**Certifying Ecological Farming Principles: The Case of Integrated Pest Management**

**Abstract:**

Categorization of farming systems based on their use or non-use of sustainable strategies is a crucial aspect of contemporary agrifood-systems governance, including green food certifications. Ecologically friendly farming systems are often based on adaptive application of principles and tacit knowledge, making their categorization much more difficult. This paper examines how 24 different food eco-certification processes operationalize the concept of “Integrated Pest Management” to classify farms as being worthy or unworthy of certification. Few certification programs covered all eight principles of IPM, and administrative requirements such as planning, record-keeping and education were more common than requirements relating to pest management practices themselves. Major differences are seen between single-commodity regional certifications and all other groups. Regional certifications were far more detailed in their standards, gave system-specific best management practices and monitoring criteria, and gave more focus to grower collective-action problems such as biosecurity and pest resistance management. Other certifications generally focused on creating a “floor” to mitigate the worst excesses; many certifications focused on low-income countries were especially focused on issues such as banning the most harmful pesticides, proper disposal of hazardous waste, and worker safety when handling pesticides. These results demonstrate the difficulty of standardizing the definitions of adaptive strategies in agriculture beyond relatively small communities of farmers.

**Introduction:**

Farmers, scientists, and civil society groups have developed and promoted many new frameworks for improving environmental and social outcomes from agriculture. Some of these strategies are associated with grassroots social movements, such as agroecology and the system of rice intensification (SRI), while others, like Climate-Smart Agriculture and conservation agriculture, are more associated with agribusiness and existing government institutions. Despite their differences, many of these strategies are conceived of as decision-making or design frameworks that can be adapted to a wide range of ecological and social contexts.

Defining these strategies as frameworks or sets of principles, rather than technological packages, presents difficulties for “Boolean” (True or False) classification of farms relative to a strategy. Organizations promoting such strategies face difficulty tracking their adoption and may counter-productively simplify a strategy into the presence or absence of a few well-defined techniques (Giller et al., 2009). Scientific inquiry can become divided between researchers who study a strategy as a “recipe” through controlled trials and those view it as a flexible set of principles to be examined through case studies of implementation on real farms. These divides are particularly large regarding “Holistic Management Planned Grazing” (Briske et al., 2008; Gosnell et al., 2020) and the “System of Rice Intensification” (Glover, 2011; Sheehy et al., 2005).

Ecological and social certification of farming systems require such Boolean classification. Such certifications have become increasingly prominent as part of the “neo-liberal turn” towards non-state governance in the late 20th century (Vogel, 2008). Between 1985 and 2000, most high-income countries developed frameworks for certifying organic agriculture, “Fair Trade” shifted from a set of grassroots relationships to a product label built upon certification and several environmental NGOs launched agriculture and forestry certification schemes. Since that time, numerous other production standards have been developed, whether by corporations seeking to “co-opt” the eco-label trend, NGOs seeking to promote sustainability or producer organizations promoting better practices and product differentiation.

Integrated Pest Management (IPM) is one of the most prominent frameworks for increasing eco-efficiency in agricultural systems. First formulated in 1959 (Stern et al., 1959), IPM is now promoted by a wide array of organizations throughout the world as a means of increasing yields while reducing harms from agrochemical use and ensuring the sustainability of food supplies. Like other ecological farming strategies, IPM is notoriously difficult to define (Bajwa & Kogan, 1996); it is alternately referred to as a “philosophy” (Sappington, 2014), “a way of thinking” (Maupin & Norton, 2010) or a ”decision-support system” (Kogan, 1998). Difficulties in Boolean classification of IPM have frustrated efforts to measure its adoption and impact (Castle & Naranjo, 2009; Ehler, 2006; Maupin & Norton, 2010; Sappington, 2014; Zalucki et al., 2009).

IPM is a concept that is broadly endorsed, but its exact meaning is contested. IPM is thus represented in a wide range of diversity of programs- certifications differ in their geographic scope, from small regions to international, and in their crop scope- from single commodity to any food commodity. Likewise, these programs differ in their origin and intentions, they may come from environmental or development NGOs, university extension services or some combination of the 3. Examining this set of certifications can give insight into the universe of possibilities for certifying and delineating alternative agriculture systems.

**Problems in certification:**

Ecological food certifications enable consumers to choose products that have un-observable characteristics that they favor, without having a personal relationship with the producer. These characteristics may be (believed to be) beneficial to the consumer, such as lower levels of pesticide residues, or conforming to the consumer’s ethical and political values, such as responsible stewardship of the environment or fairness to small farmers and farmworkers.

Alternative food movements developed ecological and social certification of agricultural products as a tactic to strengthen their reach. The Demeter Biodynamic Farming certification was established in 1928 by a German biodynamic producers’ cooperative seeking to market to a substantial community sympathetic to Anthroposophy, the philosophical basis of Biodynamics. In the mid-late 20th regional associations of organic farmers in the U.S. and Europe developed certification standards to verify that products were produced in a manner consistent with organic principles. In the 1980s and 1990s, environmental and solidarity NGOs developed environmental and social standards for farming in low-income countries to sell certified products to consumers sharing their concerns. In all of these cases, certification was at an effort to enlist consumers in a social movement or to allow consumers to support social movements through their purchases.

To many, however, these certifications have not had the intended impacts. Anthropologists have documented perverse impacts from bureaucratic standards, including the fragmentation of traditional communities and exacerbation of local inequality (Bacon, 2010; Getz & Shreck, 2006; Mutersbaugh, 2002). As the scale and reach of organic agriculture has grown, simplified organic standards have encouraged “input substitution” rather than the re-design of farming systems among many new entrants to organic farming (Guthman, 2000; Rosset & Altieri, 1997).

Complexity and adaptation are a central problem for alternative food certifications. Many original certifications were developed to empower small farmers to continue and deepen their existing ecological stewardship through price premia and technical assistance. Certification, however, necessarily limits the actions that a farmer might take. This represents a problem given the widespread belief that organic (and other ecological) farming is not based on a “recipe” (Lyon et al., 2011) but is rather built on contextual and reciprocal relations with a particular local ecology (Bell et al., 2008; Jackson & Berry, 2009). This makes developing rules to sort farms into or out of a particular view of “ecological agriculture” extremely tricky. In the case of organics, this difficulty drove rule-makers to collapse a complex philosophy into a set of record-keeping requirements and prohibited practices and materials (Chapter 3 self-cite).

Sustainable farming certifications attempt to achieve multiple goals and face trade-offs between these goals. Early organic standards were primarily focused on connecting already-existing organic farms with consumers who wanted their goods, providing the farmers with recognition and a price premium, and consumers with products produced in a way that they demanded. Today, organic and other certifications often consciously work to expand their reach in order to increase conversion to sustainable practices and access to their products. This makes increasing the number of certified acres or amount of product sold an important goal of certification programs, creating tensions between realistically achievable and highly stringent standards. Numerous scholars have argued that this tendency has degraded stringency in standards in Organic and Fair Trade (Guthman, 2004; Jaffee, 2012; Jaffee & Howard, 2010). Different standards operating in the same areas adopt different positions regarding this trade-off; in sustainable coffee, Rainforest Alliance and Utz Kapeh have deliberately adopted looser, more-attainable standards, in extend the protect of these standards to as many people and farms as possible (Raynolds et al., 2007).

Using IPM as a basis for certifying more sustainable agriculture poses a difficult problem. IPM’s branding as a decision-making framework and a toolkit make it difficult complicated to implement it as a dichotomous classification. As a decision-making framework, IPM is in-principle applicable in any farming system, no matter how biodiverse or input-intensive. Because the decision-making weighs multiple contextual factors, it may not be possible to determine adherence to IPM simply by looking at management decisions without knowing all factors going into them. Furthermore, as a toolkit of tactics categorizing farms as “IPM Practitioners” could be extremely inclusive, counting farms that utilize any IPM tactics, or extremely narrow, only including those which use a wide range of tactics. In an extreme example of this difficulty, West and Cisse (2014) found that farmers in Quebec who scored lower on their index measuring IPM adoption were *more likely* to self-identify as practicing IPM.

Additionally, IPM’s goals may be difficult to incorporate into a certification, similar to difficulties with other ecological agriculture concepts. IPM generally is conceived of as “optimizing” or “minimizing” the use of pesticides and herbicides, but minimization can take place within very different sets of constraints, and optimization may balance other factors in a variety of ways. This difficulty shows up prominently in the history of organic agriculture and the move towards certification. While organic farmers strove to minimize agrochemical usage, before certification became dominant a substantial minority utilized pesticides, herbicides or synthetic fertilizers in a limited fashion (USDA Study Team on Organic Farming, 1980). Certification of organic agriculture coalesced on banning categories of products rather than attempting to operationalize a more nuanced concept of “minimization.”

IPM is often utilized in certifications because pesticide use is an important element in agricultural sustainability concerns. Concern about personal exposure to pesticides is a primary driver of organic food purchases (Hughner et al., 2007), though also followed by concerns about the environmental and social costs of pesticide use (ibid). Exposure to pesticides is a major occupational risk factor for farm-workers (Tago et al., 2014) and pesticides may contribute to birth defects, infant mortality and cognitive impairments in children of farmworkers or in heavily agricultural communities (Garry et al., 2002; Regidor et al., 2004; Taylor, 2021). Reducing pesticide use thus unites food safety, food quality and environmental and social externality concerns that motivate consumers to seek out eco-labeled products.

IPM is also an appealing framework because standards can be made more inclusive and attainable than the pest management standards for organic or biodynamic farms. The difficulty in managing insects and weeds without chemicals is frequently cited by farmers as a reason for not converting to (Khaledi et al., 2011; Midmore et al., 2001) or discontinuing organic farming (Strochlic & Sierra, 2007). Standards based on IPM therefore hold the potential to capitalize on consumer interest in pesticide reduction while imposing smaller costs on producers, requiring smaller price-premia and achieving wider market reach.

**Methods:**

A set of eco-labels for foods sold in the United States were assembled from the ecolabel index (*Ecolabel Index | Who’s Deciding What’s Green?*, n.d.). Inclusion criteria were: labels must be used (directly or indirectly) in the United States, and that the certification protocol must reference the framework of “Integrated Pest Management” in all, 24 certification programs were identified (Table 1). The certification protocols for these programs were inspected line by line and the criteria related to IPM were coded and categorized. Because some certifications included requirements relating to worker and environmental safety in handling and storage of pesticides under the rubric of IPM, these types of requirements were analyzed for all certifications.

For the purposes of this paper, I define “pests” as all organisms that threaten the health and productivity of crop plants; as such, IPM is used as an umbrella term which incorporates weed, fungus and disease management, some certifications adopted this stance, and for consistency, this was used across all certification.

Criteria were classified as “Requirements”: the applicant fails certification if the criterion is not met, “Improvement”: the applicant does not have to initially meet the criterion to pass, but after several years in the program, it becomes a requirement, and “Scorecard”: The criterion is assigned a certain number of points, and the applicant must achieve a certain number of points in total to pass.

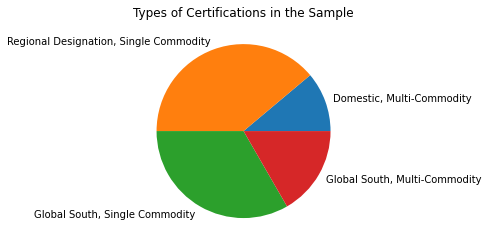
In addition to categories that were developed while coding the sample, criteria were coded based on their relationship to the 8 principles of IPM described by The EU Framework Directive 2009/128/ (OJEC, 2009). This set of principles is similar to those used by many other promoters, and is among the most expansive. The principles are:

1. Prevention and suppression
2. Monitoring
3. Decision-making based on monitoring and thresholds
4. Non-Chemical Methods
5. Pesticide Selection
6. Reduced Pesticide Use
7. Anti-resistance Strategies
8. Evaluation

Criteria could be classified as fitting more than one principle, but criteria were not included if they advanced a principle only through another lower-numbered principle. For example, while prevention and reduced pesticide should also reduce resistance among targeted pests, criteria focused on prevention or reduced pesticide use are not classified as being about “anti-resistance strategies.”

Data cleaning and analysis were conducted in Python 3.8, and all graphics were made in the matplotlib graphics library (Hunter, 2007)

**Sample Description:**

****

The scope of certifications is categorized across two dimensions, geographic and commodity group. Geographically, certifications were either for all areas within the United States, domestic but confined to a particular region, or focused on producers in the global south. In commodity scope, certifications were either for a single commodity/commodity group or for a wide range of commodities. Of the six possible combinations, only 4 were represented, there were no regionally specific multi-commodity standards and no domestic, nationally applicable standards for a single commodity group.

The organizations behind the programs differed- seven of 10 regional-designation certifications were developed by grower organizations in partnership with NGOs and/or Universities, while none of the other certifications had a high degree of grower engagement in their development. Four of the single-commodity global-south certifications were either primarily or jointly developed by businesses which market the final products. The remaining certifications were developed by Environmental and Socially focused NGOs.



Table 1: Certifications included in the Sample.

**Results and Discussion:**

**Certification Structure:**

The criteria used within certifications were coded as being ‘affirmative requirements’, which farms must meet all of to pass, “scorecard criteria” where farms must earn a certain number of points to pass, and ‘improvement criteria’ which are scorecards where the farm’s performance must increase over time. 6 standards were classified as “primarily scorecard” with relation to IPM, 5 were classified as solely requirement-based, and 8 were “mixed” between requirements and scorecards and/or improvement.

**IPM Principles:**

Of the 8 principles of Integrated Pest Management, two, Monitoring and Pesticide Selection, were mentioned in at least one criterion for all certifications (Figure 3). 2 principles, Thresholds and Evaluation, were mentioned in less than half of standards, though participation in certification itself arguably constitutes a form of evaluation. Resistance Management only appeared in 13 certifications, and only was referenced more than once in three standards, but tactics from Principles 1, 3 4 and 6 all can contribute to managing resistance by reducing pesticide use.

Chart, bar chart, histogram, waterfall chart

Description automatically generated**Figure 3: Criteria Addressing the 8 Principles of Integrated Pest Management in 24 Certifications.**

**Overall Trends:**

Out of other areas identified in the analysis, only two had criteria represented in all 24 certifications- record-keeping and training. Additionally, the vast majority of certifications had at least one criterium relating to pest monitoring (22), planning (21), how pesticides are applied (21), materials management and storage (21) and workplace safety (21). 17 certifications ban the use of some pesticides, either based on their own list or one or more globally recognized treaty lists. Five certifications had no list of banned or restricted pesticides.

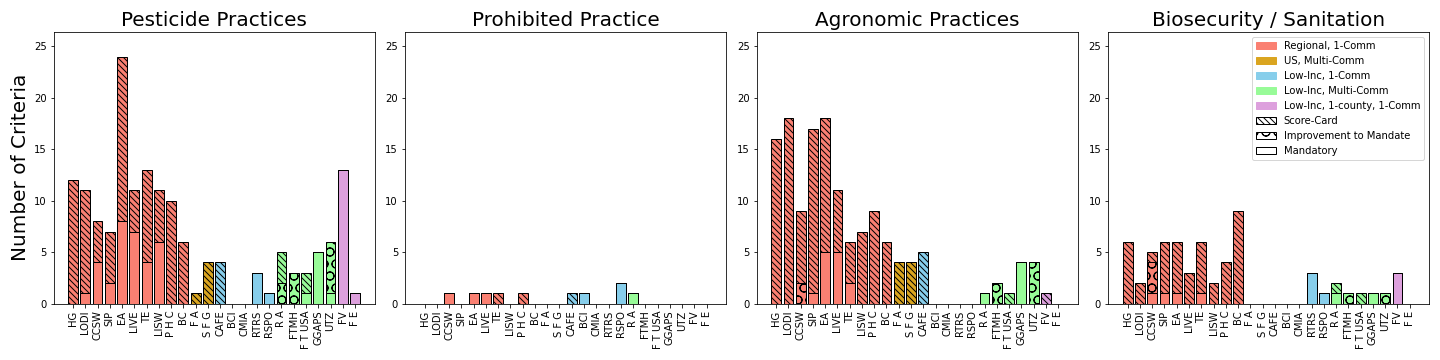
**Performance Standards:**

Three certifications, all regional-designation single-commodity, (Healthy Grown, Lodi Rules and Protected Harvest Citrus) utilized a toxicity-units model as a pass-fail criterion. These models are of the form:

For each pesticide p applied. Where TU is total toxicity units, is the toxicity score of pesticide p and is the mass of that pesticide applied. For each certification, a total TU cap is set, and farms must stay at or below that cap.

Chart, bar chart, histogram

Description automatically generated



Chart, pie chart

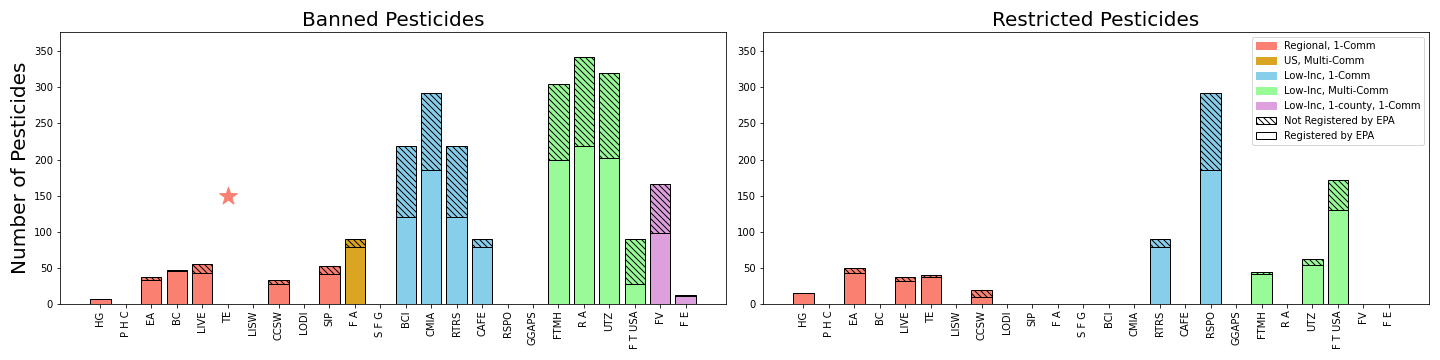
Description automatically generated

**Figure 1: Geographic and Commodity Scope of 24 Certifications in Sample**

Chart, pie chart

Description automatically generated

**Figure 2: Crops Covered by Single-Commodity Certifications in the Sample**



Chart, histogram

Description automatically generated

A picture containing calendar

Description automatically generated

**Figure 5: Relative Frequency of Certifications Covering selected sub-areas.**

Single-region single-commodity certifications stand out as different from other groupings. These certifications include the most criteria overall, more monitoring criteria, including action thresholds, more likely to promote Mode-of-Action (MOA) rotation, and included more criteria relating to biosecurity and sanitation. Further, these were the only certifications which specified the use of models for predicting pest pressure or pesticide toxicity models to measure performance. The difference in number of criteria is stark for most IPM Principles (Table X).

For prevention, monitoring and non-chemical control most regional-designation certifications included multiple region-specific or crop-specific requirements or options, while the vast majority of other certifications simply mentioned the need to incorporate these areas in a general sense. Regional-designation certifications also included more criteria for pesticide selection; many include several different environmental considerations, including threats to water quality and beneficial insects. These certifications also include far more criteria for directly reducing pesticide usage, including requirements or options for ensuring correct spray coverage and use of spot-spraying or block-spraying for specific pests.

These differences likely reflect two factors. First, standards for a specific crop in a specific agroecological zone can be more exhaustive and specific. Several of the standards in this group contained monitoring and/or threshold standards for several different insects and diseases. Comprehensive description of monitoring and threshold techniques for “any pest, any crop, anywhere” is obviously not possible within a single guidance document. Similarly, the thresholds for an acceptable toxicity load in a toxicity model may be very different across different crops or agroecologies.

Additionally, these differences in standards reflect the collective-action and public-goods aspects of IPM. In contrast to many other environmental problems in agriculture, chemical resistance in pests and the import of exotic pests and diseases are public goods problems that are spatially bounded and primarily impact the farmers themselves. The same applies to natural enemies, to a lesser extent. These issues closely resemble the types of problems successfully dealt with by informal “commons-type’ governance structures (Ostrom et al., 1999); individual efforts in these areas can have high positive externalities within the community of crop-producers, creating the potential for free-rider problems. As such, certification provides the opportunity not just for farmers to differentiate their products to consumers as ecologically friendly, but to coerce each other to better manage key public goods and bads. Resolving such collective-action problems has long been acknowledged as a key challenge and opportunity in IPM promotion (Bottrell & Schoenly, 2018; Parsa et al., 2014).

Certifications focused-on low-income countries were different in two respects. First, the number of banned and restricted pesticides tends to be much greater. This likely reflects the fact that many of the banned pesticides are not allowed for use on crops in some countries but not others. Additionally, these standards place much more emphasis on worker safety and hazardous materials handling. This not only reflects the different missions of some of the certifications, which often foreground social concerns, but also the role that these certifications play in substituting for and supplementing legal standards in agriculture in low-income countries.

One-commodity regional domestic certifications generally included some worker protections. Most of these commodities commonly utilize migrant agricultural labor. Wisconsin Healthy-Grown Potatoes is the only one of these certifications not including any worker protection criteria; migrant farmworkers do not commonly work in this crop-sector.

**Lessons:**

The differences between regional single-commodity standards and all others reflect tension between an “inside” and “outside” view of ecological best management practices in agriculture. Standards with a broad scope must adopt an external view of farming systems- the strength of a certification is tightly linked to the degree it ties the hands of farmers. Such standards may be very useful for setting a “floor” which excludes the worst practices or materials from production, but cannot define “best practices” in a rigorous way without ignoring enormous agroecological variation.

Regional-Designation certifications function very differently than others; many appear to incorporate a “view from within” of agricultural best management practices. They tend to be developed more closely with growers, pursue management of collective-action problems beyond simple marketing and codify regional best-management practices while also allowing growers more flexibility. This allows for certification standards to be potentially more rigorous without being overly constraining upon farmers’ flexibility. On the other hand, these standards can overlap, creating the potential for confusion; our sample includes three different sustainable winegrowing certifications for California.

Globally-focused standards face the tradeoff between stringency and flexibility more starkly. Employees of UTZ and Rainforest Alliance have described to researchers an explicit intention to create standards which accessible to any producer, to ensure that the standard can eliminate the worst environmental and social abuses from as many farms as possible (Auld, 2010). The content of these standards relating to pest management generally focuses on worker safety, hazardous materials handling, bans on the most toxic pesticides, and general planning and record-keeping requirements. Preventing pests and disease, and cultural/ecological methods for managing pest populations are only enforced in a general manner.

In this manner, standards with broad applicability may partly follow after the organic standard- the bulk of the power within the standards focuses simply on practices to be banned, as prescriptions for sustainability will be too contextual to fit into a global standard. Becoming too strict in standards may not only reduce the economic viability of a certification, but also have perverse impacts if a banned tool or technique is occasionally the most ecological friendly option[[1]](#footnote-1). Requiring planning, record-keeping, monitoring and training may help farmers find opportunities to reduce their impacts, but is unlikely to resolve any inherent conflicts between productivity and environmental concerns.

**Conclusion:**

Twenty-four alternative food and agriculture certifications were analyzed for how they operationalize the concept of “Integrated Pest Management”, through their standards. These standards showed markedly different patterns based on their geographic and crop scopes- while standards developed in one region for one crop function as compendia of best practices with a high degree of specificity. Other standards tend towards enforcing a “floor” of banned materials and practices and requiring basic planning and record-keeping, which may assist farmers to improve their practices and impacts.

These results emphasize the difficulties involved with defining agricultural production systems in a rigorous and repeatable manner. While this study focuses on non-governmental labeling programs, these same problems can arise in any effort to dichotomously categorize farming systems. These results show that such classifications can most easily function to uphold basic standards on a broad scale or to codify a menu of well-known BMPs on a local scale. Broadly applicable checklists for classifying farming systems as using “Integrated Pest Management” or other holistic strategies are likely infeasible.

**References:**

Auld, G. (2010). Assessing Certification as Governance: Effects and Broader Consequences for Coffee. *The Journal of Environment & Development*, *19*(2), 215–241. https://doi.org/10.1177/1070496510368506

Bacon, C. M. (2010). Who decides what is fair in fair trade? The agri-environmental governance of standards, access, and price. *The Journal of Peasant Studies*, *37*(1), 111–147. https://doi.org/10.1080/03066150903498796

Bajwa, W. I., & Kogan, M. (1996). *Compendium of IPM definitions*.

Bell, M. M., Lyon, A., Gratton, C., & Jackson, R. D. (2008). Commentary: The productivity of variability: an agroecological hypothesis. *International Journal of Agricultural Sustainability*, *6*(4), 233–235.

Bottrell, D. G., & Schoenly, K. G. (2018). Integrated pest management for resource-limited farmers: Challenges for achieving ecological, social and economic sustainability. *The Journal of Agricultural Science*, *156*(3), 408–426. https://doi.org/10.1017/S0021859618000473

Briske, D. D., Derner, J. D., Brown, J. R., Fuhlendorf, S. D., Teague, W. R., Havstad, K. M., Gillen, R. L., Ash, A. J., & Willms, W. D. (2008). Rotational grazing on rangelands: Reconciliation of perception and experimental evidence. *Rangeland Ecology & Management*, *61*(1), 3–17.

Carr, P. (2017). Guest Editorial: Conservation Tillage for Organic Farming. *Agriculture*, *7*(3), 19. https://doi.org/10.3390/agriculture7030019

Castle, S., & Naranjo, S. E. (2009). Sampling plans, selective insecticides and sustainability: The case for IPM as ‘informed pest management.’ *Pest Management Science*, *65*(12), 1321–1328. https://doi.org/10.1002/ps.1857

*Ecolabel Index | Who’s deciding what’s green?* (n.d.). Retrieved June 11, 2021, from http://www.ecolabelindex.com/

Ehler, L. E. (2006). Integrated pest management (IPM): Definition, historical development and implementation, and the other IPM. *Pest Management Science*, *62*(9), 787–789.

Garry, V. F., Harkins, M. E., Erickson, L. L., Long-Simpson, L. K., Holland, S. E., & Burroughs, B. L. (2002). Birth defects, season of conception, and sex of children born to pesticide applicators living in the Red River Valley of Minnesota, USA. *Environmental Health Perspectives*, *110*(suppl 3), 441–449.

Getz, C., & Shreck, A. (2006). What organic and Fair Trade labels do not tell us: Towards a place-based understanding of certification. *International Journal of Consumer Studies*, *30*(5), 490–501. https://doi.org/10.1111/j.1470-6431.2006.00533.x

Giller, K. E., Witter, E., Corbeels, M., & Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: The heretics’ view. *Field Crops Research*, *114*(1), 23–34.

Glover, D. (2011). The System of Rice Intensification: Time for an empirical turn. *NJAS - Wageningen Journal of Life Sciences*, *57*(3), 217–224. https://doi.org/10.1016/j.njas.2010.11.006

Gosnell, H., Grimm, K., & Goldstein, B. E. (2020). A half century of Holistic Management: What does the evidence reveal? *Agriculture and Human Values*, *37*(3), 849–867. https://doi.org/10.1007/s10460-020-10016-w

Guthman, J. (2000). Raising organic: An agro-ecological assessment of grower practices in California. *Agriculture and Human Values*, *17*(3), 257–266.

Guthman, J. (2004). Back to the land: The paradox of organic food standards. *Environment and Planning A*, *36*(3), 511–528.

Hughner, R. S., McDonagh, P., Prothero, A., Shultz, C. J., & Stanton, J. (2007). Who are organic food consumers? A compilation and review of why people purchase organic food. *Journal of Consumer Behaviour: An International Research Review*, *6*(2–3), 94–110.

Hunter, J. D. (2007). Matplotlib: A 2D Graphics Environment. *Computing in Science & Engineering*, *9*(3), 90–95. https://doi.org/10.1109/MCSE.2007.55

Jackson, W., & Berry, W. (2009). A 50-Year Farm Bill. *NYT, Jan*, *4*.

Jaffee, D. (2012). Weak coffee: Certification and co-optation in the fair trade movement. *Social Problems*, *59*(1), 94–116.

Jaffee, D., & Howard, P. H. (2010). Corporate cooptation of organic and fair trade standards. *Agriculture and Human Values*, *27*(4), 387–399. https://doi.org/10.1007/s10460-009-9231-8

Khaledi, M., Liaghati, H., Mohammadamini, M., & Weseen, S. (2011). Assessing the Barriers to Conversion to Organic Farming in Canada. *ENVIRONMENTAL SCIENCES*, *8*(2), 109–126.

Kogan, M. (1998). Integrated pest management: Historical perspectives and contemporary developments. *Annual Review of Entomology*, *43*(1), 243–270.

Kovach, J., Petzoldt, C., Degni, J., & Tette, J. (1992). *A method to measure the environmental impact of pesticides*. https://ecommons.cornell.edu/handle/1813/5203

Lyon, A., Bell, M. M., Gratton, C., & Jackson, R. (2011). Farming without a recipe: Wisconsin graziers and new directions for agricultural science. *Journal of Rural Studies*, *27*(4), 384–393.

Maupin, J., & Norton, G. (2010). Pesticide use and IPM adoption: Does IPM reduce pesticide use in the United States. *Agricultural & Applied Economics Association Annual Meeting, Denver, CO*.

Midmore, P., Padel, S., McCalman, H., Isherwood, J., Fowler, S., & Lamkpin, N. (2001). *Attitudes towards conversion to organic production systems: A study of farmers in England*.

Mutersbaugh, T. (2002). The number is the beast: A political economy of organic-coffee certification and producer unionism. *Environment and Planning A*, *34*(7), 1165–1184.

OJEC. (2009). *DIRECTIVE 2009/128/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides*. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0128

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the commons: Local lessons, global challenges. *Science*, *284*(5412), 278–282.

Parsa, S., Morse, S., Bonifacio, A., Chancellor, T. C., Condori, B., Crespo-Pérez, V., Hobbs, S. L., Kroschel, J., Ba, M. N., & Rebaudo, F. (2014). Obstacles to integrated pest management adoption in developing countries. *Proceedings of the National Academy of Sciences*, *111*(10), 3889–3894.

Raynolds, L. T., Murray, D., & Heller, A. (2007). Regulating sustainability in the coffee sector: A comparative analysis of third-party environmental and social certification initiatives. *Agriculture and Human Values*, *24*(2), 147–163. https://doi.org/10.1007/s10460-006-9047-8

Regidor, E., Ronda, E., García, A. M., & Domínguez, V. (2004). Paternal exposure to agricultural pesticides and cause specific fetal death. *Occupational and Environmental Medicine*, *61*(4), 334–339.

Rosset, P. M., & Altieri, M. A. (1997). Agroecology versus input substitution: A fundamental contradiction of sustainable agriculture. *Society & Natural Resources*, *10*(3), 283–295.

Sappington, T. W. (2014). Emerging issues in Integrated Pest Management implementation and adoption in the North Central USA. In *Integrated Pest Management* (pp. 65–97). Springer.

Sheehy, J. E., Sinclair, T. R., & Cassman, K. G. (2005). Curiosities, nonsense, non-science and SRI. *Agronomy–Faculty Publications*, 72.

Stern, V., Smith, R., Van den Bosch, R., & Hagen, K. (1959). The integration of chemical and biological control of the spotted alfalfa aphid: The integrated control concept. *Hilgardia*, *29*(2), 81–101.

Strochlic, R., & Sierra, L. (2007). Conventional, mixed and deregistered organic farmers: Entry barriers and reasons for exiting organic production in California. *California Institute for Rural Studies*, 1–32.

Tago, D., Andersson, H., & Treich, N. (2014). Pesticides and health: A review of evidence on health effects, valuation of risks, and benefit-cost analysis. *Preference Measurement in Health*.

Taylor, C., A. (2021). Cicadian Rhythm: Insecticides, Infant Health and Long-term Outcomes. *Columbia Center for Environmental Economics and Policy Working Paper Series*, *9*. https://ceep.columbia.edu/sites/default/files/content/papers/n0.pdf

USDA Study Team on Organic Farming. (1980). *Report and recommendations on organic farming*. US Department of Agriculture.

Vogel, D. (2008). Private Global Business Regulation. *Annual Review of Political Science*, *11*(1), 261–282. https://doi.org/10.1146/annurev.polisci.11.053106.141706

West, G. E., & Cisse, I. A. (2014). *Social Determinants Of Adoption Of Integrated Pest Management (Ipm) By Quebec Grain Farmers*.

Zalucki, M. P., Adamson, D., & Furlong, M. J. (2009). The future of IPM: Whither or wither? *Australian Journal of Entomology*, *48*(2), 85–96.

1. For instance, organic agriculture’s ban on herbicides may promote unsustainable levels of tillage in some farming systems (Carr, 2017), while bans on synthetic pesticides may not result in lower total environmental impact from pest control in all crops (Kovach et al., 1992). [↑](#footnote-ref-1)