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Extension’s Role in Reducing Uncertainty for New Technology Adoption

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Risk and uncertainty come with any new technology (Feder and Umali, 1993), and adoption is not a foregone conclusion. Land grant universities are at the forefront of developing new technologies to improve production, sustainability, and efficiency of farming operations. But the very definition of “new” imparts uncertainty in the minds of potential adopters. Are the projected benefits accurate, and will those benefits exceed the adoption costs? To what extent will the estimated costs and benefits change as new technology moves from the experimental to the commercial phase? How steep is the learning curve for incorporating new technology into existing operations? What is the likelihood of costly mistakes and operational inefficiencies? Are decisions reversable? This paper uses a case study approach to examine selected technology transitions in specialty crops, highlighting the critical role extension services play in reducing uncertainty. By analyzing specific instances where new technologies were introduced, the study provides insights into the challenges faced by producers and the strategies employed by extension services to facilitate adoption and mitigate risks.

New Technology and the Economic Impact of Uncertainty

New production technologies in agriculture offer opportunities to increase yield, improve quality, and lower costs. Uncertainty is prevalent with any change, and farmers must prepare for substantial costs. Large upfront expenditures in infrastructure, training, and equipment are often necessary to successfully implement new technologies. This cost can be especially taxing for small-scale farmers with tight budgets (Feder and Umali, 1993), though larger operators must also be cognizant of cost.

Impacts go well beyond a simple comparison of expenditures. For example, substituting mechanical harvesting systems for manual labor in specialty crops fundamentally alters the cost structure. Manual labor typically is paid by the piece, with the duration of employment limited to the harvest period (e.g., in Florida, October–March and December–early May for Florida tomatoes and juice oranges). As such, manual harvest labor can be viewed as a variable cost. When the farm transitions to mechanical systems, harvest becomes heavily weighted to fixed costs. The capital expenditures of the harvest machines will be expensed across several years, independent of whether a crop is harvested (Nobuyuki, Emerson, and Walters, 2008; Roka and Hyman, 2003). High upfront costs for new infrastructure and equipment may not promptly result in sufficient returns. Maintaining positive cash flow, reducing financial risks, and guaranteeing operational stability all depend on quick returns on large upfront investments. Return delays might reduce chances for investing in new initiatives, restrict money, and raise vulnerability to technology or market uncertainty.

Adjustment periods to adapt to new technology, operational inefficiencies, and economic losses from errors further increase uncertainty. These expenses are especially significant for resource-constrained, small-scale producers. Operational mistakes that result in crop damage, lower yields, or higher input costs often occur when new technology is introduced into the farming operation, with profitability directly impacted (Feder and Umali, 1993). The expense of regular maintenance and repairs may increase due to learning curves associated with new technology, adding to short-term inefficiencies. As farm resources are diverted to accommodate new challenges, there may be additional opportunity costs incurred from adjustments necessary across the entire farming operation. For example, spraying a hayfield with Curtail, a combination of 2,4-D and clopyralid herbicides, forces a farmer or rancher to delay hay harvest for at least 30 days so that Curtail’s active ingredients will be deactivated by sunlight and soil microbes (Davis, Johnson, and Jennings, 2020).

Most farmers recognize these costs as an investment. Most believe that once the technology is adopted and its promised efficiencies fully exploited, the returns on the investment will surpass the original costs. At the very least, it takes time for a farm manager to fully optimize the efficiencies expected from new technologies. Early adopters are especially vulnerable as they pioneer the use of a new practice or machine. Technology developers do not fully account for costs due to inexperience and design limitations (Rogers, Singhal, and Quinlan, 2014). Successful adoption is greatly facilitated if a farmer has sufficient financial resources to weather risks associated with early prototypes. Farmers without adequate resources gamble on an immediate payoff or risk significant losses from prototype failures. In these scenarios, the new technology may (1) not perform, (2) perform but cannot be sustained, or (3) perform but not at a sufficient level to cover investment and operational costs.

Additional uncertainties arise from the fit of the new technology within a production system. What works under controlled experimental conditions does not always translate to commercial-scale operations. For example, platform harvesters and in-field conveyors were introduced as aids to boost manual labor productivity for tree fruit harvesting. Unfortunately, these designs failed to consider that system productivity was limited to the slowest worker on the platform, as well as the variability of fruit growing on a single tree (USDA-ARS, 1998; Sarig, Thompson, and Brown, 2000). Several growers in Southwest Florida attempted to incorporate a conveyor belt system as a harvest aid for fresh market tomatoes. Conveyors improved harvest labor productivity by eliminating a worker’s time spent carrying 30-pound buckets between a field row and crop collection truck or gondola. The productivity gains, however, were not sufficient to pay for the added capital costs of the conveyor.

Technology Transitions

Transition in technologies is not new for specialty crops. After an adaptation, it is easy to gloss over the operational challenges that had to be overcome. We offer several examples to illustrate the pressures that led to the transition, the uncertainties that impacted successful implementation, and the role of extension throughout.

Florida Sugarcane Harvest (1980–1990)

Before the 1970s, Florida’s sugarcane harvest was difficult and labor-intensive, relying on a significant number of guest workers from Jamaica and the Bahamas (Nobuyuki, Emerson, and Walters, 2008). The development of mechanized harvesters offered to drastically decrease labor expenses and reliance on immigrant workers. While the transition offered a significant boost in harvest productivity, several obstacles arose. Mechanical harvesters weakened plant root structures, reducing the viable lifespan of a sugarcane stand from around 7 years to 4 years (Roka et al., 2010). While producers in regions with lower yields implemented mechanical harvesting in the mid-to-late 1970s, growers in other regions of the state did not switch over until the early 1990s. To close the gap, extension services provided training courses, held field demonstrations, and disseminated best practices. In addition, sugarcane breeding research shifted to identify varieties that could better withstand the rigor of machine harvesters. In the end, this assistance enabled wider adoption by lowering the perceived and real limitations of mechanical harvesters.

Michigan Tart Cherry Harvest (1960–1980)

Public pressure for workplace reform can amplify economic pressure to adopt new technologies. Michigan tart cherry growers in the early 1960s faced serious concerns in terms of labor availability and affordability to manually harvest their trees (Michigan State Extension, 2019). Farm labor union organizers effected strikes and walk-outs to increase Michigan tart cherry farm workers’ earnings. The harvest window for tart cherries is relatively short, between 4 and 6 weeks. Consequently, any disruption in harvest labor services could result in serious economic ramifications for the growers. The labor market challenges motivated cherry growers to find harvesting solutions that were less dependent on migrant manual labor.

University researchers, growers and equipment manufacturers combined efforts to design and develop mechanical harvesting systems. Early prototypes were problematic and significant number of cherry trees were destroyed (Wright, Martinez, and Thornsbury, 2006). However, as research advanced, more sophisticated, less damaging mechanical harvesting systems evolved. In addition to improved equipment design, the tree structure and horticultural practices were reconfigured to better accommodate the new harvesters. Post-harvest fruit handling was fundamentally altered to include water cooling systems both in field and at processing facilities. During this time, extension educators were crucial in fostering dialogue between producers and equipment manufacturers, assisting in the identification and resolution of several technical issues that sprang up during the mechanization process (McManus, 2012).

Florida Citrus Harvest (1960–1970, 1997–2007)

Mechanical harvesting of Florida’s juice oranges was explored for the same reasons that motivated Michigan tart cherry and Florida sugarcane growers—availability and cost of manual labor for harvesting. The first iteration of citrus mechanical harvesting (1960-1975) was driven largely by university and USDA-ARS researchers. These efforts did not achieve commercial success. Meanwhile, a series of freezes during the 1960s reduced juice-orange acreage in Florida to where concerns over sufficient harvesting labor were largely abetted.

The second iteration of Florida's citrus mechanical harvesting program (1995-2007) proved more successful. Equipment from the California almond and nut tree industries was utilized, and new canopy-shaking technology was introduced into Florida citrus groves. One fundamental difference from the first program was the greater level of engagement by growers in the second program. The Florida Department of Citrus (FDOC) created a special grower-led harvesting committee to coordinate research and development. The committee allocated more than $2 million each year for research and development projects conducted by manufacturers and university researchers. Extension faculty provided the harvesting council with vital data on machine performance and the development of fruit abscission products. Technological confidence expanded over this period, demonstrating the critical role of extension in promoting mechanical harvesting (Whitney, 2006).

Despite some commercial adoption, mechanical harvesting of juice oranges was never completely embraced. The "high-water" mark of 12,000 mechanically harvested acres in 2005 represented less than 2% of the total state juice orange acreage. Commercial adoption was concentrated in Southwest Florida, where larger, more uniform citrus plantations had been established.

In retrospect, extension faculty failed to fully embrace grower concerns about tree damage and post-mechanical "shiners."[1] A first impression of a freshly mechanically harvested block of oranges could be horrific. Broken tree limbs, leaf litter, and smashed fruit covered the grove floor. Many growers reacted negatively to these visual signs and concluded that tree damage was irrevocable. Most of the damage was superficial and a subsequent study indicated that long-term tree productivity was not adversely affected by mechanical harvesters (Mosley, House, and Roka, 2012). First impressions, however, proved hard to shake. After the initial group of early adopters, the perception of tree damage caused subsequent waves of adopters to wane.

An important condition for mitigating tree damage was that trees were well-nourished and healthy ***before and after*** mechanical harvesting. Ultimately, Florida's second mechanical harvesting program collapsed with the confirmation of citrus greening or Huanglongbing (HLB) in 2005. HLB, a bacterial infection, removed the ongoing assumption that trees were well-nourished and that vigorous trunk or canopy shaking only added stress to the trees, thereby exacerbating HLB impacts. HLB was the final factor in a list of other concerns that contributed to the slow acceptance of mechanical harvesting. In addition to worries about tree damage, growers expressed concerns about fruit quality, million-plus dollar capital investments per harvesting unit, inconsistent machine performance under varying grove conditions, and greater volumes of debris being handled at juice processing plants.

Florida Citrus Oxytetracycline (OTC) Injection (2023–Present)

Just as a catastrophic threat like HLB can discourage the adoption of some new technologies, it can also add significant pressure to find new solutions to address the threat. Millions of dollars have funded the development of numerous strategies to combat citrus greening, but a definitive solution remains elusive, underscoring the complexity of the disease and the ongoing need for dedicated research and innovation (UF/IFAS, 2023). When the OTC injectable bactericide was first proposed in December 2022, there was some doubt about its overall efficacy. Trees had to be individually injected by hand, which raised even greater concerns that this technology would be economically feasible. The bactericide was designed to mitigate the adverse effects of HLB, restore tree health, and enable trees to produce more fruit.

Prior to release, extension faculty worked closely with private companies and individual growers to develop an effective treatment formulation and administration protocol. Several large trials were established on growers' properties. Although these trials were under "crop-destroy" requirements, these growers enjoyed a front-row seat to observe how the proposed OTC bactericide could affect HLB-infected trees, including a noticeable improvement in tree health. Grower observations rapidly spread through the citrus industry. When OTC technology became available in early 2023, adoption was widespread. Growers participating in early trials innovated methods of bactericide injection that were more economical than predicted. Practical assistance for growers to implement technologies remains a priority (McGill, 2023).

Role of Extension Services

New technology adoption is often driven by high-stakes situations where farmers have no choice but to change. Given the time lag between developing and applying a new technology, it is crucial to build risk management strategies into the innovation process. As the pace of change accelerates, multiple perspectives must be integrated to ensure successful outcomes. However, even with decisive action, success is not guaranteed. This raises the question: How can extension services help increase the chances of success?

Holt (1989) emphasizes the need for extension services to evolve alongside technological advancements. A flexible, responsive extension service keeps stakeholders agile and informed about innovations and

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[1] A "shiner" is an orange remaining in a tree after a harvesting crew leaves a grove.

emerging challenges. On the other hand, misunderstandings and knowledge gaps create significant barriers to adoption. Extension agents must proactively address these challenges by staying current with technological developments, understanding farmers' unique needs, and adjusting communication strategies accordingly.

Effective knowledge diffusion has always been key to breaking down adoption barriers. While providing accurate, reliable information remains essential (Rogers, Singhal, and Quinlan, 2014), today's information-saturated environment demands more than just dissemination. Extension services must actively dispel myths and address misconceptions that hinder adoption. By offering clear, practical, and relevant information, extension agents empower growers to make well-informed decisions, ultimately enhancing productivity, efficiency, and satisfaction.

The role of extension services goes beyond communication—it involves building trust, offering technical support, and bridging the gap between researchers and practitioners. This includes broad awareness campaigns that highlight the benefits of new technologies through traditional channels such as print, radio, and television, as well as newer platforms like social media (Vanclay, 2004). Social media can be a valuable tool to reach a wider audience of growers and other stakeholders more effectively. Extension agents must encourage stakeholders to become active participants in development. The importance of the early involvement of growers has been demonstrated by the rapid adoption of OTC injections to combat HLB infection after several commercial growers participated in early trials.

Misinformation and incomplete information among stakeholders are one of the main obstacles to adopting new technologies. In some cases, stakeholders may simply be unaware of new technologies that could potentially help their operations. Extension professionals must learn about farmers' problems and levels of expertise firsthand. Information on the technical characteristics of developing technologies, potential advantages, and related costs is often lacking.

More challenging, however, is when stakeholders are fully aware of new technology but do not trust recommendations. The second citrus mechanical harvesting program in Florida (1997–2007) illustrated this point. Early impressions of damage from trunk and canopy shakers created doubts and made new growers cautious about venturing into mechanical harvesting. If the citrus mechanical harvesting program had continued beyond 2007, equipment refinement and operational adjustments may have reduced overall tree damage. More growers might have adopted mechanical harvesting for the sheer labor savings advantage.

Extension services must constantly adapt to the shifting demands of farmers and the agricultural sector to better support technological adoption. To remove obstacles, extension services must take the initiative to identify and solve them. Extension agents must also engage in ongoing professional development to stay current on the most recent advancements in technology and the most effective communication strategies.

It is essential to use communication techniques customized for the needs of various stakeholder groups (Vanclay, 2004). This entails tailoring messaging to the intended audience and utilizing a range of communication channels. It is necessary to establish monitoring and evaluation methods to gauge how well information distribution tactics work. This requires gathering input from interested parties, assessing the results of extension initiatives, and making ongoing adjustments considering these discoveries.

Conclusion

For new technology to be widely adopted in specialty crop industries, it is crucial to overcome barriers that delay the spread of information. Extension services play a vital role in reducing the risks associated with uncertainty and promoting technical innovation in agriculture. By effectively sharing knowledge through extension services, farmers can be motivated to embrace new methods that enhance productivity and sustainability as trust and confidence grow. Addressing knowledge gaps and grower concerns about unintended consequences from crop damage and higher operational costs can ensure that farmers receive personalized assistance and choose techniques that maximize efficiency and competitiveness.

Extension services bring academics, industry players, and farmers together to ensure that new technologies are useful and easy to use. The efficacy of these extension initiatives is critical to the specialty crop industry's acceptance of new technologies. These case studies demonstrate how important extension services are to fostering agricultural innovation and maintaining the industry's viability long-term.

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