© *Journal of Higher Education Outreach and Engagement*, Volume 17, Number 1, p. 27, (2013)

 ISSN 1534-6104

Pecan Research and Outreach in New Mexico: Logic Model Development and Change in Communication Paradigms

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Abstract

Universities develop strategic planning documents, and as part of that planning process, logic models are developed for specific programs within the university. This article examines the long-standing pecan program at New Mexico State University and the deficiencies and successes in the evolution of its logic model. The university's agricultural experiment station's pecan program logic model has evolved along with increased external funding, but never has developed into a complete logic model because the outcome-impact component remains incomplete. With increased assistance from the university, the pecan industry grew and became stronger and more economically viable; however, the incomplete development of a pecan program logic model has prevented development of a complete synergy. The evaluation of outcome-impact is most efficient and accurate when at least part of the evaluation is conducted with methods independent of the growers.

Introduction

Changes in crop management occur through research and extension activities at the national and state levels in the United States. State universities develop strategic planning documents to guide the development of their research and extension activities, with the goal of improving crop management, decreasing environmental degradation, and improving economic return. Consequently, as part of that planning process, logic models are developed for specific agricultural commodity research and extension programs within the university. A logic model defines how a program of agricultural research and extension intends to produce particular results. It consists of input, output, and outcome-impact components. The inputs of the logic model are personnel and economic resources; the output is a communication system; the impacts are the changes in activity of the intended audience. The audience can be producers, marketing systems, government regulators, or government funding agencies. The effectiveness of the communication system is the outcome-impact.

These integrated programs defined by the logic model involved multiple department, research, and extension expertise. The logic model concept was developed during the 1960s and 1970s when the U.S. government needed a method to measure the value and impact of governmental social programs. The government found that programs and measures of outcomes or impacts did not generally correspond to program objectives. Program logic models became a formal part of extension programs only in the 1970s *(Weiss, 1972)*. Penn State University's Cooperative Extension in the College of Agriculture has used logic models to develop 5-year plans of work *(Corbin, Kiernan, Koble, Watson, & Jackson, 2004)* that involved both research and extension activities.

Inputs to a logic model can change with funding sources and amounts because these external forces affect change in any institution's priorities *(Miller, 1992)*. The outcome component of the logic model is usually the least developed component of the model. New research has been conducted on the use of remote sensing to evaluate the outcome-impact, but this technology has yet to be incorporated into logic models. Remote sensing outcome-impact tools have been developed to determine the increase in crop yield due to the release of new varieties and changes in management *(Serrano, Filella, & Penuelas, 2000)*. Remote sensing also has been used to evaluate the reduction in soil erosion due to changing farming practices *(Frazier & Cheng, 1989; Jakubauskas, Legates, & Kastens, 2002)*.

Currently, even though new proposals to the U.S. government require it, few logic models exist as part of the academic community program development. Generally, only part of a given logic model will be developed and implemented; that part consists of the allocation of personnel and economic resources (inputs) and the implementation of a change in the communication system (output). New Mexico State University has had a pecan program extension/research for growers in the state since the early 1900s. Before the 1970s, the concept of developing a formal logic model did not exist, but part of the process often was followed as common sense plans were made and implemented. The university created inputs and outputs but did not create outcome-impact evaluation to evaluate a change in the way the pecan crop was produced in the state. Outcome-impact did occur but never was evaluated in a formal methodology. Throughout the history of communication between New Mexico State University and the pecan growers, the communication system and the pecan program logic model changed due both to internal actions by the university and to external forces caused by the formation of pecan grower associations and the acquisition of research grants. Figure 1 shows the current form of the pecan research/extension logic model.

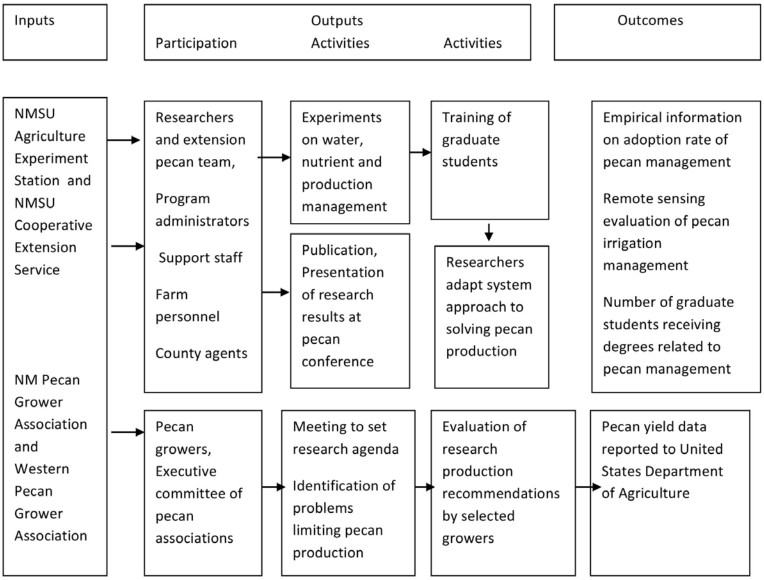

Figure 1. Current Status of Pecan Logic Model

Over time, the output communication component in the activities area of the logic model has undergone the most change. The output communication system is a transfer of documented scientific facts or an interpretation of these facts by the communicator *(Fisher, 1989)*. The methodology can consist of communication by scientific peer review, as well as professional (no review process), interpersonal, and small-group communication.

Objectives

The objectives of this study were to document and understand the evolution of the pecan logic model and the communication system within the logic model of New Mexico State University due to these (external and/or internal) forces. An understanding of how the communication system changed over time and how resource allocation occurred can give guidance on directions for future communication and resource allocation to develop an effective program logic model for the pecan industry as well as other agricultural commodities.

History of the Pecan Program and Communication System Between New Mexico State University and Pecan Growers and Change in the Pecan Logic Model

The basic assumption when developing a logic model is that facilities and personnel needed for the inputs to the model are available and that the inputs are compatible in scope with the desired outputs and outcomes. Consequently, the history of the pecan logic model changed with changing financial resources due to both internal and external funding at New Mexico State University. The first publication by researchers at the university evaluated the pecan varieties planted in the university orchard in 1915 *(Garcia & Fitz, 1925)*, and the communication system to the growers was by written for scientific peer-reviewed publications using a scientific expert (formal) vocabulary (Table 1) and researcher-to-grower personal communication. At that time, the inputs to the pecan logic model were university researchers with the agricultural experiment station. This communication resulted in the outcome-impact of growers starting new pecan orchards and the first large-scale commercial planting of pecans in New Mexico in 1934 and 1935 on a farm south of Las Cruces. The variety planted was “Western Schley” with the variety “Burkett” as the pollinator *(Herrera, 2008)*. Had it formally existed, the outcome-impact component in the pecan logic model would have been an increase in planted acreage of pecan trees. Pecan acreage was not measured, but pecan production was measured starting in 1920 *(Herrera, 2008)*. Total pecan acreage planted can be estimated from total pecan production. The largest pecan farm was the Stahmann farm, which in the 1930s and 1940s planted 4,000 acres of mostly “Western” and “Bradley” trees along the Rio Grande. Currently, the technology is available to measure the increases in pecan acreage by remote sensing *(Masoner, Mladinich, Konduris, & Smith, 2011)*, but a user-friendly software tool to analyze the remote sensing data available on the Internet must be developed.

Table 1. Description of Communication Systems, Pecan Logic Model Inputs, Outputs, and Outcomes Over Time

Communication type	Inputs	Outputs	Outcomes
1. Written, New Mexico State University Agricultural Experiment Station publication and journal articles (peer-reviewed).	Researcher, New Mexico State University Agricultural Experiment Station and Cooperative Extension Service.	A pecan orchard was established. Research on pecan management started. New Mexico State University Agricultural Experiement Station publication on pecans.	Growers came to know about the feasibility of pecan production in New Mexico. Growers started showing interest in planting pecans. By 1920, 370 acres planted.

Table 1 Continued. Description of Communication Systems, Pecan Logic Model Inputs, Outputs, and Outcomes Over Time

Communication type	Inputs	Outputs	Outcomes
2. Written journal articles (peer-reviewed) and New Mexico State University Agricultural Cooperative Extension Service publications (no review process). Oral presentations to growers.	Growers, researchers, New Mexico State University Agricultural Experiment Station and Cooperative Extension Service. Extension specialist (75% extension, 25% research) for nut trees, grapes, and fruit trees was hired.	Start of Western Pecan Growers Association conference. Presentation at the conference by New Mexico State University Agricultural Experiment Station and Cooperative Extension Service personnel. Proceedings of Western Pecan Growers Association published by New Mexico State University Cooperative Extension Service. Research on pecan management continued.	Pecan orchard acreage increased to 8,200 acres by 1979. Hiring of graduate students to conduct pecan management research.
3. Expansion of oral and personal communication among growers and specialists. Continuation of writing communication through journal articles and New Mexico State University Cooperative Extension Service publications.	Growers, researchers, New Mexico State University Agricultural Experiment Station and Cooperative Extension Service. Extension specialist and executive committee of Western Pecan Growers Association.	Started a dialogue between Western Pecan Growers Association and university involving executive committee (consisting of growers) in setting research priorities every 5 years. Continuation of research presentations at the conferences, proceeding publication, and one-on-one consulting.	Pecan orchard acreage increased to 29,000 acres by 1996. Hiring of graduate students to conduct pecan management research.
4. Small-group communication. Written, oral lecture, and oral personal communication, web-based communication.	Individual team members from New Mexico State University, University of California at Davis, Texas A&M University, including Extension specialist.	Pecan researchers and extension personnel formed a pecan research team. Started research collaboration with other states. Continued with marketing, research, and extension activities.	Team (New Mexico State University, University of California at Davis, Texas A&M University) conference and journal publications. Pecan orchard acreage increased to 36,000 acres by 2009. Hiring of graduate and postdoctoral students to conduct pecan management research.

New Mexico State University between 1953 and 1963 published articles on pecan production management *(Harper & Enzie, 1956)*, controlling zinc deficiency in pecans *(Harper, 1960)*, economic aspects of pecan production *(Burke & Sydney, 1963)*, and a survey of pecans and apples *(Statistical Reporting Service, 1963)*. The limited number of publications represented the limited university resources allocated to pecan research and outreach. When the number of pecan growers in the western United States reached a sustainable level in 1966, the Western Pecan Growers Association was formed and set a goal of strengthening collaboration among growers and research and extension personnel involved with pecans. Consequently, the input component of the pecan program logic model was increased to include growers' participation (Figure 1). The professional verbal communication (no review process) between researchers and producers was expanded considerably with the annual conference of the Western Pecan Growers Association, which focused on all aspects of pecan production management. The research findings of the New Mexico State University faculty were, and continue to be, presented at the conference in both oral lecture and written non-peer-reviewed proceedings, including the effect of availability of nitrogen fertilizer on mature pecan trees *(Sullivan, O'Connor, & Herrera-Aguirre, 1976)*, marketing of pecans *(Clevenger & Campbell, 1971)*, costs and returns to help growers reduce production costs *(Gorman, Landrum, & Hicks, 1980)*, and the use of a pecan irrigation scheduling model *(Kallestad, Mexal, Sammis, & Heerema, 2008)*.

The attendance of 600 to 700 participants at the annual conferences led to the assumption that some of the research management recommendations presented at the conferences were implemented. No survey was performed nor data collected to substantiate this assumption. The number of presentations varied from nine in 1969 to 33 in 1974. Presentations have covered a wide range of topics, including frost protection, leaf analysis, the effect of chilling and stratification on nut germination, the effect of growing-degree days on the adaptability of pecan varieties, and reduced irregular bearing with mechanical nut thinning (Table 2).

Table 2. Type and Number of Presentations at the Western Pecan Growers Association Annual Meetings from 1966-2007

Topics	Presentations (No.)	Area covered
Insecticide and insects (aphids and case bearer, pecan weevil)	100	Use, impact on beneficial insect types, systemic versus contact, biological control, integrated pest management
Orchard management	52	Harvesting, pruning, pollination
Marketing	47	Marketing organizations, types of promotion, cost, and support
Irrigation	45	Irrigation design and management
Fertilizer	27	Amounts, timing, nitrogen source, zinc, manganese, nutrition
Tree planting	18	Density of planting, new plantings, transplanting, rootstock
Economics	12	Production cost, industry survival, insect control economics
Weeds	9	Type, control
Disease	9	Nematode, pecan shuck, and bunch disease
Salinity	6	Management, impact on yield, root uptake

However, at this time, no formal outcome-impact assessment on the impact of any change in pecan production management was conducted as required by a complete pecan logic program model. Anecdotal evidence was collected that pecan producers changed the way they pruned their trees, that they applied nitrogen more frequently and in smaller amounts, and that a large pecan grower established a retail outlet. However, no survey was conducted to substantiate this information. Only pecan yield data in total pounds for the crop was collected at that time.

Research continued on variety development, and in 1983 the "Sullivan" variety, which is the result of a controlled cross between "Stuart" and "Nugget" pecans, was released by the agricultural experiment station. Another variety, "Salopek," was released in 1990 *(Herrera, 2005)*. The agricultural experiment station projected that these new releases would be planted in new orchards and would result in increased yield and profits for the pecan growers, and concluded that future research on pecan management should be conducted for these new varieties. However, the communication system lacked a feedback evaluation to inform growers of the new releases. Consequently, no follow-up communications were implemented, and neither variety was planted in any large acreage.

Extension Specialist Impact of Logic Model

The hiring in 1978 of a pecan and fruit specialist by New Mexico State University's Cooperative Extension Service expanded the input to the pecan logic model. The increase in inputs resulted in more extension and research publications, demonstration workshops, and a pecan conference. The output was expanded to include not only New Mexico State University Extension Guide publications, which were a series of management guides on pecan production, but publication in *Pecan South*, a non-peer-reviewed journal. *The Pecan Handbook*, a management handbook on how to produce pecans, first published in 1985, was a compilation of research and extension activities *(Herrera, 2009)*. The hiring of the extension specialist also provided the feedback needed in the logic model as part of the outcome-impact. However, the outcome-impact was communication between only the growers and the extension specialist, and this communication was not documented in any formal manner. Consequently, their communication does not fit the definition of an outcome assessment in the pecan logic model. Because the extension specialist was also part of the research team defining future research needs, the verbal feedback was incorporated to a limited degree in future pecan research proposals, which in turn affected the economic return of the pecan industry to the economy of New Mexico *(Evenson, 2000)*.

External Funding Impact on Logic Model

The first source of external monetary support for pecan research became available in 1983 when a water-use project was funded by the New Mexico Water Research Institute *(Sammis, Riley, & Lugg, 1988)*. This external funding increased the New Mexico State University Agricultural Experiment Station's input efforts in the logic model. By 1995, the resulting output activity of the logic model expanded to include lobbying the U.S. congressman representing southern New Mexico to influence the allocation of federal research dollars for pecan research management in the western United States through a specific cooperative agreement between the U.S. Department of Agriculture, the Agricultural Research Southeast Fruit and Nut Research Laboratory, the agricultural experiment stations at New Mexico State University, and the University of Arizona. This new funding resulted in research on pecan growth, pecan yield, and management of pecan orchards through the development of a pecan growth model (*Andales et al., 2006)*, as well as a pecan irrigation scheduling model *(Kallestad et al., 2008)*. These funds continue to support research to date, albeit at a diminished level. But again, no formal tool has been developed and used to evaluate the logic model outcome-impact, which may have been part of the reason for a decrease in the allocated research funds in the current 5-year funding cycle.

In 1995 pecan growers initiated a new communication system. Pecan growers and the research and extension personnel began meeting once every 5 years at the renewal of the Agricultural Research Service project to set research priorities (Table 1). At the meeting between the researchers and growers, the vocabulary tended to be at the expert level of use by the researchers, which at times caused communication problems. The traditional extension oral and written professional communication system was not intended for setting research priorities, but was mainly for conveying research results at the intermediate vocabulary level. Growers wanted research results for immediate problems. Researchers wanted to conduct research that would lead to journal articles and research funds. The funding requests from government agencies may not be in areas directly related to many pecan growers' immediate needs. The pecan growers in New Mexico, unlike other commodity groups, would not support a check-off system to support research activities, but were frustrated when their research priorities did not always match university activities.

By the time the pecan extension and fruit specialist retired in 2002, pecans had become one of the most important crops in the state. The inputs to the logic model had to be expanded because New Mexico State University (internal force) believed the pecan industry had expanded to a size requiring a dedicated specialist and decided to hire a pecan specialist whose job description was limited to nut-tree extension activities. This led to an increase in the output of the logic model via more extensive oral lectures and oral professional and interpersonal communication, as well as through web-based communication, all at the intermediate vocabulary level. The result was a more focused communication system between New Mexico State University and pecan growers. Even with this increased communication, the outcome-impact assessment did not occur in a formal manner but continued to be based only on verbal communication between the pecan growers and the specialist. However, communication among pecan growers of New Mexico increased, and in 2005, with help from the New Mexico State University Agricultural Experiment Station and the university's Cooperative Extension System, the New Mexico Pecan Growers Association was formed as a spin-off of the Western Pecan Growers Association. Its objectives are the presentation and coordination of information on all aspects of pecan production in New Mexico.

In 2008, a new grant by the U.S. Department of Agriculture's Specialty Crop Research Initiative was secured to conduct research appropriate to almond and pecan growers. This grant greatly increased the input resources in the logic model and brought about a change in the logic model output through the addition of a small-group communication system. The research and extension group formed a pecan research team similar to the university chile research team *(Sammis, Shukla, Mexal, Bosland, & Daugherty, 2009)*. In addition to expanding the collaboration of researchers and growers in California and Texas, the research team, mostly through an extension team member, communicated to the growers.

Outcome-Impact Evaluation of Pecan Management Recommendations

The change in the logic model outcomes as a result of this change in the communication system with the formation of the pecan research extension team remains under evaluation because, again, no formal outcome-impact methodology has been identified except for the use of remote sensing to evaluate irrigation management of pecan orchards. Current research is developing the automation of the remote sensing tool needed for this impact assessment. As part of the pecan research project, the university has added the requirement of including, in all program logic models needed for research funding, the training of future pecan researchers by employing graduate students. When this part of the outcome-impact component is missing from a program logic model, federal and state research funds will be difficult to acquire. Consequently, with inputs of agricultural experiment station personnel, additional research funding was initiated through the writing of grants and lobbying of congressmen for earmarked federal funds. From 1995 through 2007, funding from these sources for pecan research resulted in 102 publications and 10 master's degree and doctoral graduates (Table 3).

Table 3. Summary statistics of pecan publications supported by the U.S. Department of Agriculture, Agriculture Research Service research program at New Mexico State University, from 1995 through 2007.

Category	Pest mgt.	Water mgt.	Nutrient mgt.	Waste mgt.	Misc.	Total
Journal articles	12	11	3	1	6	33
Proceedings	13	5	7	2	3	30
Cooperative Extension Service pubs	5	0	1	0	1	7
MS/Ph.D. theses	2	3	2	1	2	10
Misc. pubs.	5	3	6	4	4	22
Total	37	22	19	8	16	102

The number of trained scientists graduating is a formal outcome-impact indicator that has been used in the pecan logic model. This information is readily available because it is part of the ongoing outcome assessment tool for the university. Other outcome-impact evaluations also are needed. For example, anecdotal evidence indicates that New Mexico State University research on pruning residue management has resulted in reduced burning of the residue, with much of the pruning residue now being incorporated back into the soil. This practice can improve air quality in the pecan-growing areas of New Mexico, but no study on changes in pecan acreage using this management procedure has been implemented, and no evaluation of air quality has been undertaken since this orchard management procedure was promoted. This is an example of how remote sensing can be used to determine the decrease in the number of pecan trash-burn piles over the years during the winter months to measure the reduction in burning and the increase of residue incorporation into the soil.

The current logic model must include, other than simple surveys, research and implementation of the development of outcome-impact assessment tools. Researchers at New Mexico State University have used remote sensing to determine what the farmers are doing and how they are changing their actions *(Samani et al., 2009)*. The Regional Evapotranspiration Estimation Model (REEM) tool was used to evaluate the outcome-impact of a pecan irrigation scheduling tool *(Kallestad et al., 2008)* that was based on pecan evapotranspiration research in New Mexico's Mesilla Valley *(Sammis, Mexal, & Miller, 2004; Simmons et al., 2007)*. Samani et al. *(2009)* measured the growing season evapotranspiration of 279 pecan orchards and determined that 15% of the farmers were practicing proper irrigation management under non-stress conditions, whereas the rest of the farmers were practicing deficit irrigation. This outcome-impact assessment tool presented a way to measure the change in irrigation management and the adoption rate of irrigation scheduling tools by pecan growers. If the use of this REEM tool is incorporated in the future logic model, then the tool will be used to evaluate the economic impact of increased pecan yield through proper irrigation management. However, the remote sensing outcome-impact evaluation tool cannot be used to explain why pecan growers change their irrigation practices. Farmers' motives for change probably can be ascertained only by surveys.

The development of a remote sensing evapotranspiration outcome-impact tool has propelled the university on the road to a more complete logic model, but until this tool is implemented using a regular time interval (every 3 to 5 years) and other independent measurement tools are developed, the logic model will remain incomplete.

Summary of New Mexico State University's Public Relations Project

An informal pecan program logic model was started with the planting in 1915 of the first pecan orchard in New Mexico. As acreage and research efforts have increased, the pecan program logic model has developed; changes in inputs have led output communication systems to evolve from a single communication between New Mexico State University and a large number of pecan growers to a communication system between western pecan growers, New Mexico pecan growers, and New Mexico State University, with the emphasis changing from growing the crop to marketing it as well. External funding determined the evolution of the logic model input and output and the expansion of inputs to include research from other states.

Currently, New Mexico State University researchers are collaborating with researchers and growers in California, Texas, and New Mexico through a grant funded by the U.S. Department of Agriculture's Specialty Crop Research Initiative program that would not have been funded if pecan research and outreach had not evolved to the current level. Increased communication, along with changing communication systems, has resulted in a stronger and economically more viable industry. However, increased inputs to the logic model resulted in increased outputs, but no measured outcomes. This is the main shortfall of the current logic model. To generate additional research funding in the future, the logic model must include methods to measure outcomes. Consequently, implementing a complete formal pecan program logic model was again identified as a goal of the New Mexico State University Agricultural Experiment Station. Because of the difficulty of measuring outcomes, development of this part of the logic model will be the most difficult in the future. The university has developed one remote sensing outcome-impact tool, but it has not been incorporated in a formal pecan logic model. The history of the pecan industry in New Mexico is a success story, but the programs were better at changing and expanding communication systems than they were at documenting outcome-impacts. Inclusion of more formal, independent, well-designed research to supply feedback and to better evaluate impact will lead to a more productive research-extension program. The history of the pecan industry in New Mexico highlights the need for a more complete logic model as New Mexico State University pecan research and extension activities progress into the future.

Conclusion

It is difficult to design and execute a research and extension program that continues for over 90 years and results in the documented outcomes for the short- and long-term needed by a logic model. Even when information is transferred by the new web technology, it is difficult to document how many people use the information to change their methods of farming. Generally, it is assumed in the current web-based technology and the old paper technology that page counts of information accessed have some relationship to user changes in farming practices that reflect this information. However, no research supports this assumption, and independent remote sensing data or farmer surveys are needed to document outcomes. The future for universities should include more time in evaluating the outcome of research and extension activities and less time just presenting technical information. Changing current methods of farming to adopt a new technology involves financial risk, and only external forces that are not available to the university will cause that change. Consequently, more collaboration among universities, private industry, and government that can supply the external forces to cause change is needed, both to document outcomes and to improve the adoption rate of technology change.

Acknowledgment

The work was supported by New Mexico State University's Agricultural Experiment Station.

References

Andales, A., Wang, J., Sammis, T. W., Mexal, J. G., Simmons, L. J., Miller, D. R., & Gutschick, V. P. (2006). A model of pecan tree growth for the management of pruning and irrigation. *Agriculture Water Management 84*(1–2), 77–88.

Burke, G. M., & Sydney, J. C. (1963). *Some economic aspects of the marketing of pecans in southern New Mexico*. N.p.: Agricultural Experiment Station, New Mexico State University.

Corbin, M., Kiernan, N. E., Koble, M. A., Watson, J., & Jackson, D. (2004). Using the logic model to plan extension and outreach program development and scholarship. *Journal of Higher Education Outreach and Engagement, 10*(1), 61–67.

Clevenger, T., & Campbell, G. R. (1971). *Marketing practices, problems, and alternatives of the pecan shelling industry in the Southwest* (Agricultural Experiment Station Bulletin Series, Bulletin No. 582). Las Cruces, NM: New Mexico State University, p. 38.

Evenson, R. E. (2000). *Economic impacts of agricultural research and extension*. Retrieved Feb. 10, 2010, from: http://escop.ncsu.edu /infobook/EvensonHandbookChapter1.pdf

Fisher, W. R. (1989). Clarifying the narrative paradigm. *Communication Monographs, 56*, 55–58.

Frazier, B. E., & Cheng, Y. (1989). Remote sensing of soils in the Eastern Palouse region with landsat thematic mapperstar. *Remote Sensing of Environment 28*, 317–325.

Garcia, F., & Fitz, A. B. (1925). *Preliminary pecan experiment* (Bulletin No. 145). N.p.: New Mexico College of Agriculture and Mechanical Arts, p. 18.

Gorman, W. D., Landrum, D. F., & Hicks, S. D. (1980). *Pecan orchard costs and returns for 40 and 320 acres, southern Rio Grande Valley, New Mexico, 1979* (Research Report 413). Las Cruces, NM: Agricultural Experiment Station, NMSU, p. 12.

Harper, R. E. (1960). *A chelate for controlling zinc deficiency in pecan trees*. N.p.: Agricultural Experiment Station, New Mexico State University of Agriculture, Engineering, and Science.

Harper, R. E., & Enzie, J. V. (1956). *Pecan production in New Mexico*. N.p.: Agricultural Experiment Station, College of Agriculture and Mechanic Arts.

Herrera, E. (2005). *Pecan varieties for New Mexico* (NMSU Guide H-639). Retrieved February 10, 2010, from: http://aces.nmsu.edu/pubs/h/h-639.pdf

Herrera, E. (2008). Historical background of pecan plantings in the western region guide (H-626 PH 1-110). Retrieved February 10, 2010, from http://aces.nmsu.edu/pubs/_h/h-626.html

Herrera, E. (2009). *The pecan handbook* (Guide H-631 PH 1-100). N.p.: College of Agriculture and Home Economics, New Mexico State University.

Jakubauskas, M. E., Legates, D. R., & Kastens, J. H. (2002). Crop identification using harmonic analysis of time-series AVHRR NDVI data. *Computers and Electronics in Agriculture, 37*(1-3), 127–139.

Kallestad, J. C., Mexal, J. G., Sammis, T. W., & Heerema, R. (2008). Development of a simple irrigation scheduling calendar for Mesilla Valley pecan growers. *HortTechnology, 18*(4), 714–725.

Masoner, J. R., Mladinich, C. S., Konduris, A. M., & Smith, S. J. (2011). *Comparison of irrigation water use estimates calculated from remotely sensed irrigated acres and state reported irrigated acres in the Lake Altus drainage basin, Oklahoma and Texas, 2000 growing season* (Oklahoma Water-Resources Investigations Report 03-4155). Retrieved from http://pubs.usgs.gov/wri/wri034155/

Miller, D. (1992). Environmental fit versus internal fit. *Organization Science, 3*(2), 159–178.

Samani, Z., Bawazir, A. S., Bleiweiss, M., Skaggs, R., Longworth, J., Tran, V. D., & Pinon, A. (2009). Using remote sensing to evaluate the spatial variability of evapotranspiration and crop coefficient in the Lower Rio Grande Valley, New Mexico. *Irrigation Science, 28*, 93–100.

Sammis, T. W., Mexal, J. G., & Miller, D. R. (2004). Evapotranspiration of flood irrigated pecans. *Agricultural Water Management, 69*(3),179–190.

Sammis, T. W., Riley, W. R., & Lugg, D. G. (1988). Crop water stress index of pecans. *Applied Engineering in Agriculture, 4*(1), 39–45.

Sammis, T. W., Shukla, M. K., Mexal, J. G., Bosland, P., & Daugherty, L. A. (2009). Improving the chile industry of New Mexico through industry, agriculture experiment station, and Cooperative Extension Service collaboration: A case study. *Journal of Extension* [on-line], *47*(1), Article 1RIB4. Available http://www.joe.org/joe/2009february/rb4.php

Simmons, L.J., J. Wang T. W. Sammis D. R. Miller. 2007 An evaluation of two inexpensive energy balance techniques for measuring water use in flood-irrigated pecans (Carya illinoinensis). *Agricultural Water Management*, Vol. 88(Issues 1-3), p. 181-191.

Serrano, L., Filella, I., & Penuelas, J. (2000). Remote sensing of biomass and yield of winter wheat under different nitrogen supplies. *Crop Science, 40*, 723–731.

Statistical Reporting Service. (1963). *New Mexico apple and pecan survey*. Las Cruces, NM: New Mexico Department of Agriculture, Agricultural Statistics; U.S. Department of Agriculture.

Sullivan, D. T., O'Connor, G. A., & Herrera-Aguirre, E. (1976). The effect of controlled-availability nitrogen fertilizers on mature pecan trees. *Soil Science Society of America Journal, 40*(3), 470–472.

Weiss, C. H. (1972). *Evaluation research: Methods for assessing program effectiveness*. Englewood Cliffs, NJ: Prentice-Hall.

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