

**New Mexico State University's  
Agricultural Experiment Station's Contribution  
to New Mexico's Economy**

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## Executive Summary

New Mexico State University's College of Agricultural, Consumer, and Environmental Sciences (ACES) is focused on contributing to economic and community development within the state. Research, teaching, and Extension within the College is centered on four primary pillars, with a foundation of education and training. The four pillars are (1) food and fiber production and marketing; (2) water use and conservation; (3) family development and health of New Mexicans; and (4) environmental stewardship.

A large component of the College's efforts is housed within the Agricultural Experiment Station (AES) system. The New Mexico Agricultural Experiment Station system consists of faculty, staff, and resources located at New Mexico State University's main campus in Las Cruces as well as at 12 Agricultural Science Centers located throughout the state. The 12 research stations allow faculty and staff of the Agricultural Experiment Station system to conduct applied research important to diverse local communities and to support local communities through participation in community organizations and events.

This report summarizes the potential contribution that the AES system has on New Mexico's economy. The economic contribution that NMSU's AES system makes to the state's economy can be traced to two major components (1) research expenditures funded by the state, the federal government through capacity and competitive grants, and other funding sources such as industry and non-profit organizations and (2) increases in agricultural productivity, primarily associated with increased effectiveness of inputs. Contributions for this later component are much more difficult to accurately quantify. Other non-quantifiable or difficult to quantify contributions were not addressed in this study.

Economic contribution estimates used input-output analysis facilitated using the IMPLAN software. While based on several rather strong assumptions, the software and method are commonly used to measure economic contributions or impacts. Two models were implemented to estimate potential contributions from NMSU's Agricultural Experiment Station research, one related to expenditures and the second considered increased productivity.

The total contribution of NMSU's Agricultural Experiment Station system derived from both research expenditures and potential increased agricultural productivity on the state's economic output (sales) was estimated to be more than \$137 million. Total contribution to the State's gross domestic product was estimated at more than \$77 million. In terms of state employment, the AES system is estimated to support 1,191 jobs within the state.

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## Background

### The Land-Grant University System

Two months after the establishment of the United States Department of Agriculture (USDA) with the passage of the Morrill Act of 1862, the land-grant university system was established. The mission of the land-grant university system, as designated in the original Morrill Act, is to provide a practical education including topics of agriculture, military tactics, the mechanic arts, and classical studies so that working classes can obtain a liberal, practical education (APLU, 2020). Expansions of the system occurred in 1890, providing funding to states that created land-grant institutions for African Americans, and in 1994, conferring land-grant status to Native American tribal colleges.

The Hatch Act of 1887 created agricultural experiment station (AES) systems as a component of land-grant institutions. The Act allowed for the use of federal funds to establish an agricultural experiment station at each land-grant institution. Annually, the federal government supports individual state agricultural experiment station systems with funds, a majority which must be matched by states, determined by a formula that accounts for the number of small farmers in the state. Established by the Smith-Lever Act of 1914, the Cooperative Extension Service is tasked with disseminating information generated by the agricultural experiment station system (APLU, 2020).

Today 93 established land-grant universities are operating in the United State (Figure 1). Of these, 57 are classified as 1862 schools, 19 as 1890 schools, and 36 as 1994 schools. New Mexico is home to four land-grant institutions, one 1862 and three 1994 schools. These schools include New Mexico State University, Navajo Technical College, the Institute of American Indian Arts, and the Southwestern Indian Polytechnic Institute (USDA-NIFA, ND). In addition, Shiprock, New Mexico, is home to a campus of Diné College, a 1994 land-grant school headquartered in Tsaile, Arizona.

### New Mexico State University

New Mexico State University (NMSU) was established as the New Mexico College of Agriculture and Mechanic Arts in 1888. In 1889, the New Mexico territorial legislature authorized the creation of an agricultural college and experiment station in or near Las Cruces. The University was designated as the land-grant college for New Mexico under the Morrill Act. Today, the University is home to more than 14,000 students and four community or branch campuses in Las Cruces (Dona Ana), Carlsbad, Alamogordo, and Grants. The University is home to nine colleges. The colleges include:

- The College of Agricultural, Consumer, and Environmental Sciences
- The College of Arts and Sciences
- The College of Business
- The College of Education
- The College of Engineering
- The College of Health and Social Services
- The Honors College
- The Graduate School
- The NMSU Library

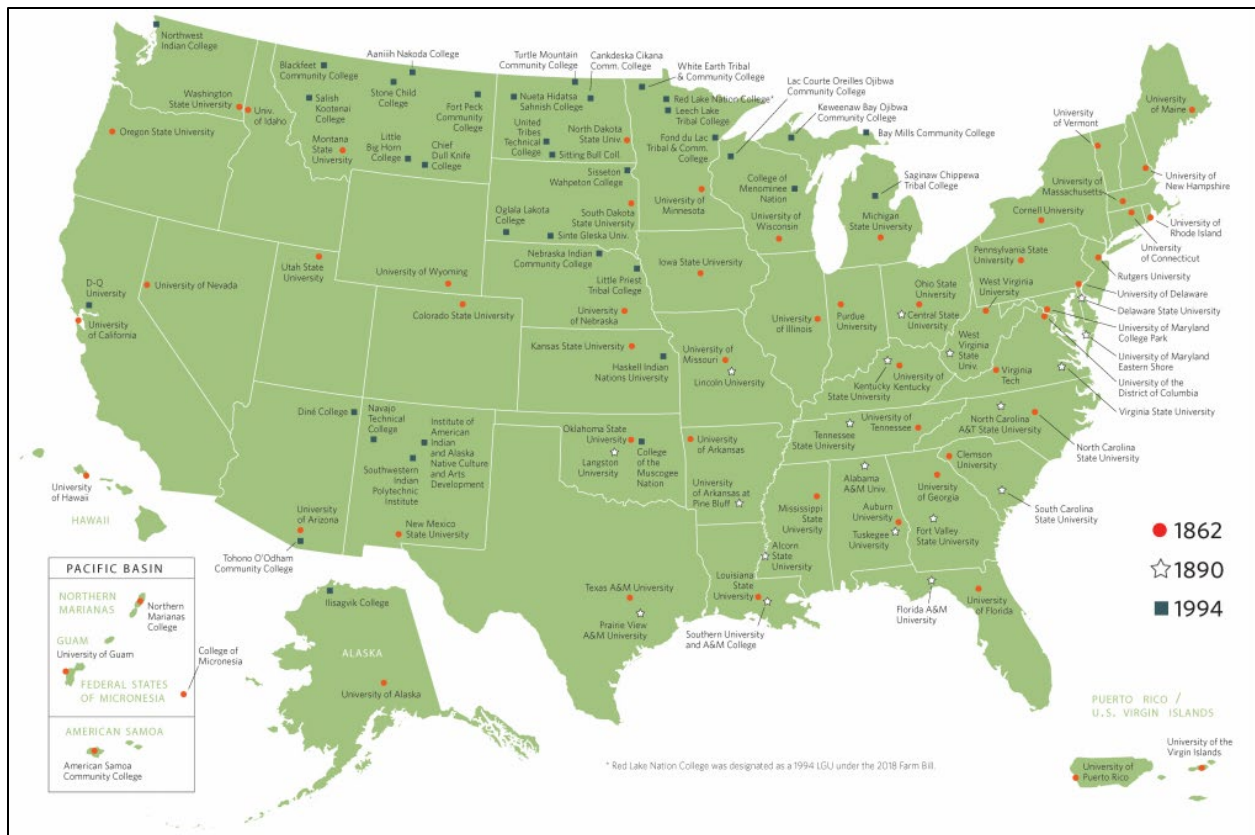


Figure 1. U.S. Land-Grant Universities.

### College of Agricultural, Consumer, and Environmental Sciences

The College of Agricultural, Consumer, and Environmental Sciences (ACES) teaching, research, and Extension activities are designed to make the College a driving force in economic and community development. Research, teaching, and Extension within the College focus on four primary pillars, with a foundation of education and training that support the College’s mission of economic and community development (NMSU-ACES, ND). The four pillars are (1) food and fiber production and marketing, (2) water use and conservation, (3) family development and health of New Mexicans, and (4) Environmental stewardship (Figure 2).



Figure 2. NMSU College of ACES Pillars.



## ***Teaching***

The College has eight academic/research departments, each providing academic training for college students as well as conducting fundamental and applied agricultural research. The College is home to more than 1,400 undergraduate students and more than 200 graduate students (NMSU-OIA, 2020). Many undergraduate and graduate students participate in research projects funded from various sources. Participation in research activities provides students with experiential learning opportunities often not available in non-land-grant institutions. Academic/Research Departments within the College of ACES include:

- The Department of Agricultural Economics and Agricultural Business
- The Department of Agricultural and Extension Education
- The Department of Animal & Range Science
- The Department of Entomology, Plant Pathology, and Weed Science
- The Department Family and Consumer Sciences
- The Department of Fish, Wildlife and Conservation Ecology
- The Department of Plant and Environmental Sciences
- The School of Hotel, Restaurant, and Tourism Management

## ***Research***

In addition to teaching responsibilities, a majority of academic faculty appointments within the College include research responsibilities. In 2020, there were 365 faculty and staff associated with the AES system, i.e., who have at least a partial AES appointment. Additionally, faculty and staff housed at the 12 agricultural science centers throughout the state conduct applied research, complementary to research conducted on the main campus. These faculty tend to have 100% research appointments (Figure 3).

## ***Extension***

The College of ACES has Extension Specialists in six specialist departments. Extension specialists provide applied research, develop training, and outreach programs related to animal science and natural resources, economics, family and consumer sciences, plant sciences, youth development programs, e.g., 4-H programs, and Innovative media. Extension specialists work closely with Extension county agents located throughout the state. There are Cooperative Extension Service offices in all 33 counties within the state where county agents provide hands-on education and training for interested stakeholders.

## **New Mexico Agriculture**

New Mexico is recognized as one of the older agricultural production regions of the United States. For example, records indicate that mission grapes planted as early as 1629 by Franciscan monks were used to produce sacramental wine in Central New Mexico (NMSU Viticulture, ND). Similarly, chile, for which the state is famous, was introduced in the region in 1598 by the Spanish conquistador Don Juan Oñate (New Mexico True, ND).

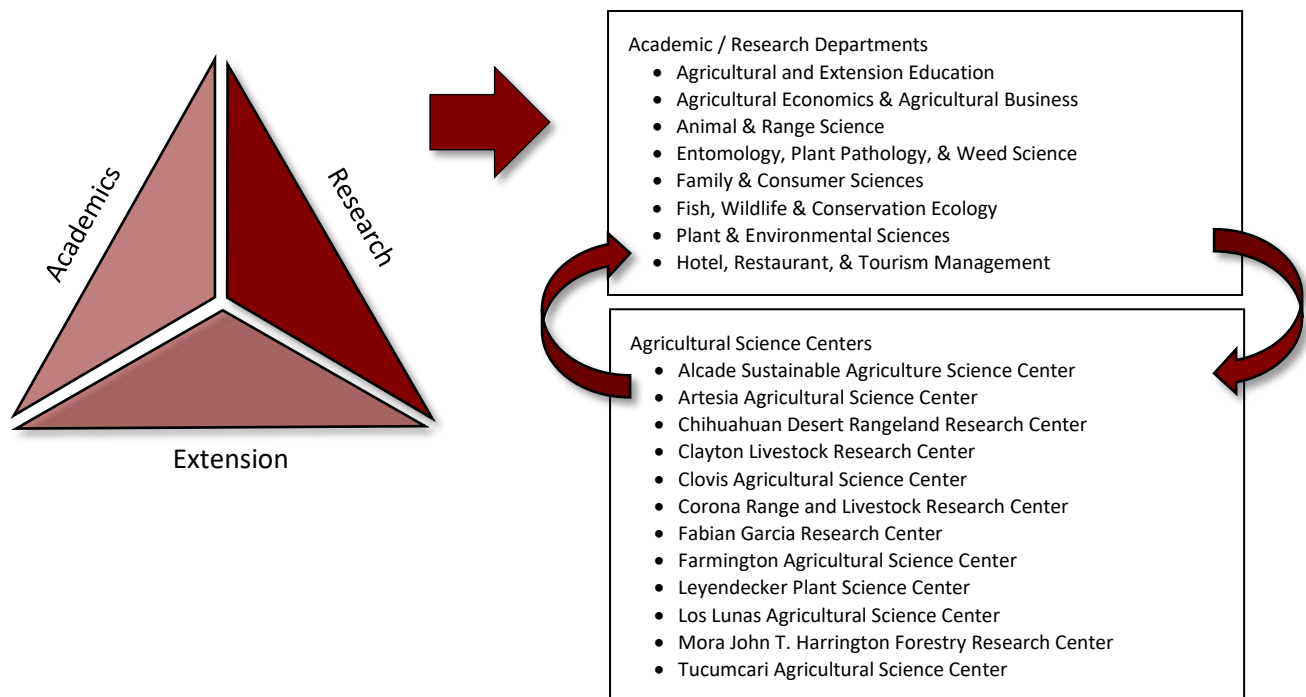


Figure 3. Research within the Land-Grant University and College of ACES Missions.

Today, the state is home to nearly 25,000 (24,800) farmers and ranchers that produced more than \$3.4 billion in agricultural output in 2019 (USDA-NASS, 2019). More than three-quarters of the agricultural product value, 77.2% is from livestock operations, mainly dairy and cattle operations. In addition, the state has 221 food and beverage manufacturing establishments, 475 food and beverage stores, and nearly 3,000 (2,929) restaurants (U.S. Census, 2020).<sup>1</sup>

The state is a national leader in pecan production, ranked first in production with 87 million pounds produced in 2019, 34.4% of total U.S. production. The state also led the country in chile production in 2019 producing 126.1 million pounds (76.7% of total U.S. production). Other notable New Mexico agricultural production includes Pima cotton, 4<sup>th</sup> in the U.S. (5.7% of U.S. production); dry onions, 5<sup>th</sup> in the U.S. (5.7% of U.S. production); milk, 9<sup>th</sup> in the U.S. (3.8% of U.S. production); and cheese, 4<sup>th</sup> in the U.S. (7.3% of U.S. production) (USDA-NASS, 2019).

### New Mexico's Agricultural Experiment Station System

The New Mexico Agricultural Experiment Station (AES) system consists of faculty, staff, and resources located at New Mexico State University's main campus in Las Cruces as well as at 12 Agricultural Science Centers (ASCs) located throughout the state. The 12 research stations allow the faculty and staff of the AES system to conduct applied research under the varying agricultural and weather conditions around the state. New Mexico has a diverse agricultural environment consisting of four different crop

<sup>1</sup> The analysis described in this report explores the economic contributions of production agriculture only, i.e., it does not account for food manufacturing or retailing (except to the extent that contributions to production agriculture influence these down-stream industries).

production regions, 11 plant hardiness zones, five different watersheds, and 126 different soil types (Moorman, 2020). Faculty and staff housed at ASCs regularly interact with faculty and staff at the NMSU Las Cruces campus in coordinating research projects. Additionally, having research stations throughout the state allows each station to support local communities. For example, station faculty and staff commonly participate in community organizations and events.

### **The Economic Contribution of the Agricultural Experiment Station Systems**

The economic contribution or potential contribution of New Mexico State University's AES system on the state's economy comes from two different sources. The first and most immediate contribution source is associated with research expenditures, funded by both the state and external partners, e.g., the federal government. The second contribution source is associated with increased agricultural productivity resulting from the research conducted by faculty and staff within the system. Both contributions can be estimated using input-output analysis. The analytical method is described below, along with the explanation of how each of the two sources identified above can impact the state's economy.

#### **Methodology**

Input-output analysis has been used for many years as a methodology to estimate economic relationships of geographically defined economies. The method was developed in 1930 by Wassily W. Leontief to help model national economies by quantifying the interrelationships between the nation's industry sectors within the economy. Today, the input-output methodology is used often to measure the impacts or contributions that a particular event has on nations, as well as on States and counties.

#### **Assumptions**

While extremely useful for evaluating and describing the impacts that can occur with underlying changes in one particular industry, the input-output methodology does have several limiting simplifying assumptions to note. These assumptions or limitations include (IMPLAN, ND):

- (1) *Backward linkages*. Only backward linkages and the impacts on industry segments before the industry that experienced changes ("upstream participants") are measured;
- (2) *Constant returns to scale*. Input requirements remain constant per unit of output, regardless of how much output is generated, i.e., a ten percent increase in output requires a ten percent increase in inputs;
- (3) *No supply constraints*. There are unlimited amounts of inputs available for production;
- (4) *Fixed input structure*. Substitutions in inputs in response to changes in output are not allowed;
- (5) *Industry technology assumption*. An industry uses the same technology to produce each of the products within the industry;
- (6) *Constant make matrix*. Industries increase outputs proportionately, i.e., one output produced within the industry will not increase without a proportionate increase in other outputs within the same industry; and

(7) *Time is static*. Changes in input mixes, i.e., adoption of technologies over time that would change input uses, are not reflected in the methodology.

### **Contribution Classifications**

Contributions<sup>2</sup> to the economy identified by the input-output methodology are commonly defined by three categories: direct, indirect, and induced. The various categories might be thought of as “ripple effects.” Direct contributions arise due to a specific action, e.g., AES system research expenditures. Induced and indirect contributions are “ripple effects” in the economy generated as a result of the initial impact occurring (Figure 4).

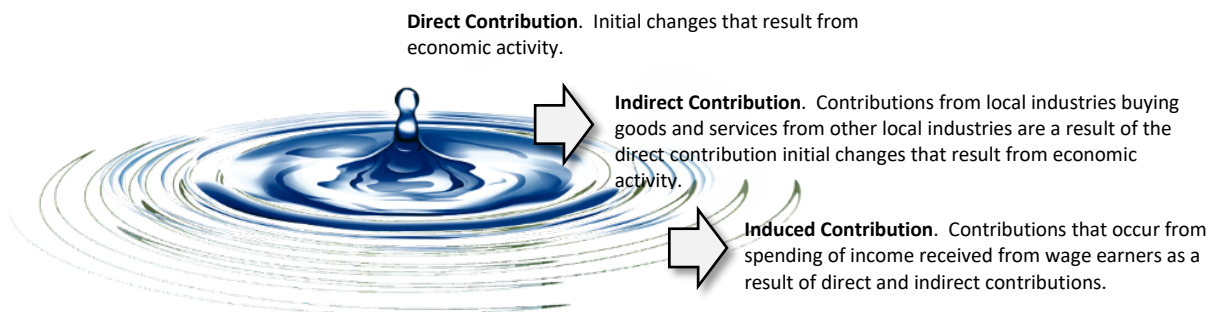


Figure 4. Direct, Indirect, and Induced Contributions.

**Direct contributions.** Direct contributions are estimates that are the result of the initial change within a particular industry sector or sectors. For example, in the analysis described in this report, the initial research expenditures made by faculty and staff within the AES system might be thought of as a “direct contribution” or injection of money into the state’s economy. Similarly, increased farm or ranch revenues created by research advancements could be considered direct contributions of the AES system.

**Indirect contributions.** Indirect contributions are contributions that result from intermediary purchases among industry sectors (business-to-business) within the economy that are derived as a result of direct contributions. For example, an auto mechanic purchasing supplies and tools to work on AES system automobiles would constitute an indirect contribution to the economy. These contributions can continue as economic activities continue. For example, the equipment dealer (who sold tools to the mechanic) purchases fuel for their tool truck, again creating an indirect economic contribution to the state’s economy.

**Induced contributions.** Induced contributions are associated with increased household spending resulting from direct and induced contributions. For example, when AES system employees purchase groceries from the local grocery store, they are generating indirect contributions to the state’s economy.

<sup>2</sup> Input-output analysis is commonly used to quantify “impacts” or “contributions” that a specific event has on an underlying economy. The difference between an “impact” or “impact study” and a “contribution” or “contribution” study depends on the nature and size of the event. A discussion of the difference is beyond the scope of this report. The following references detail the differences: Lucas (ND); Watson et al. (2007).

Like induced contributions, these contributions can continue to be generated as employees throughout the economy spend their income. For example, the grocery store employee uses some of their income (a result of prior induced and indirect contributions) to have the oil in their car changed.

**Economic Multipliers**

Economic multipliers associated with output, employment, and/or added value, e.g., gross state product, are often reported in economic impact or contribution analyses. A multiplier is a simple way to describe the magnitude of a direct impact or contribution on the economy as those initial impacts ripple through the economy. Figure 5 illustrates graphically how the multiplier is calculated. Assume that one dollar is spent inside the state as a direct impact or contribution and that (by assumption) 40% of the expenditure leaves the state. Given that the money is no longer able to be spent by other businesses or individuals within the state, only \$0.60 is available for the second round of spending (associated with indirect and induced contributions), continuing throughout six cycles (until the contribution is essentially zero), the total spending within the economy has increased to \$1.66 (a multiplier of 1.66). That is, an additional \$0.66 has been generated or spent through the economy as various economic participants (businesses and households) spent money.

**Sources of Economic Contribution**

There are two primary ways in which the AES system contributes to the State’s economy. The first contribution arises as each Agricultural Experiment Station unit (Academic/Research Department or Agricultural Science Center) uses funds provided by the state, combined with funds provided by the federal government and other organizations, e.g., non-profit foundations, to conduct research. The research expenditures circulate through the economy creating economic activity and generating economic output. These impacts are relatively easy to identify and measure.

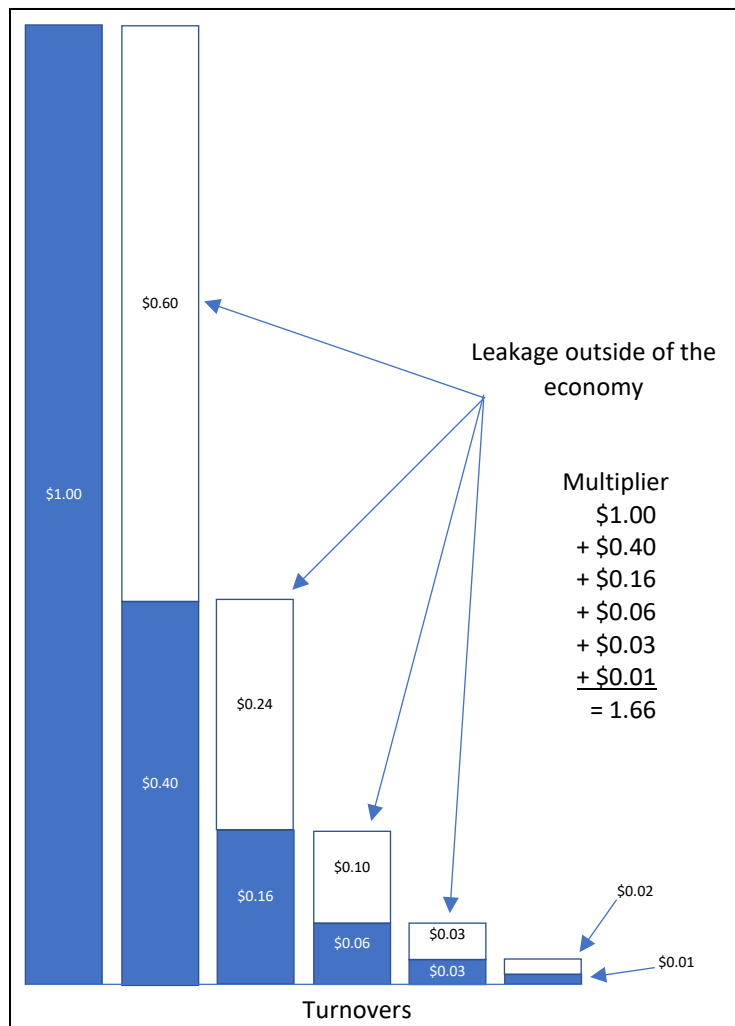


Figure 5. Economic Multiplier. Source: Crawford (2011).

The more difficult contributions or impacts to measure, which may in fact be impossible to completely measure, are those that result in new or improved agricultural products<sup>3</sup> (or other products, e.g., pharmaceuticals) resulting in greater agricultural productivity or increased efficiencies leading to production cost reductions. These benefits, which have been referred to as “functional impacts” or “functional contributions” (Tripp, Grueber, and Cummings, 2018) are significant, likely much more significant than those created by research expenditures, and they are much more difficult to measure.

In both cases, the direct contribution or impact must first be identified, and its expected contribution quantified. Once these benefits have been quantified, the input-output analysis described can be used to identify additional indirect and induced contributions.

## **The Agricultural Experiment Station’s Contribution to New Mexico’s Economy**

### ***Contributions from Expenditures***

Funding for the NMSU AES system comes primarily from three sources. The first is state-allocated funding, referred to as “unrestricted” in the University budget vocabulary. Second, “restricted” funding is appropriated funds from the federal government in the form of “capacity funding,” which requires a one-to-one match from unrestricted sources. Lastly, funding obtained by faculty through competitive processes of writing grants and obtaining contracts is also referred to as “restricted” funds. Federal funds allocated by the USDA’s National Institute of Food and Agriculture (NIFA) in 2020 are shown in Figure 6 (CRS, 2020). Last, a small amount of revenue is derived from sales and services at the ASCs.

Figure 6 shows that approximately one-half (48%) of federal funds in 2020 were allocated to the country’s 112 land-grant institutions in the form of capacity grants. These funds are allocated to universities based on a formula provided in federal statutes. The formulas use Census-based statistics that include, among other factors, the number of small farms within the state. The other 52% of federal funding is allocated through the competitive grant process that includes peer-review and can be awarded to both land-grant institutions and non-land grant institutions. Funds available to land-grant institutions support both research (the AES system) and Extension (the Cooperative Extension Service). In many cases, funding from both the capacity grant side and the competitive grant side are designated for certain programs or schools, e.g., veterinary and forestry schools or land-grant university designations, e.g., 1862 and 1890 schools.<sup>4</sup>

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<sup>3</sup> The new or improved products are not necessarily agricultural in the traditional sense. For example, research related to agricultural production/commodities has been successful in identifying valuable pharmaceutical products and providing insights into ways to manage human diseases, e.g., cancer.

<sup>4</sup> A broader debate about the appropriate mix of capacity and competitive grant funding for universities is underway, with proponents on both sides, i.e., proponents for increasing the proportion of funding that is determined competitively and proponents for increasing the proportion of capacity funding. Relative to the topic of this report, it should be noted that some research has suggested that capacity funding has a larger positive impact on agricultural productivity over the long-run and is spread out across a wider range of states (CRS, 2020).

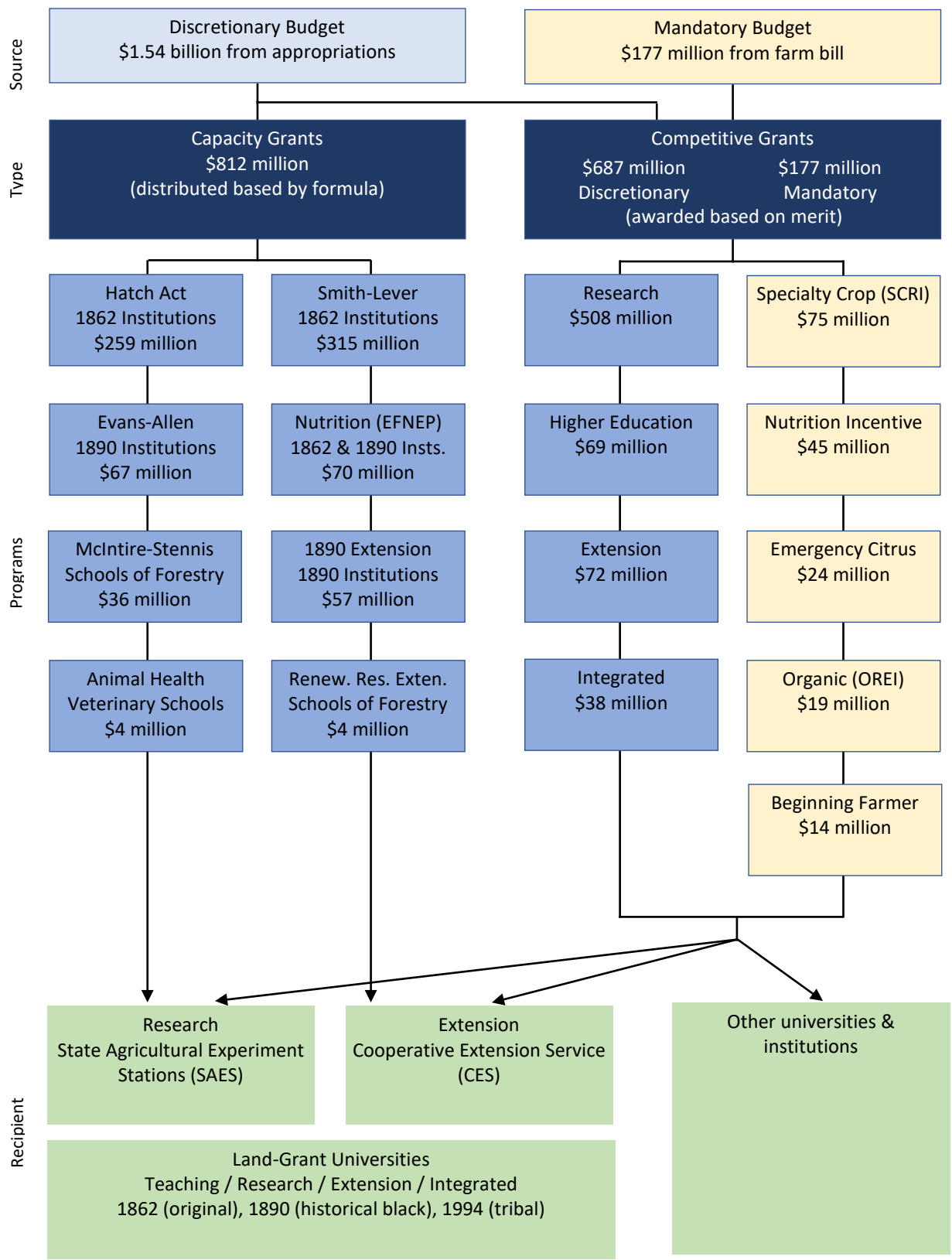


Figure 6. National Institute of Food Agriculture Budget (FY 2020 budget authority). Source: CRS, 2020.

Over the past seven years, New Mexico State University’s AES system has received an average of \$18,728,048 in unrestricted funding from the state of New Mexico. This funding has been matched with federal restricted funding at an average rate of 81%, that is, for every dollar that the state of New Mexico provides to the New Mexico State Agricultural Experiment Stations, the system is able to obtain \$0.81 in outside funding via competitive grants and contracts. The matching rate has increased over the increasing participation and becoming more competitive in the competitive grant process. Last seven years. In FY2020 the system match rate was 98% (Figure 7), suggesting that faculty are increasing participation and becoming more competitive in the competitive grant process. For the fifth consecutive year, faculty in the College of ACES have led other NMSU colleges in grants and contracts requested and awarded.

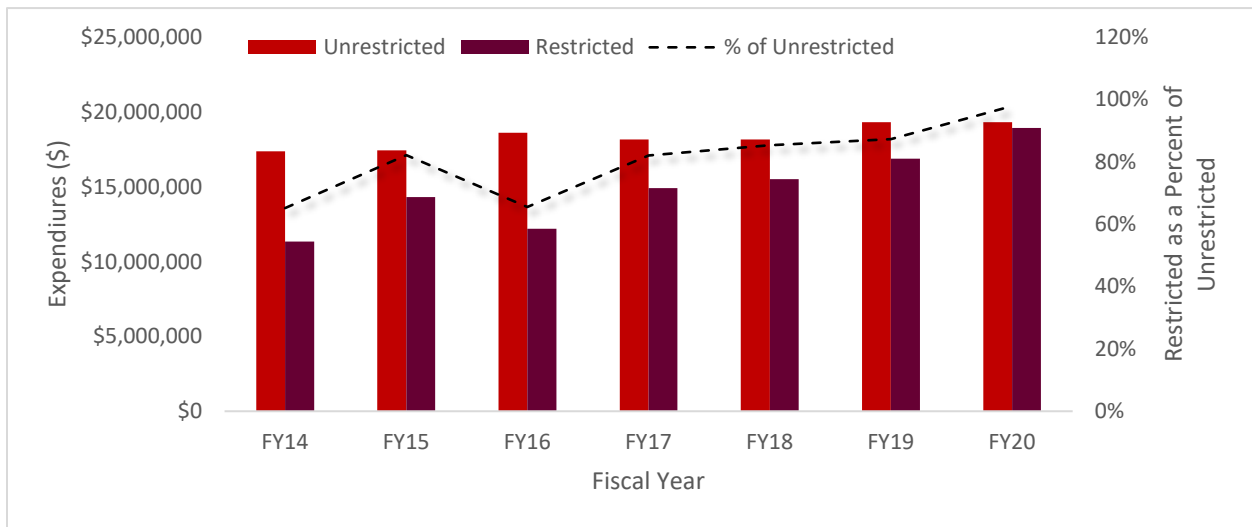


Figure 7. NMSU AES Unrestricted and Restricted Funds, FY14-FY20. Source NMSU ACES.

Funds provided by both the State to support expenditures in FY20 (\$19,332,308) and expenditures from funds provided by the federal government (\$18,938,102) can be considered “direct contributions.” These funds are expended throughout the AES system via expenditures made by researchers and staff located at the system’s 12 agricultural science centers and by researchers with joint appointments located at the Las Cruces campus. These expenditures support local economies as well as contribute to the overall economic activity within the state.

Using input-output analysis implemented using the IMPLAN software, the direct contribution of about \$38.3 million from the sources described above resulted in a total economic contribution in terms of economic output to the state of more than \$63 million (Table 1). The economic multiplier associated with output contributions of the AES system was estimated to equal 1.67. This multiplier indicates that every dollar invested in NMSU’s AES system results in an additional \$0.67 of economic activity (sales) in the State. Similarly, for every dollar invested into NMSU’s AES system, the state’s gross domestic product increases by an additional \$0.45 (a multiplier of 1.45).<sup>5</sup>

<sup>5</sup> The multiplier is calculated as the total contribution (employment, value-added, or output) divided by the direct contribution. For example, the multiplier associated with value-added (state gross domestic product) is calculated as \$42,965,174 / \$29,624,633 = 1.45.



An additional 161 jobs were created as a result of the efforts of the Agricultural Experiment Station operating within the state, resulting in a total employment contribution of 526 jobs. The total contribution to the state’s domestic product referred to as “valued-added” (Clouse, ND) in the IMPLAN modeling software was estimated to be more than \$42 million. These contributions are associated only with the System’s expenditures and do not include contributions that are associated with potential agricultural productivity increases which are discussed in the next section.

Table 1. Economic Contributions from NMSU AES System Related to Research Expenditures

| Contribution | Employment | Value Added  | Output       |
|--------------|------------|--------------|--------------|
| Direct       | 365        | \$29,624,633 | \$38,270,410 |
| Indirect     | 39         | \$3,307,917  | \$7,472,796  |
| Induced      | 123        | \$10,032,624 | \$17,996,380 |
| Total        | 526        | \$42,965,174 | \$63,739,586 |

Industries that are most influenced by the research expenditures described above, based on total economic activity associated with the spending, are shown in Table 2. Industries that are most influenced by the research expenditures, based on employment, are shown in Table 3.

Table 2. Top 10 Supported Industries from AES Expenditures, Based on Output

|    | Industry  | Output Impact  |
|----|---|----------------|
| 1  | Other real estate   | \$3,800,124.65 |
| 2  | Owner-occupied dwellings                                  | \$2,464,387.15 |
| 3  | Other local government enterprises                        | \$1,199,849.82 |
| 4  | Hospitals   | \$1,192,630.16 |
| 5  | Insurance carriers, except direct life                    | \$776,674.20   |
| 6  | Full-service restaurants                                  | \$636,328.03   |
| 7  | Limited-service restaurants                               | \$628,140.35   |
| 8  | Tenant-occupied housing                                   | \$577,228.60   |
| 9  | Offices of physicians                                     | \$572,866.83   |
| 10 | Monetary authorities and depository credit intermediation | \$554,707.58   |

Table 3. Top 10 Supported Industries from AES Expenditures, Based on Employment

|    | Industry                            | Employment (Jobs) |
|----|-------------------------------------|-------------------|
| 1  | Other real estate                   | 19                |
| 2  | Full-service restaurants            | 10                |
| 3  | Limited-service restaurants         | 8                 |
| 4  | Hospitals                           | 6                 |
| 5  | Individual and family services      | 4                 |
| 6  | Offices of physicians               | 4                 |
| 7  | Retail - General merchandise stores | 4                 |
| 8  | Home health care services           | 4                 |
| 9  | Other local government enterprises  | 4                 |
| 10 | All other food and drinking places  | 4                 |

***Economic Contributions from Increased Productivity***

The following provides a discussion and an example of how the AES system contributes to New Mexico's economy. The estimates provided at the end of this section should be considered only as potential impacts given the difficulty associated with linking specific research to productivity increases, as discussed below.

*Productivity and Public R&D in Agriculture*

Agricultural output in the United States has grown significantly over time, while input use has remained relatively constant (Figure 8). In broad terms, increases in agricultural output can occur as the result of three factors: increased factor productivity growth, e.g., using existing resources more efficiently, increased use of inputs, i.e., using more inputs, and short-term shocks, e.g., weather or short-term policy actions. A core driver of factor productivity and, to a lesser extent, input use/growth is the quality of the input. Input quality, including land, human capital, and others, e.g., water, fertilizer, equipment, can be increased directly via public and private research and development (R&D) efforts. Extension training and quality infrastructure also play a role in the process of improving input quality and ultimately increasing agricultural output growth (Figure 9).

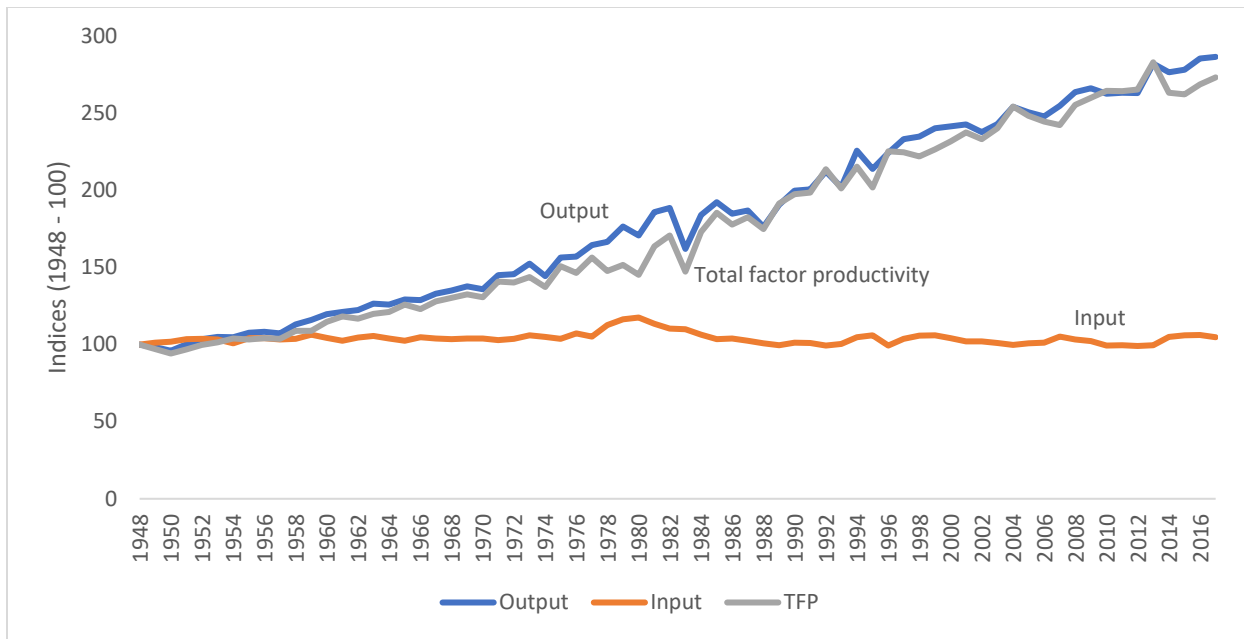
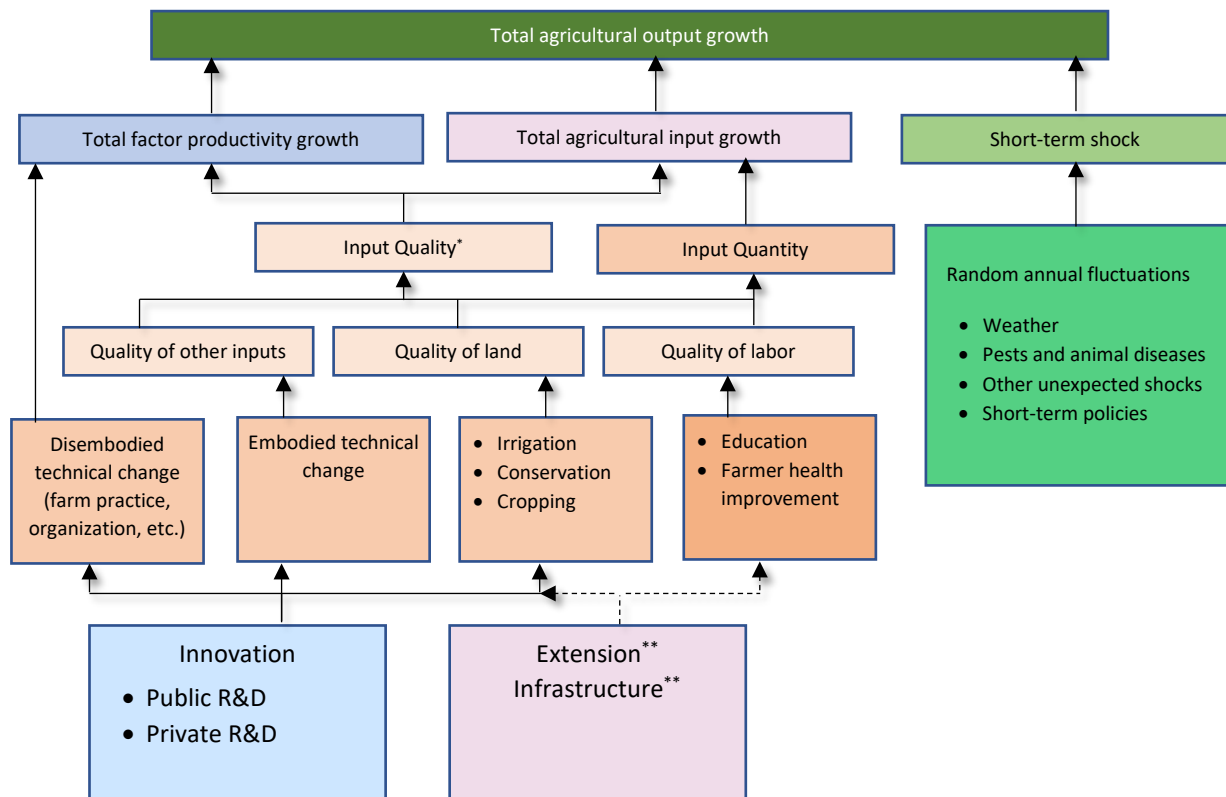


Figure 8. Agricultural Output, Input, and Factor Productivity, 1948-2017. Source USDA-ERS (2020).



\* Direction of input quality depends on how TFP and input are defined and measured.

\*\* These activities may enhance knowledge dissemination to improve input quality and farmers' operational skills.

Figure 9. Sources of Agricultural Output. Source: Wang et al. (2015, modified).

The impacts of public agricultural research (and extension) on agricultural productivity have been studied in some detail. Research has shown that Federal-State partnerships in public agricultural research and development (R&D) have been a key factor in increased agricultural productivity (Fuglie et al., 1996; Huffman and Evenson, 2006; Alston et al., 2010; and Heisey et al., 2010). Additionally, some research has suggested that public research expenditures also spur private research, thus leveraging public monies with private funding and increasing overall productivity.

Estimating the returns to public research investments is difficult for a variety of reasons, including the time it takes for research findings to be commercialized (sometimes referred to as the “gestation period”) and estimating the time that the innovation will be used commercially, (sometimes referred to as the “time path”).

For example, one method of estimating the returns to research and development that has been used in the literature is to estimate the social internal rate of return of R&D investments. The “social internal rate of return” is defined as the internal rate of return that accounts for benefits to both farmers (higher profits) and consumers (more food or assortment of food at lower prices). A return of 17%, as estimated by Baldos et al. (2015), shown in Table 4, might be interpreted as an annual return of \$0.17 for every \$1.00 invested in R&D, for the useful life of the improvements, i.e., the R&D time path.

Estimates of the social internal rate of return (IRR) to public agricultural R&D range from 17% to 67% (Table 4). An alternative way of assessing the impacts of R&D investments (as opposed to social IRRs) is to estimate the ratio of benefits to costs, i.e., the benefit-cost (BC) ratio. The BC ratio can be approximated by dividing the IRR estimate by the real interest rate faced by the government. For example, if the cost of government borrowing is 4% (in real terms) the IRR estimate of 17% would suggest that for every dollar invested in R&D, the cumulative discounted benefits to society, in this case, farmers and consumers would be \$4.25. Long-term real Treasury rates, a measure of the government’s cost of borrowing, ranged from 0.27% to 1.19% in 2019. Using an estimate of 1.19% for the real Treasury rate (most conservative), approximated benefit/cost ratios associated with social IRRs reported in Table 4 ran from 14.3 to 56.3.

Estimates reported in Table 4 depend on several assumptions, a key one being the “time path” of R&D efforts. The time path describes the length of time the R&D is assumed to contribute to agricultural productivity. Included in the period is the time taken to commercialize developed technologies, the time for technology adoption and diffusion by agricultural stakeholders, and the time before the adopted technology becomes obsolete. In general, studies that assumed a long life for capital developed via R&D (the period before the technology becomes obsolete) also assumed a longer “gestation” period. Hence, longer time paths are correlated with lower social IRRs (Alston, 2010). The gestation lag suggests that while agricultural R&D investments may have high returns, current expenditures (outside of the contribution discussed above) will have little impact on contemporaneous agricultural productivity (Heisey and Fuglie, 2018).

Table 4. Estimated Social IRR to Agricultural R&D. Source: Heisey and Fuglie (2018, Modified)

| Authors / Researchers      | Social IRR <sup>1</sup> | Approximated BC Ratio <sup>2</sup> | Period    | R&D Time Path |
|----------------------------|-------------------------|------------------------------------|-----------|---------------|
| Baldos et al. (2015)       | 17%                     | 14.29                              | 1949-2011 | 50 years      |
| Anderson and Song (2013)   | 21%                     | 17.65                              | 1949-2002 | 50 years      |
| Alston et al. (2010)       | 23%                     | 19.33                              | 1949-2004 | 50 years      |
| Wang et al. (2012)         | 45%                     | 37.82                              | 1980-2004 | 35 years      |
| Jin and Huffman (2016)     | 67%                     | 56.30                              | 1970-2004 | 35 years      |
| Huffman and Evenson (2006) | 56%                     | 47.06                              | 1970-1999 | 35 years      |

<sup>1</sup> Presented in real terms, i.e., adjusted for inflation.

<sup>2</sup> Approximated using real long-term Treasury rate estimate of 1.19%.

#### *Examples of NMSU AES Research with the Potential to Increase Productivity*

Researchers affiliated with NMSU’s Agricultural Experiment Stations are involved in many research projects capable of producing returns similar to those identified in Table 4. In the following section, a small sample of current research projects/programs is identified. Appendix I contains a more comprehensive, yet still non-exhaustive list of research efforts currently underway within the system. New Mexico State University’s College of Agricultural, Consumer, and Environmental Sciences (ACES) maintains a database of “ACES Impacts” that provides a summary of a large number of research projects currently underway.

#### **Strengthening Existing Crops and Exploring New Alternatives: Apples and Jujube Fruit**

New Mexico historically had a significant fresh apple industry within the state. The state’s peak apple production occurred in 1964 when the state produced 47.3 million pounds of apples. But production diminished over time due to a variety of factors. In the 2002 Agricultural Census, New Mexico reported 1,814 acres of apples. In the 2017 Census, less than one-half of the acreage reported 15 years earlier was shown (Figure 10). In 2019, apple sales for New Mexico were estimated to equal \$797,056.

Recognizing the needs of the state’s apple producers, NMSU Agricultural Experiment Station researchers are exploring alternative varieties of apples that may be better suited to the state’s current growing conditions and are in demand by consumers. Additionally, researchers are exploring new fruit crops that might supplement and, or in some cases, replace apple production as a source of farm income. For example, Agricultural Experiment Station researchers are exploring opportunities to grow jujube fruit, originally from China. The fruit is highly nutritious and well-suited to New Mexico growing conditions, e.g., they bloom later in the year avoiding frost issues often observed in apple production and are relatively low water users. Research is exploring varieties that are best suited to New Mexico growing conditions and most preferred by U.S. consumers.

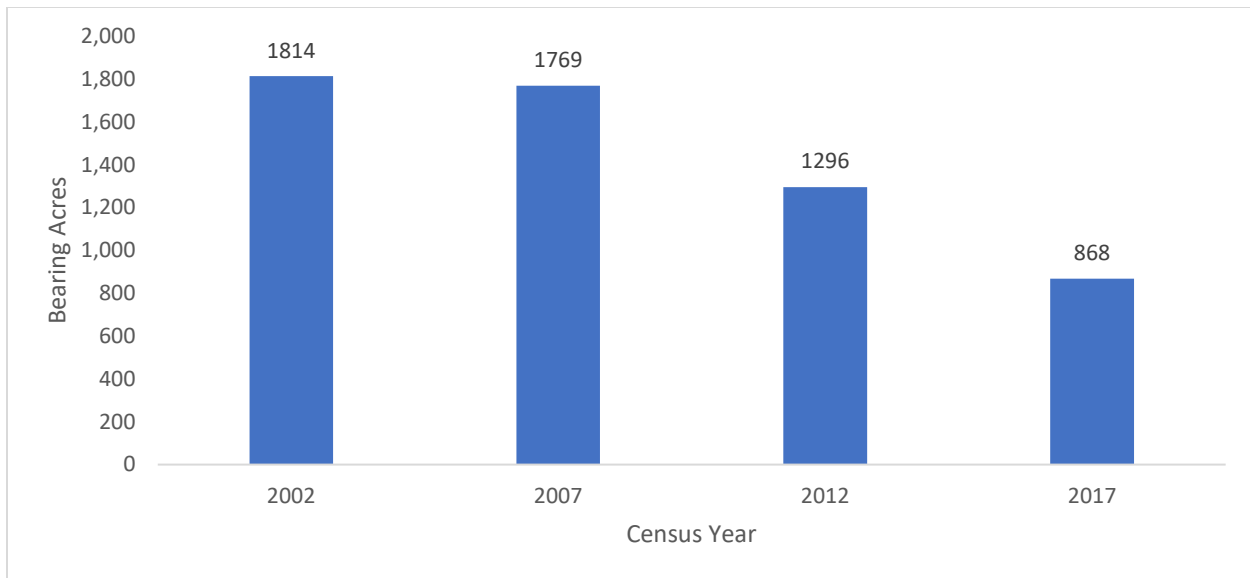


Figure 10. New Mexico Apple Acreage, 2002-2017. Source U.S. Census, 2017.

#### Improving Genetics: Pecan Genetics

New Mexico is a leading pecan producer in the United States, producing nearly 88 million pounds in 2019 with a production value of \$165,064,000 on 45,000 acres. Pecan trees are generally heavier water users than other crops, with consumptive use estimated to range from 3.3 to 4.3 acre-feet per year depending on several factors including tree size and density (Magnuson et al., 2019). Researchers associated with NMSU’s Agricultural Experiment Station system along with other researchers throughout the U.S. successfully obtained a five-year grant for nearly \$5 million from USDA to explore pecan genetics. By better understanding the genetic makeup of pecans, researchers may be able to develop trees that can produce similar yields using less water.

Estimating the potential return to the state is complicated as the estimation requires numerous, for-the-time unverifiable assumptions. Assumptions needed to estimate the long-term potential impact of this research includes the value of water (over time), the amount of irrigation water that could be saved from more water-efficient trees, the length of time to get commercialize the research (get it from the research lab to the producer), the amount of time that producers would take to adopt the new trees, the length of time before trees began to produce pecans, the length of time that the technology would be in existence before it becomes obsolete, price reactions to potentially reduced water demand and/or increased pecan production.

The following narrative illustrates how pecan research might benefit the state, based on untested assumptions for illustrative purposes (not meant to be construed as actual benefits based on proven assumptions). Using the water price estimates from Hurd and Coonrod (2012) of \$54.17 per acre-foot, if NMSU research resulted in pecan trees using one less acre-foot per year the value of the research, each year would be \$2.4 million. Using the multiplier estimated above (1.67) this value would increase to \$4.0 million. An internal rate of return (IRR) similar to those reported earlier could be constructed for these

water savings but would depend on how long it takes to get trees into production, adoption rates, and the length of time the trees would continue to produce.<sup>6</sup>

### Reducing Livestock Disease Impacts

New Mexico farmers and ranchers reported 1.5 million cattle and calves in 2019. Beef cattle used for meat production are placed on feedlots and more than 20% of those cattle experience Bovine Respiratory Disease (BRD). Existing treatments that include the use of antibiotics are expensive, estimated to be more than \$20 per animal, and have varying levels of success (some estimates that existing treatments are approximately 70% effective). At the national level, BRD costs to the industry are estimated at more than \$600 million per year. Researchers are exploring alternative strategies to prevent and manage BRD based on nutritional strategies that can reduce antibiotic use and increase cattle immunity.

### *Estimates of New Mexico Agricultural Productivity Growth*

New Mexico has seen impressive agricultural productivity growth over the last 60 years.<sup>7</sup> Between the period of 1960 to 2004, New Mexico ranked 7<sup>th</sup> in the country in terms of growth of farm output with an annual average growth rate over the period of 2.25% (Figure 11).<sup>8</sup> The average agricultural productivity growth over the same period for the U.S. was 1.33%.<sup>9</sup> Since 2004 (between 2004 and 2017), agricultural productivity for the entire U.S. has grown at a rate 0.92%.

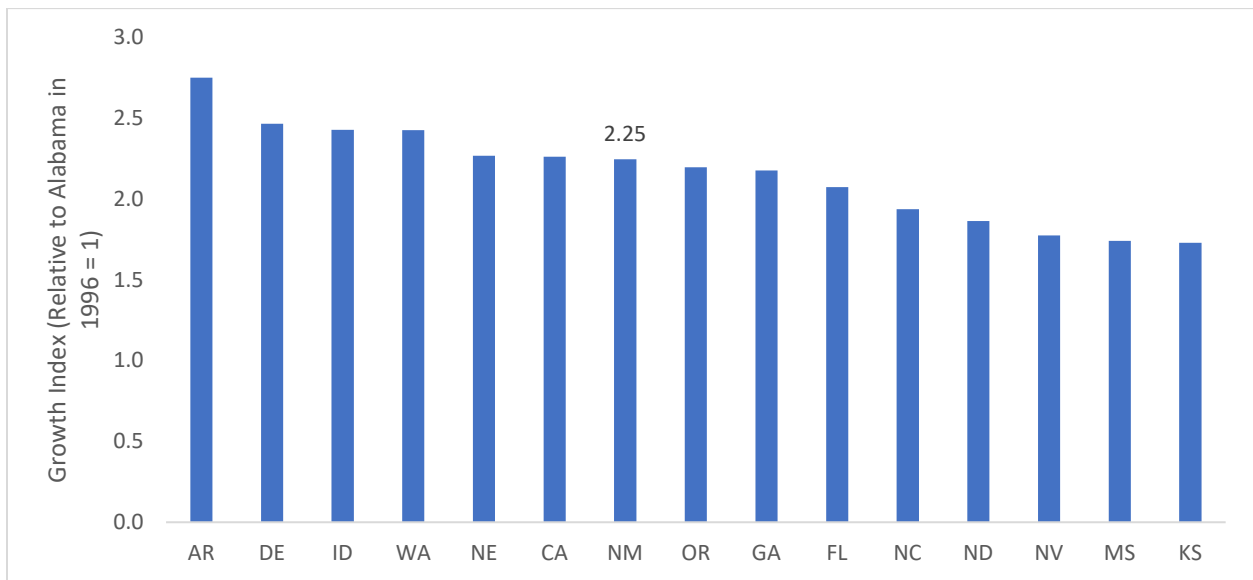


Figure 11. Annual Growth in Agricultural Output, 1960 to 2004. Source USDA-ERS (2020).

<sup>6</sup> As indicated previously, estimating the social IRR is extremely difficult and must account for the potential that the research never translates into a commercial product, the gestation period, and the time path.

<sup>7</sup> Only looking at production level growth. Does not include other components of the agricultural supply chain, e.g., food manufacturing.

<sup>8</sup> USDA compiled state-level growth rate data beyond 2004 is not available.

<sup>9</sup> Excludes Alaska and Hawaii.

One of the contributing factors to New Mexico’s productivity growth, exceeding the average growth for the U.S. is farmers (and ranchers) using more inputs. During the same 44-year period identified earlier, New Mexico’s annual growth rate in input use rate was the second highest in the country with an average increase of 0.80%. If we assume positive and negative short-term shocks, on average, offset each other, the difference between the total agricultural productivity growth (2.25%) and the growth in input use (0.80%) may serve as a rough growth measure of input quality largely attributed to agricultural R&D.

New Mexico’s agricultural cash receipts in 2019 totaled more than \$3.18 billion, approximately 77% coming from livestock and livestock products and 23% from crops and crop products. If the difference between overall agricultural productivity and input use, is considered a measure of productivity attributable to agricultural R&D, and we ignore the time path lag, in 2019 more than \$46 million of the state’s agricultural cash receipts could be attributed to productivity growth. Assuming further that public R&D created through NMSU’s Agricultural Experiment Station makes up the majority of R&D attributable to the productivity increase, the \$46 million can serve as a “direct contribution” associated with the AES system.<sup>10</sup> Using the input-output methodology described previously to estimate contributions generated by research expenditures, the total contribution to the state’s economy associated with the Agricultural Experiment Station system, given the assumptions described earlier, is estimated to equal \$73,370,808 (Table 5).

Table 5. Economic Contributions from NMSU AES System Related Productivity Growth

| Contribution | Employment | Value Added  | Output       |
|--------------|------------|--------------|--------------|
| Direct       | 499        | \$20,798,818 | \$46,528,772 |
| Indirect     | 79         | \$7,272,060  | \$14,721,928 |
| Induced      | 87         | \$6,637,826  | \$12,120,107 |
| Total        | 665        | \$34,708,704 | \$73,370,807 |

### Conclusions

The economic contribution that NMSU’s Agricultural Experiment Station (AES) system makes to the state’s economy can be traced to two major components. The first contribution is associated with the research expenditures that are made throughout the year. These expenditures are funded by several sources including the state, the federal government through capacity and competitive grants, and other funding sources such as industry and non-profit organizations. Estimating the contribution that occurs as a result of system expenditures is relatively easy.

<sup>10</sup> Values are related to one-year productivity increase in agricultural production only, i.e., does not include down-chain participants (manufacturing, retailing, consumers). The assumptions described bay met rather heroic in that they ignore private agricultural R&D and potential productivity benefit carryover from other states. Further work could explore refining these assumptions, including accounting for time path lags as well as evaluation of productivity increases related to non-NMSU and non-New Mexico input quality factors.



The second contribution that the system makes towards the state's economy is associated with increases in agricultural productivity, primarily associated with increased input qualities that increase the effectiveness of inputs. These contributions are much more difficult to accurately quantify. Factors that make quantifying these contributions difficult include:

- *Commercialization.* The uncertain nature of research efforts, for example, some research may never be commercialized.
- *Time Considerations.* Research that is commercialized and used by producers has time lags associated both with the time it takes to commercial the results, i.e., gestation period and the time that it takes for producers to adopt the new technologies, i.e., the time associated with adoption and diffusion of the technology, and useful life of the technology, i.e., length of use before the technology become obsolete.
- *Attribution / Spillover Effects.* It is difficult to tie specific research to productivity growth. It is also difficult to measure the impacts that research in one area (geographical or functional) may have on other areas. For example, how much of New Mexico's productivity increases are a function of research that was conducted by the NMSU Agricultural Experiment Stations versus how much of the increases can be attributed to research conducted outside of New Mexico or conducted by industry.

Other non-quantifiable or difficult to quantify contributions were not addressed in this study. These contributions include:

- The contributions that faculty and staff have within their community via social interactions, for example, service in community organizations.
- Productivity increases outside of production agriculture. While much of the Agricultural Experiment Station system's research applies to production agriculture, research also covers other areas of the food and fiber supply chain such as food manufacturing and consumer well-being.
- Potential non-agriculture-related contributions or impacts that the Agricultural Experiment Station system may have in the future were not considered. For example, some research conducted within the system may have carryover benefits for humans. These types of research projects may help advance knowledge of factors that contribute to human diseases like diabetes or cancer and contribute to cures.
- The spillover benefits that research provides to students studying at the university. The opportunity to participate in cutting-edge research projects, i.e., experiential learning, increases the educational value, and potential economic value of a university education.

Economic contribution estimates reported in this work were derived using input-output analysis, implemented through the IMPLAN software. While based on several rather strong assumptions, the software and method are commonly used to measure economic contributions or impacts. Two models were implemented to estimate potential contributions from NMSU's Agricultural Experiment Station research, one related to expenditures and the second considered increased productivity.

The total contribution of NMSU's Agricultural Experiment Station system derived from both research expenditures and potential increased agricultural productivity on the state's economic output (sales) was estimated to be more than \$137 million. Total contribution to the State's gross domestic product was estimated at more than \$77 million. In terms of state employment, the Agricultural Experiment Station is estimated to support 1,191 jobs within the state.

Acknowledging the difficulties relating to measuring the impacts of public and private agricultural R&D activities, including data availability and reliability, model choices, and specifications, Alston (2010 p. 19) concluded:

“... the world as a whole and individual nations have benefited enormously from productivity growth in agriculture, a substantial amount of which has been enabled by technological change resulting from public and private investments in agricultural R&D. The evidence suggests that the benefits have been worth many times more than the costs. This is still so, even if we discount the estimates heavily because we suspect they may have been upwardly biased, perhaps inadvertently through unfortunate choices of methods or limitations of the available data ...”.

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## Appendix I. AES Research Examples

The NMSU agricultural science centers are located at twelve sites around the State. Each site provides unique conditions for studying crops, animals, trees, and agricultural inputs in natural environments to determine their potential benefits and costs for farmers, ranchers, and consumers in New Mexico, in the U.S., and possibly around the World. The locations of the 12 research centers are shown in Figure A1. Selected research projects are listed for each of the centers as well. This is not a complete list of ongoing projects and research efforts: it is meant to highlight the wide range of issues agricultural scientists are addressing.

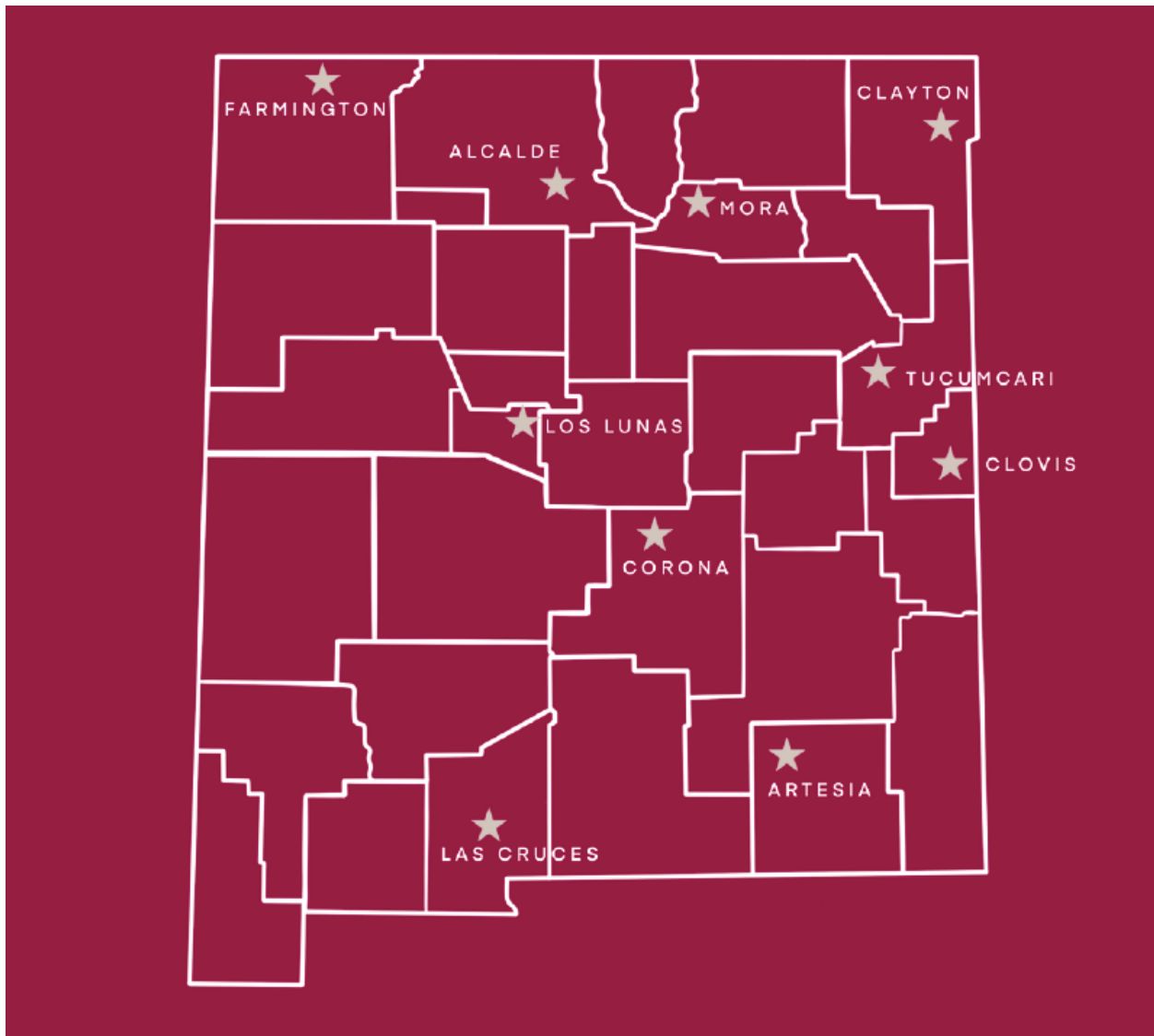


Figure A1. NMSU Agricultural Experiment Station Agricultural Science Centers.

### **Alcalde Sustainable Agricultural Science Center**

Jujube Cultivar Trial and Marketing. Center scientists have been evaluating more than 50 jujube fruit cultivars in the past eight years and have identified 8-10 cultivars suitable for fresh consumer fruit products while increasing the number of jujube cultivars currently commercially available in the U. S. The center scientists hope to develop shelf-stable fruit that is marketable beyond fresh fruit seasons. These cultivars will offer growers nationwide more choices with extended maturation dates that could provide \$1-2 premiums per pound sold.

NC-140 Organic Apple Rootstock Trial. Potential impacts of this project are unknown as it is ongoing with completion expected in 5-7 years. Growers will be able to identify and adopt the top-performing rootstock for high pH soils and the tall spindle production system that contribute to opportunities to increase sales and revenues.

### **Artesia Agricultural Science Center**

Several research and extension programs have resulted in savings from reduced input costs and increased yields. Research has suggested total potential cost savings of over \$10 million per year in New Mexico. That total comes from; treatment of cotton seed for thrips (\$2.7 million), biological control of alfalfa weevil (\$1.2 million), biological control of Pecan Nut Casebearer (\$1.6 million), and sugarcane aphid biocontrol and plant resistance (\$4.6 million).

Research center scientists have also studied pest management issues that threaten the sustainability of low water use crops, particularly cotton, guar, and sorghum. It was determined that 60% of kissing bugs in Southeast New Mexico carry the Chagas disease pathogen. Such information highlights the need to educate residents and mitigate risk in Southeast New Mexico. The Artesia Agricultural Science Center has benefited the community by having an open house, workshops, presentations, guest speakers, and providing demonstrations.

### **Chihuahuan Desert Rangeland Research Center**

Some potential impacts at Chihuahuan Desert Rangeland Research Center located in Dona Ana County, New Mexico. The future potential impacts from research projects include different attributes such as being able to check water levels, the location of a specific livestock individual, and a notification stating a livestock individual is ill all from technological devices such as a computer, phone, and tablet. This can help ranchers improve livestock production to bring in more revenue. Another potential impact given the amount of grass eaten by cattle is to apply metrics to see what an efficient breed for the type of the location. Another positive impact is the community benefits from grazing programs, open houses, and work-study for students.

### **Clayton Livestock Research Center**

The scientists at this center focus primarily on the health and characteristics of cattle raised on ranches. A research project at the station titled 'Effects of Supplemental Phyto molecules on Performance and Carcass Characteristics of Finishing Beef Steers' is focusing on the use of a novel approach to decrease respiratory disease.

The estimated cost to the feedlot industry of Bovine respiratory disease is \$50 to \$70 billion. The dairy industry adds faces an additional cost of \$212 to \$257 per animal compared with heifers not treated for the disease. The scientists at Clayton have evaluated the impact of Phyto molecule compounds as a replacement for other feed additives that enhance the performance and carcass characteristics of finishing beef steers.

### **Clovis Agricultural Science Center**

Tillage systems research at Clovis evaluating conventional and conservation tillage systems such as strip-tillage, minimum-tillage, and no-tillage has revealed conservation tillage systems in drylands could restore the SOC lost due to continuous tillage. The conservation systems also reduced soil erosion by 27%, improving soil health and resilience of dryland agriculture.

Research at Clovis also focuses on the Ogallala aquifer, the major source of irrigation water supplies in the Great Plains. The aquifer is declining rapidly and if current use rates continue, more than 35% of the irrigated acreage that is producing \$2.5 billion worth of agriculture products will be dryland in 20 years. Research on alternative crops like winter canola, safflower, and guar suggests these viable, deeper-rooted, resource-efficient (including lower water requirements), climate-resilient crops offer rotational benefits for crop producers. One of these crops, guar, produces raw materials for the oil and natural gas, food, dairy, and bioenergy industries.

Clovis has the only plant-breeding center located away from the NMSU main campus. The peanut plant-breeding program located in Clovis has emphasized the development of Valencia peanuts (3-4 seeded pods, red skin, sweet taste, and good flavor). About 60% of peanut acreage in the U.S. is planted to Valencia varieties developed in New Mexico. Overall, the Valencia peanuts industry adds more than 500,000 dollars per year to the state economy.

### **Corona Range and Livestock Research Center**

The ongoing research at this site takes place on a self-sustaining working ranch of 28,000 acres. The scale of the research activities is greater than at other facilities in the State. Some notable research results are presented here.

On-going research has shown:



Cows grazing dormant forages experience seasonal diabetic effects and continued investigation of this phenomenon could lead to a significant reduction of supplemental feed costs and increased reproductive function in cows and heifers;

Feeding bypass arginine has led to improvement in progeny performance on dormant rangeland through enhanced pancreatic function, as well as potential increases in dam reproductive function;

An initial acclimation to increases in dietary Sulphur, which results in changes in rumen kinetics. Thus, the ongoing research will examine effects of changes in water source and supplemental feeding and how to manage for maximum performance; and lastly

The commercial cow efficiency exhibited by Corona ranch animals is gaining attention around the world as animal scientists across the globe have expressed interest in studying the Corona commercial cow genome.

### **Farmington Agricultural Science Center**

The Agricultural Science Center at Farmington is the only NMSU agricultural science center in the State west of the Continental Divide and the only 1862 land grant institution working on sovereign First Nations land (the Navajo Reservation). Research on crops is most common for this station. Among crop projects underway are:

The 'Heading Date and Grain Yield of Eighteen Winter Wheat Cultivars' project was designed to provide local growers, seed industry personnel, and extension workers with accurate, up-to-date information on varietal wheat health and performance under local conditions. Information from performance testing is useful for growers who want to increase yields and generate enough revenue to cover harvest costs.

A second project called 'Effect of Plant Density and Planting Date on Maize Crop Growth, Yield and Yield Components, and Resource Efficiency' provides local growers, seed industry personnel, and extension workers with accurate, up-to-date information on corn. Knowledge of local planting window dates, plant density, the potential for increasing corn yields, improving resource productivity (mainly of water), and economic returns from corn production are all important for producers who might be considering corn production.

Other crops that have garnered interest in the northwest corner of the state include alfalfa, a major forage crop for supporting the New Mexico dairy industry; hops, a fundamental component of beer brewing, a growing New Mexico industry, and industrial hemp.

One final project of note is the '2019 Alfalfa Variety Trial results from 2018-Plant Alfalfa.' Alfalfa (*Medicago sativa*) is a major hay crop in New Mexico and San Juan County. It is important to know which varieties have the best long-term yields and pest tolerance under local conditions. The dairy industry in the State offers a large local market for local alfalfa growers.

## **Fabian Garcia Research Center & Leyendecker Plant Science Research Center**

The Fabian Garcia and the Leyendecker Science Centers both carry out a wide variety of plant-focused research, much of it focused on chile and the chile industry. The following research projects exhibit that emphasis:

‘Ensuring Safe Application of Flumioxazin in Furro-Irrigated Chile Pepper in New Mexico’ focuses on producer’s opportunities to reduce production expenses by using an herbicide in place of hand hoeing.

‘Mustard Seed Meal to Manage Mid-Season Weeds in Chile Pepper’ examined methods for managing soil-borne pests. A promising, but an untested technique for chile pest management: use of mustard seed meal (MSM) as a soil amendment. Results indicated that MSM amendments after the emergence of chile plants reduce weed seedling emergence and protect crop yield. The results of the study will help chile farmers reduce synthetic pesticide usage.

‘Development of NM Green Chile Cultivars for Mechanization’ is, given labor availability its relatively high cost, is studying ways to mechanize green chile harvesting. Reducing labor costs is important to maintaining the large-scale, profitable production of this crop.

Pecan research is also an important component of the work conducted with the Experiment Station. One example of the work being conducted at the Leyendecker Plant Science Research Center on pecans includes work related to pecan nutrient uptake.

Pecan roots lack root hairs which allow many other plants to more efficiently explore and exploit the soil for resources such as nutrients and water. However, pecan roots can form symbiotic relationships with mycorrhizal fungi that might serve a similar function as root hairs by dramatically increasing the volume of the soil “mined” by the tree’s root system. Research conducted on the Leyendecker research station documented the diversity and abundance of the microbes (including mycorrhizae) associated with pecan tree roots in the Southwest. The data will allow researchers to evaluate relationships of pecan tree micronutrients to the root microbiome and identify potential key microbes that could increase pecan tree health and productivity. The knowledge will help New Mexico pecan farmers to conscientiously manage the root microbiome and increase pecan health and profitability.

## **Los Lunas Agricultural Science Center**

The Agricultural Science Center at Los Lunas, New Mexico, is uniquely located in a peri-urban environment that offers urban programming opportunities but it does also undertake traditional projects.

The ‘Mustard Seed Meal to Manage Mid-Season Weeds in Chile Pepper’, project has evaluated the weed suppressive potential of mustard seed meal (MSM). Study results indicated that MSM

soil amendments after crop thinning provided pre-emergence control of weeds and did not reduce yield. Such results offer farmers potential for non-synthetic weed control or hand hoeing.

The Agricultural Science Center has joined with the Sandia National Laboratory, New Mexico Tech, and the University of New Mexico to develop field-test sensor technologies for monitoring plant and soil health. If successful these sensors will improve agricultural energy use for food production by decreasing water usage, improving crop quality, and detecting plant stress caused by abiotic and biotic factors before they are visible to the human eye.

### **John T. Harrington Forestry Research Center at Mora**

The research center operates the only program in the Southwest U.S. that focuses on forestry issues. The research center has produced better quality seedlings than found in other states, which are sought out after the 300,000 seedlings allocated to New Mexico are provided.

The potential impact includes the value of the seedlings outside of New Mexico. Another potential impact for research study under 'Assisted migration-defining seed transfer guidelines for Pinus Ponderosa in a changing climate has shown that southern seed sources are outperforming local sources. The significant impact is the seedling survival and growth is connected to the log microsite, which improves soil water retention for the seedling during dry conditions.

A 2019 research project called 'Southwestern White Pine Blister Rust Resistance Gene Conservation' produced grafted seedlings in 2019 to be out-planted in late 2020. The grafted seedlings have been thriving and will become the future seed orchard southwestern white pine for the entire southwestern United States. The science center has hosted a field day for fifth grades students to learn about forestry at no additional cost, thus the community benefits.

### **Tucumcari (Rex E. Kirksey) Agricultural Science Center**

Studies at the agricultural science center focus on both animal and plant agriculture. Some examples include the following:

The research center has conducted a bull test and sale since 2013. Cattle producers in New Mexico can maximize to improve the proportion of genetics in their cattle herd.

As a matter of perspective, 75 bulls can pass on their genetics to approximately 1,500 offspring per year, whereas 350 tested animals pass on their proven genetics to over 6,300 offspring per year.

The use of cover crops during the traditional winter fallow period in semi-arid cropping systems could help farmers achieve higher resource-use efficiencies and greater productivity. Efficient planting of diverse winter crops in the fallow provides livestock feed and forage, but also can,

under favorable weather conditions, generate additional income by producing seed and ensure better soil health.

Preliminary results of ongoing research have reported potential effects of wastewater on the nutritive value of alfalfa and changes in soil fertility characteristics.