Invasive Pest Monitoring in California: The eDNA Metabarcoding Opportunity*

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Executive Summary

Invasive pests costs hundreds of billions of dollars per year in lost crops, damage to human and animal health, and biodiversity damage globally. The risks invasive pests pose are growing as pest migration is becoming easier. In response, farmers invest in pesticides and pest testing. However, even with these solutions in place, agricultural losses due to invasive pests in California alone cost over $3 billion per year. Moreover, widespread pesticide use has its own human health and biodiversity costs. New technologies that leverage our growing understanding of DNA and Artificial Intelligence have the potential to reduce agricultural losses due to invasive pests while reducing the extent of pesticide use. Given the potentially massive positive externalities these technologies will have on food security, human health, and the environment, additional public support for them may be warranted.

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1 Invasive Pests and California Agriculture

The agricultural industry in California generates $49B in sales annually and contributes at least twice that if indirect and induced revenues are included.[1] This is critical for the state's economy and for US food security as California is the largest state producer of agricultural products in the country.[2] A crucial contributor to the productivity of California's farming is the extent to which it integrates cutting edge science and technology. For example, close to one-third of US AgTech Venture Capital (VC) investment in 2024 ($1.9B of $6.6B) went to California startups[3] In theory, this scientific advancement supported by scientifically informed agrilcultural policy should help the state mitigate costs of invasive pests. However, the most recent evidence demonstrates these pests continue to cost the industry $3B per year or more than 6% of the industry's value.[4]

Invasive pests are organisms that are not native to an area and can proliferate unchallenged as a result and cause environemntal harm. They include insects, bacteria, and viruses.[5] Among the most costly invasive pests in California agriculture are the Mediterranean fruit fly that can critically important California crops, including avocados, tomatoes, and citrus fruit.[6] The silverleaf whitefly first invaded California crops in 1991, including melon, broccoli, and cabbage plants, and has since cost the state's agrilcutural industry half a billion USD.[7]

The government of California has responded to its invasive pest problem in several ways. In addition to border control efforts to prevent invasive pests from entering the state[8], the California Department of Food and Agriculture (CDFA) employs a number of invasive pest management and eradication measures. These include a program that introduces natural enemies of specific invasive pests into the areas pests are destroying agrilcultural products and programs that educate the public and farmers about the potential risks of invasive pests.[9]. The state also has pest-specific programs and policies. For example, citrus greening disease, caused by the Asian citrus psyllid, could generate $2.7B in losses to the California citrus industry over 20 years if not addressed Durborow (2012), leading the state to develop specific interventions for its management. These include legally binding quarantines for affective groves , and pest monitoring programs based on so-called sticky traps and leaf sample testing.[10]

California farmers have invested in invasive pest prevention and management techniques in an approach labeled integrated pest management (IPM). This approach integrates strategies that increase crop resiliency over the long run. These include planting disease-resitent plants, precise irrigation, pest traps, ongoing monitoring, and pesticide use.[11]

Despite policy and industry efforts to address increasing threats from invasive pests, there is no evidence that the damage these pests are having on California's agriculture are declining. With invasive species expected to increase by 36% globally by 2050, new approaches for addressing this threat are needed.

2 A New Approach to Pest Detection

The dominant existing approaches for detecting invasive pests on California farms rely on being able to trap or see pests. For example, the sticky yellow traps used to detect the pests that cause citrus greening disease work by trapping them so that they can be visually assessed for pest abundance and tested for the disease in entomology laboratories[12]. Not only does this method depend on a sufficiently large number of pests on site that at least one lands on a trap[13], accurate evaluation of the sticky trap contents is challenging[14]. Mediterranean fruit flies are similarly monitored with traps (for example, Jackson traps) that are prone to human error and require large samples of the pests to generate accurate measurements.[15]

Limitations with existing invasive pest detection reduce the speed and effectiveness of response efforts. Taking action to eradicate a pest invasion before the population has established itself can reduce the cost of damages by millions or even billions of dollars.[16] Moreover, inaccurate or delayed pest identification increases the use of pesticides[17], imposing direct costs on farmers and substantial human health and environmental costs to society.[18]

Fortunately, applications of newly advanced general-purpose technologies have the potential to revolutionize the detection of invasive pests. In particular, the combination of machine learning and DNA analysis can facilitate early and fast detection of invasive pests. Given California's strengths in both of these technologies, it is positioned to be an industry leader in applying them to agricultural production.

2.1 DNA Metabarcoding for Invasive Pest Detection

DNA Metabarcoding is a process "that identifies multiple species from a mixed sample (bulk DNA or eDNA) based on high-throughput sequencing (HTS) of a specific DNA marker."[19] This approach combines research on genomics with machine learning to identify DNA barcodes (standardized short sequences of DNA) that characterize all known species on earth.[20] The eDNA, or environmental DNA, used for this analysis in agricultural settings can be collected from soil, water, or air.

This approach facilitates the identification of thousands of species with a small number of samples.[21] This eliminates the need for pest-specific traps, increasing the likelihood that new or unexpected invasive pests are detected, and reduces the burden on farmers and monitors to lay out multiple trap types. Moreover, this approach eliminates the need for visual inspections, further reducing monitoring labor demands on farmers and overcoming the need for large pest population densities before detection is possible. Most critically, there is now a wealth of rigorous evidence demonstrating the success of DNA metabarcoding in identifying invasive pests in agricultural settings.[22] In addition early and accurate identification of invasive pests, this approach allows farmers, policy makers, and researchers to better understand ecosystems and biodiversity.

Several startups and established companies in California are beginning to offer eDNA metabarcoding services for agriculture and other industries. For example, Illumina, a large, San Diego-based biotech company, offers an eDNA Metabarcoding service for ecosystem research[23], and Genidaqs, a Sacramento-based SME, offers eDNA Metabarcoding services for aquatic environments.[24] Wild Genomics, an early-stage startup based in San Diego, has developed and begun piloting a method for eDNA Metabarcoding of air samples from farms.[25] As this technology is moving out of research labs and into the market, now is the time to ensure that it has the right policy environment and financial support to achieve its potential in both the quality of the approach firms take to implement it and the breadth of adoption among California farms required for it to reduce agricultural damage from invasive pests.

3 Supporting Dissemination of eDNA Metabarcoding in California Agriculture

As eDNA Metabarcoding technologies become more developed and widely adopted, they will likely be cost-effective for many farmers to adopt with or without regulatory support. Early and accurate detection and detailed information about farm ecosystems will reduce farmer expenses on pesticides and increase revenue by, for example, reducing lost output from invasive pests. However, in the shorter run, as these technologies are maturing in the sector, policies that encourage early adopters may increase the speed at which this scale is reached.[26]

Examples of support governments in California could provide to increase farmer willingness to experiment with eDNA Metabarcoding include:

1. Educational resources that inform farmers about the technology, including the government's scientifically informed perspective on its current and projected effectiveness.

2. Subsidies for farmers who agree to pilot the technology to ensure that high quality commercializing firms can stay afloat during this phase of market development.

3. R&D grants for firms and research institutions to speed up technological development.

4. Forward-looking invasive pest regulatory reviews to consider the point at which eDNA Metabarcoding may displace or complement current government-supported invasive pest monitoring approaches.

5. Collaboration across state departments and agencies involved in ecosystem monitoring and management[27], to take advantage of complementarities in research and funding for eDNA Metabarcoding.

California has an opportunity to be a leader in novel technologies for invasive pest management in agriculture, both because of the importance of its agricultural sector and its strength in science and technology. Achieving this will help farmers reduce their risks and increase their profits, improve food security for the state and country, and reduce negative environmental impacts from pesticides.

Notes

[1] https://www.cdfa.ca.gov/CDFA-History.html

[2] https://business.ca.gov/industries/agriculture-and-ag-tech/

[3] https://agfundernews.com/us-agrifoodtech-funding-up-14-driven-by-investment-in-ai

[4] https://ipm.ucanr.edu/Invasive-and-Exotic-Pests/aboutexotic.html?utm_source=chatgpt.com

[5] https://ag.santaclaracounty.gov/pest-exclusion/what-invasive-pest

[6] https://www.aphis.usda.gov/plant-pests-diseases/medfly

[7] https://cisr.ucr.edu/invasive-species/silverleaf-whitefly

[8] https://www.cdfa.ca.gov/plant/PE/transport_animals_plants.html

[9] https://www.cdfa.ca.gov/plant/ipc/

[10] https://ipm.ucanr.edu/PMG/PESTNOTES/pn74155.htmlsrc=302-www&fr=4370

[11] https://ipm.ucanr.edu/what-is-ipm/#gsc.tab=0

[12] Snyder et al. (2022)

[13] Hall et al. (2010)

[14] Hall (2009)

[15] https://www.cdfa.ca.gov/plant/PDEP/insect_trapping_guide/docs/Insect_Trapping_Guide_web.pdf

[16] Alvarez and Solís (2018)

[17] https://www.epa.gov/safepestcontrol/integrated-pest-management-ipm-principles

[18] Rufo et al. (2024)

[19] Liu et al. (2020)

[20] Kress and Erickson (2008); Kimura et al. (2022)

[21] https://arrellfoodinstitute.ca/wp-content/uploads/2025/06/Hebert-Brief-CARE.pdf

[22] Johnson et al. (2023); Martoni et al. (2023); Valentin et al. (2018)

[23] https://www.illumina.com/techniques/sequencing/dna-sequencing/targeted-resequencing/environmental-dna.html

[24] https://genidaqs.com/

[25] https://wildgenomics.co/

[26] Hall and Khan (2003)

[27] For example, the California Department of Food and Agriculture, the California Department of Fish and Wildlife, and the California Environmental Protection Agency

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