary in order for California's small farmers to increase their irrigation efficiency and remain operational. However, much of this irrigation management technology is not explicitly designed to meet the practices and needs of small farmers, nor is it within their means to acquire.

This study investigates the irrigation practices and challenges of small farmers in California, and the extent to which these align with irrigation sensing and management technology through open-ended interviews with relevant stakeholders in California's central coast. This preliminary analysis suggests that Californian small farmers are largely unable to benefit from the intended applications of these technologies because of their resource limitations and marginal status. Additionally, these findings suggest that the complexity of small farmer systems (e.g., diverse cropping patterns or heterogeneous topography) present an obstacle to a technologically mediated management approach that current devices and extension approaches are unable to surmount.

However, these findings are limited by the quantity and scope of participants interviewed. This study will go on to interview more small farmers and technology developers in order to better examine small farmer irrigation and the political economy of technological development. This critical examination of technology design and extension can reveal how such efforts can better meet the needs of small farmers and explain the limitations of such approaches.

REVIEW OF LITERATURE

Precision irrigation

Precision irrigation (Smith & Baillie, 2009) is an approach to farm scale water management which aims to optimize the efficiency of water and solute inputs by utilizing sensing, environmental modeling and controlled application technology to detect, interpret, and account for spatial and temporal heterogeneity of soil water availability. The precision irrigation approach promises a highly scalable means of improving the economic and environmental sustainability of irrigated agriculture by reducing non-beneficial water use, application related energy use, and environmental degradation associated with 'conventional' irrigation (Sadler et al., 2005, Adeyemi et al., 2017). In recent years, technical advancements in areas such as IoT technology have moved precision irrigation from the realm of theory into practice, enabling the replacement of human perception and labor with data-driven digital management platforms (Tang et al., 2024).

Proponents of precision irrigation position traditional irrigation as unable to make use of the world's increasingly precarious water supplies in a manner efficient enough to provide yields demanded by a growing global population. Precision irrigation scholars suggest that traditional methods of surface must be replaced by pressurized systems such as sprinkler and drip irrigation technology (e.g., Anjum et al., 2023) which allow for the precise application of water and solute inputs (Chauhdary et al. 2023). Furthermore, these scholars see qualitative farmer decision making practices (e.g., timing irrigations based on personal experience) as a source of inefficiency which should be replaced by real-time decision support tools and environmental models (Zhang et al., 2021). Despite this anticipated advantage, researchers note persistent difficulties in realizing adoption of precision irrigation technology (Pothula & Singh, 2022). Advocates of precision irrigation suggest that the technology must be made less expensive, more easily usable and be subsidized by the public sector to overcome farmer's apparent lack of technical knowledge and inability or unwillingness to invest in precision irrigation technology (Su & Singh, 2024).

Political economy of sensing technology

Critical agricultural technology scholars suggest that precision agriculture's means of achieving input efficiency legitimize the political and economic goals of large agribusiness firms and advance the privatization and industrialization of agricultural production (Wolf & Wood, 1997). In recent years, the digitalization (Shepherd et al., 2018) of agriculture and the emergence of Agriculture 4.0 (Rose & Chilvers, 2018) has received attention in this academic space as scholars analyse and anticipate how technology such as IoT influence agricultural production, labor, agrarian life, and political economic power structures (Klerkx et al., 2018).

Scholars in this space question the scientific objectivity of the sensing technology required to realize precision agriculture's promises of sustainable efficiency and suggest that these devices reproduce the power structures in which they are embedded (e.g., Alvarez and Gleason, 2017). Liu and Sengers (2021) utilize Scott's (1998) concept of legibility to examine digital agriculture's ways of knowing as a simplification of the agroecosystem which primarily serves to enable extraction. Heimstädt's (2023) examination of a plant pathology detection software found that the elimination of site-specific complexity and context required in order for the service to function had the effect of prioritizing pesticide recommendations over alternative management methods. These scholars suggest that because technologically driven management operates through a simplification of the sensed environment, their applications tend to provide the most value to the input-focused and consolidated management approach of conventional agriculture.

METHODS

To examine the outcomes of sensing and management technology extension in California small farms, semi-structured interviews were conducted with small farmers, extensionists, and technology developers whose work involves small farmer irrigation. Between February and May of 2026 fourteen participants were interviewed: two small farmers, two technology developers and twelve extension professionals. The majority of individuals interviewed operate in California's central coast with the exception of one advisor located in San Diego county and one private-sector developer who works internationally. Interviews were coded iteratively. Open coding was first used to identify primary descriptive codes and explore thematic associations. Then, focused coding was used based on thematic and analytical associations.

These findings are limited by the number of individuals interviewed, particularly the number of small farmers. As such, this study is a preliminary analysis. More small farmers and technology developers will be interviewed. Additionally, more individuals of all affiliations from regions other than the central coast will be interviewed in order to examine how these factors differ across California's many regions.

RESULTS AND DISCUSSION

Description of technology

The majority of technology extended by the public and private sector mentioned in our interviews (Table 1) are sensing devices that are intended to monitor some feature relevant to soil moisture or water potential. Most of these quantitative sensors collect data in a way which is intended to be uploaded to a remote or local server, from which it can be viewed or integrated into higher order decision making tools. The exception to this is soil probes, which extensionists described as a tool they use to introduce farmers to the concept of qualitatively assessing soil moisture at depth or to collect samples for laboratory assessment.

Table 1. Irrigation sensing and management technology extended in the central coast of California

Device	Category	Function	Method of extension
Soil probe	Sensor	Obtain soil samples at one or more depths	Providing to farmer, teaching how to use
Flow meter	Sensor	Quantify water use from water source, data source for management platforms	Subsidizing purchase
Variable frequency drive	Application controller	Controls rate of well pumping	Subsidizing purchase
Capacitive sensor	Sensor	Quantify volumetric soil water content, data source for management platforms	Developing low cost open source device, subsidizing purchase
Tensiometer	Sensor	Quantify soil water potential, data source for management platforms	Developing low cost open source device, subsidizing purchase
Data logger	Data utility	Transmit data from sensing devices	Subsidizing purchase
Weather data	Sensor	Estimate crop evapotranspiration, data source for management platforms	Developing models for specialty crops
Integrated systems	Other	Platforms or devices which utilize multiple data streams to provide irrigation recommendations or allow for remote operation or automation	Developing system

None of the technologies mentioned by our interview subjects are explicitly designed for use in small farmer systems or to address small-farmer-specific challenges. Instead, extensionists mentioned that some of the technology they utilize in their work with farmers happen to have applications in small farmer systems (Table 2). Therefore, their technology extension efforts with small farmers consists of minimizing obstacles to adoption using grant funded subsidy programs, leveraging the coincidental applications and providing long term support services.

Table 2. Obstacles and applications of technology mentioned by extensionists and small farmers

Name of Device	Obstacles to small farmers	Small farm applications
Soil probe	Finding time to take measurements	Accessible means of assessing soil moisture
Flow meter	Expensive, devices with more features are more difficult to use	Quantifies system performance, assists with regulatory requirements reporting
Variable rate drive	Expensive, difficult to operate	In shared parcels, allows constant pressure despite distance from water source
Soil moisture sensor	Expensive, difficult to calibrate and operate, most must be moved during tractor work	No small farm specific application mentioned
Tensiometers	Requires labor to maintain, must be moved during tractor work	Considered more approachable to small farmers than digital sensors
Data loggers	Expensive, requires power and network connectivity, complicated to use	Allows remote access to information for busy farmers
Weather data	Complicated, cannot be used in some systems (e.g., greenhouses), specialty crops are not modeled	No small farm specific application mentioned
Integrated systems	Complicated, expensive, difficult to use in diverse plantings	Reduces labor, allows remote irrigation management

Technology enables rational irrigation

Interviews suggested that most extensionists utilize these technologies in order to improve the efficiency of irrigation by replacing subjective information sources (e.g., embodied senses, personal experience) with quantitative data. Many extensionists shared that irrigation decisions should exclusively be based upon soil moisture, as exemplified in the following quote: "...the amount of water you need to replace is directly related to the amount of water that the crop is losing, which is indicated by the evapotranspiration loss. The timing on when you might need an irrigation is because the soil is running dry. That's where the soil moisture sensors help". This approach can be understood as an act of simplification. The scientific model of soil, plant, and water relations reduces the relevant sources of information from which to make an irrigation decision to a single physical feature.

Furthermore, many extensionists expressed a belief that soil moisture can only be properly assessed with sensing technology. One extensionist asserted that assessments of soil moisture through touch or sight are "not accurate and could fool you sometimes. The lighting, it could be cold in the morning... that works at least to know that there's soil there. But how much do you really need to water? Because every soil is different". For this professional, the empirical reality of soil moisture is inscrutable to the senses. Variables such as temperature, light environment and soil composition confound an accurate reading of soil moisture. This participant went on to state that "unless you're a robot it's really hard to stick your finger in the soil and know exactly how much water your soil is holding in terms of... [water potential] or [volumetric water content] ...". This extensionist characterizes sensory experience as an unavoidable source of error and therefore an obstacle to rational irrigation management. While neither the human nor the sensor 'know' soil moisture, to this extensionist, the technological process of inference is more reliable (and useful) than the human process of inference.

Many extensionists stated that this quantitative assessment of soil moisture enables a particular method of irrigation management which aims to maximize beneficial water use. An extensionist described the role of soil moisture sensors for irrigation as being able to address the question of “how do you put water on the field without it getting past the roots? And how do you keep enough water on the roots, where they're happy? How are you not getting past that permanent wilting point?”. Such sensing devices account for spatial heterogeneity at various scales and therefore enable irrigation scheduling to become a process of ledger balancing. Water is applied in order to maintain soil moisture within the margin of allowable depletion.

Some extensionists shared that they consider the adoption of this approach to irrigation management as essential to the continuance of small farmer systems. As one extensionist shared, “I would categorize smaller growers mostly as being very wasteful... and larger growers, well, they run their farms like an agribusiness, which is exactly how you should run your farm, because it's a business.... [Small growers] just want to grow food, and they seem very disinterested in the business side, which is why they continue to struggle”. This sentiment suggests that the simplification of irrigation management through technology is sometimes connected to a broader simplification of political economy.

This rational approach to irrigation narrows the relevant sources of information from which to make an irrigation decision to a model of soil moisture flows and sinks. This reduction is essential to the deployment of sensing and management technology. The state of these sinks is quantified through sensing devices and therefore rendered understandable to the decision maker. These technologies enable the simplification of the soil medium to remove all uncertainty regarding irrigation scheduling. This scientific rationality is connected to an economic rationality that suggests that small farmers must adopt an agribusiness logic in order to survive.

Small farmer technology use

Our interviews suggest that Californian small farmers currently make limited use of technology. Those that do use technology do so to support a non-rational approach to irrigation. For instance, simple devices such as soil probes allow farmers to see, touch, and otherwise sense soil they would otherwise not be able to access, effectively ‘extending’ their senses. One farmer shared that they use soil probes to “check if water’s going down to the root zone... like most of our row crops are 6 to 12 inches deep so just checking if the soil is wet down there... this is a tool to use if you’re ever wondering if we need to irrigate more”. This farmer considers soil probes to be an effective means of qualitatively assessing the performance of their irrigation practices. They do not wish to quantify soil moisture in relation to water use efficiency, but instead simply want to know whether or not water has reached a certain depth.

Interviewees also shared that small farmers make use of sensing technology to assess features which are difficult to detect sensorily. For instance, one farmer recently began using evapotranspiration data to determine the amount of water they apply with each irrigation set. While this farmer still relied on their senses and expertise to assess the state of their soil moisture, they found it useful to time their irrigation based on this weather data. As they put it quite simply, “the ‘when to water’ is decided by us, doing the practices. The ‘how much to water’ is done with data.”

Farmers and extensionists suggested that farmers engage with technology as a decision support tool which is subordinate to their embodied experience, knowledge and deep place-based knowledge. Another farmer who uses evapotranspiration data to guide their irrigation timings shared that they regularly deviate from the quantity of water recommended by this system based on their perception. They shared that, “if something looks water stressed... I'm not following a specific protocol. I'm making the call to water based off [the ET recommendation] and then adding 30 minutes or maybe even an extra hour because I could tell that these plants need water”. This farmer also deviates from ET recommendations to account for the diversity of their planting scheme, “... something small like spinach or scallions. Maybe there's 30 minutes left for zucchini right next to it, but the scallions and spinach, I could just turn those off because I know they don't need as much water as something as productive as a big old zucchini plant. So yeah, those are my case-to-case. And I tell the people I train they have the freedom to also do the same with an idea or a thought behind why they're doing that.”

In both of these cases, ET data serves as a baseline recommendation which is modified by the expertise of the irrigator. The irrigator utilizes their senses, personal experience and knowledge to not only respond to the situation in a way that is closer to the 'fact-of-the-matter' than weather data, but also to account for complexity that is unknown to the sensing system. In this way, sensing technology is one of many sources of information that these farmers use to guide their practices. These findings suggest that farmers find more value in these subjective information sources than in quantitative data. As another farmer shared, "...a lot of things do happen by feel. Even though we have the [data], we're not making decisions on when to irrigate without actually going in and touching the soil. You're never going to replace that..."

Potential of technology is limited in small farm systems

Regardless of whether or not small farmers are interested in adopting sensing and management technology, most extensionists shared that the intended benefit of the sensing and management technology extended in the central coast cannot be fully realized by small farms. Interviewees attributed this to the fact that small farmer irrigation systems often have poor performance, as well as systemic land tenure insecurity and their inability to devote labor to maintain their systems and these devices.

Many small farmers on the central coast are unable to afford stable land tenure. Extensionists described that this has an indirect effect on the performance of their irrigation system. One interviewee shared that because they must move on a regular basis, some small farmers they work with purchase single use equipment and therefore, "since it becomes a single use irrigation system, then it needs to be cheap.... which [is not] the most efficient, the most uniformly distributing.... And then any improvement that [our team] would implement.... the next year we would go to another ranch of the same grower and those improvements are gone... we would find the money to implement the improvement and then [we] would go back there to do another distributional uniformity measurement and they were back to square one." Lack of land tenure indirectly affects irrigation efficiency by forcing farmers to resort to disposable, poor quality equipment and preventing continuance of knowledge amongst farmers or between farmers and technical advisors.

Additionally, some extensionists shared that these farmers are often priced out of all but the most marginal lands. These parcels are often located on hills and valley edges which cause pressure gradients, decreasing distribution uniformity. Additionally, these sub-prime lands are often equipped with failing irrigation infrastructure which decreases efficiency in the form of decreased pressure and water lost to leaks. This issue is compounded by the lack of knowledge continuance mentioned in the previous quote, leaving farmers unable to understand and repair their irrigation infrastructure.

Lastly, participants shared that most small farmers do not have sufficient labor at their disposal to maintain a rationally managed irrigation system. One technical advisor shared that, for many of the farmers they work with, irrigation is "...almost like an afterthought... small farmers are trying to get a lot done with little resources and so when it comes to irrigation, they just need to get water on plants. They're really often piecing things together, throwing it together, barely thinking... We think so technically about irrigation and efficiency, but that is not where a lot of small farmers are". Similarly, other extensionists shared that some small farmers' irrigation practices are shaped by temporal constraints, such as when farmers find time to water between harvest, deliveries and child care, or in the case of water allocation arrangements between farmers who share a parcel and water source. These findings suggest that the limited resources and labor capacity of small farmers means that their myriad other concerns regularly outcompete rational irrigation's occupation with issues of efficiency. While some of the technology described by participants can help small farmers with these specific issues – as in the case of flow meters which allow farmers who share a parcel to accurately divide their water bill among individual users – they do so in a limited and unintended manner.

Additionally, interviewees suggested that the diverse cropping patterns utilized by some small farmers present a significant obstacle to the adoption of sensing technology and the rational irrigation approach. In considering the outcomes of sensing technology adoption outcomes on the central coast, one extensionist remarked, "...you'll have a one acre farm and every row on that acre is a different plant with

a different water need. And half of those plants aren't even identified in the readily available known crop coefficients, or you have to dig way down for them.... Let me put it this way, it makes a lot more sense to do it on a thousand-acre processing tomato farm in the Central Valley, or almonds or pistachios or any sort of monocrop system that's high dollar and has readily available crop data, it's much easier". Diverse cropping patterns utilized by small farmers present a source of complexity that must be accounted for in the deployment of sensing and management devices. This preliminary analysis suggests that extensionists do not have a ready-made solution to apply to these unconventional systems. Instead, these data suggest that sensor-based irrigation is most effective in a simplified agroecosystem typified by the central valley tree-nut plantation. Therefore, it seems that small farmers can only take full advantage of irrigation sensing and management technology if they mimic this industrial model of production.

CONCLUSION

This preliminary analysis suggests that irrigation sensing and management technology extension efforts are limited in small farmer systems because of a fundamental disconnect between how extensionists and small farmers approach irrigation, as well as the marginal status of many small farmer systems. The 'rationalization' of irrigation enabled by sensing and management technology aligns with the findings of scholars such as Liu and Sengers (2021), which suggest that the development and application of such technology are shaped by political economic forces which prioritize an input intensive and extractive approach to agricultural production. The findings of this study will be deepened through further interviews with small farmers, technology developers from the public and private sector, and stakeholders of all affiliations located across the state of California. These additional data will allow an examination of the political economic forces which influence technological development and extension, as well as how these extension efforts can better support small farmer systems.

REFERENCES

- Adeyemi, O., Grove, I., Peets, S., & Norton, T. (2017). Advanced Monitoring and Management Systems for Improving Sustainability in Precision Irrigation. *Sustainability*, 9(3), 353. <https://doi.org/10.3390/su9030353>
- Alvarez, L. F., & Gleason, C. J. (2017). Production, Property, and the Construction of Remotely Sensed Data. *Annals of the American Association of Geographers*, 107(5), 1075–1089. <https://doi.org/10.1080/24694452.2017.1293498>
- Anjum, M., Cheema, M., Hussain, F., & Wu, R. (2023). Precision irrigation. Elsevier EBooks, 85–101. <https://doi.org/10.1016/b978-0-443-18953-1.00007-6>
- Chauhdary, J.N., Li, H., Jiang, Y., Pan, X., Hussain, Z., Javaid, M., & Rizwan, M. (2023). Advances in Sprinkler Irrigation: A Review in the Context of Precision Irrigation for Crop Production. *Agronomy*, 14(1), 47–47. <https://doi.org/10.3390/agronomy14010047>
- Heimstädt, C. (2023). Making plant pathology algorithmically recognizable. *Agriculture and Human Values*. <https://doi.org/10.1007/s10460-023-10419-5>
- Klerkx, L., Jakku, E., & Labarthe, P. (2019). A Review of Social Science on Digital agriculture, Smart Farming and Agriculture 4.0: New Contributions and a Future Research Agenda. *NJAS - Wageningen Journal of Life Sciences*, 90-91(1), 100315. <https://doi.org/10.1016/j.njas.2019.100315>
- Liu, J., & Sengers, P. (2021). Legibility and the Legacy of Racialized Dispossession in Digital Agriculture. *Proceedings of the ACM on Human-Computer Interaction*, 5(CSCW2), 1–21. <https://doi.org/10.1145/3479867>
- Sadler, E. J., Evans, R. G., Stone, K. C., & Camp, C. R. (2005). Opportunities for conservation with precision irrigation. *Journal of Soil and Water Conservation*, 60(6), 371–379. <https://doi.org/10.1080/00224561.2005.12435829>
- Pothula, S. B., & Singh, A. K. (2022). Precision Irrigation Water Management - Current Status, Scope and Challenges. *Indian Journal of Fertilisers*, 18(4), 372–380. https://www.researchgate.net/publication/360119350_Precision_Irrigation_Water_Management_-_Current_Status_Scope_and_Challenges
- Scott, J. C. (1998). *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*. Yale University Press.

- Shepherd, M., Turner, J. A., Small, B., & Wheeler, D. (2018). Priorities for science to overcome hurdles thwarting the full promise of the “digital agriculture” revolution. *Journal of the Science of Food and Agriculture*, 100(14). <https://doi.org/10.1002/jsfa.9346>
- Smith, R., & Baillie, J. (2009, January). Defining precision irrigation: A new approach to irrigation management. In *Irrigation Australia 2009: Irrigation Australia Irrigation and Drainage Conference: Proceedings*. University of Southern Queensland.
- Su, Q., & Singh, V. P. (2024). Advancing irrigation management: integrating technology and sustainability to address global food security. *Environmental Monitoring and Assessment*, 196(11). <https://doi.org/10.1007/s10661-024-13145-5>
- UC ANR. (n.d.) “Defining Small Farms in California | Small Farms and Specialty Crops in Fresno and Madera Counties.” UC Agriculture and Natural Resources, ucanr.edu/site/small-farms-and-specialty-crops-fresno-and-madera-counties/defining-small-farms-california.