PROFITABILITY ANALYSIS OF DROUGHT MANAGEMENT STRATEGIES ON SOUTHWEST INDIAN RESERVATIONS

by

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ABSTRACT

Profitability Analysis of Drought Management Strategies

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by

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Climate change has generated great impacts globally, influencing the availability of water resources, the workforce, the spread of diseases, a decrease in the capacity to cultivate, etc. Climate change has exacerbated natural and meteorological phenomena such as drought. The negative economic consequences produced by drought are very significant, especially those economic resources provided by agriculture. Drought causes loss on both sides of agricultural production (livestock and crops), making it the greatest threat to this sector.

Over time, farmers have adapted to these impacts with momentary responses, and over time these practices have become more common strategies. For this reason, this document studies the strategies of depopulation of animals, purchasing feed/hay, and leasing private grazing land. Simultaneously, implementing more efficient irrigation and using drought-resistant varieties were the strategies evaluated for alfalfa operations. We used data reported in literature, reports, interviews, and official government webpages to be as close to reality as possible. Additionally, we used the partial budget methodology to project possible results of each strategy and compare them. Thus, to contribute with critical knowledge, the strategy that shows the best profitability in a drought scenario is leasing private grazing land. Purchasing feed/hay, and the depopulation of animals tend to compete with each other to the second place. When talking about drought management strategies in alfalfa operations, using drought-resistant varieties shows a better result than installing a more efficient irrigation system. However, there is a big probability that the returns may be negatives. It is concluded that the strategies dependent on the state where it was evaluated and the farm's size. The information about agricultural production in a drought still requires further investigation.

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Drought is one of the meteorological phenomena with the most negative implications in the economy and agricultural production. Empirically, farmers have developed many options to cope with droughts; however, information about the effectiveness of these options or strategies is scarce. This study was carried out to evaluate the most used strategies in hay and livestock of the most representative native reservation of Utah, Arizona, Nevada, and New Mexico to face the drought. The data reported from different databases, reports, surveys, and publications were collected to obtain as much information as possible about these states' current production. Subsequently, with the information collected, simulations were made for each of the strategies. It is obtained that the rental of land seems to be the most effective strategy to face the drought, followed by the purchase of supplements and the depopulation of livestock. While the strategy of the purchase of drought-resistant crop varieties could be the better option to face a drought. And implementing efficient irrigation systems is the least profitable.

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1. INTRODUCTION

Agriculture, one of the main activities of the economy, culture and environment of the humans since ancient times, was in Central America the main occupation of the Indians 7,000 years before the European settlers established agriculture in North America (United States Department of Agriculture, 2007). In tribal communities, agriculture represents the backbone of more than 200 communities; between 2002 and 2007 agriculture has shown an 88% increase (evaluating the number of indigenous farmers) and by 2007 the production of these communities exceeded $1.4 billion (National Congress of American Indians, 2019).

One of the most large Indian reservations is the Navajo Nation, whose primary economic activity is agriculture, providing financial support for hundreds of farmers (Nania et al., 2014). Livestock is a significant economic activity within the Southwest Indian Reservations. Livestock production directly and indirectly, contributes to making the land increasingly arid and helps cheatgrass invade semi-arid grasslands (Grahame & Sisk, 2002). This invasion, with the lack of irrigation, contributes to soil erosion in this region (Nania et al., 2014). Most agricultural producers are aware that agriculture is affected by climate change, especially due to the decrease in food availability, low quality of crops and forages, and the spread of diseases (Rust, 2019), and when climate change is coupled with droughts the impact on health, economy and ecosystem is exacerbated.

The drylands in southwest in United States are mostly exposed, not only to low and high temperatures due to climate change but also, and more importantly, to interruptions in their hydrological cycles, which it will result in erratic rains and generating scarcity of water and conflicts over water allocation (Thomas, 2008). The study by Gaitán et al., (2020) showed that periods of drought and evapotranspiration would be increasingly intense due to climate change. Drought can be responsible for increasing the weeds in a crop, which worldwide represents about 34% of crop losses. Similarly, animal pests can also be triggered by droughts; animal pests are responsible worldwide for 18% of crop losses (Walthall et al., 2013).

About 70,000 acres on Navajo Nation are irrigated for the production of agricultural products that include small grains, alfalfa, potatoes and corn, pumpkin, among others. These products are labeled with the Navajo Pride stamp and are sold nationally and internationally, which contributes more than 30 million annually to the economy of this region (NAPI, 2013). However, this activity has been dramatically affected by the limitation of access to water for irrigation (Yurth, 2009).

Throughout history, farmers (whether from indigenous reservations or not) have learned to cope with the difficulties presented by unforeseen weather; in the same way that they have been faced with the increase in damage caused by climate change that has forced them to create strategies. The 2003 Navajo Drought Contingency Plan recommended strategies to manage droughts in the region (NAPI, 2013). Recommendations include: improving water reserve operations, improving the efficiency of irrigation systems, improving operations and maintenance, repairing and improving hydraulic structures, and pre-irrigation, among others (Navajo Nation Department of Water, 2003).

Aside from the recommendations made by the Navajo drought contingency plan, another known strategy for mitigating the impacts of drought is livestock feed supplementation. The most common is the use of hay for livestock. Supplementation in animals has had great results, however, on certain occasions, this is not the best option since the composition of the hay often deteriorates the quality of livestock, as demonstrated by the study carried out by Ferreira & Teets, (2020), where they ensure that feeding with alfalfa hay deteriorates the quality of the by-products compared to grass hay and turns out to have an imbalance between significant income and cost of food. While Santana et al., (2019) obtained as a result that when evaluating the other compositional characteristics of the hay, there is no significant difference with its replacements, in the same way, Eastridge et al., (2009) showed that alfalfa hay is the best option when compared to others. Despite a large number of published studies on hay supplementation, few studies evaluate this possibility as a cost-effective strategy to cope with droughts.

One of the most used tools in evaluating the economic impacts of various drought management strategies on farms is partial budget analysis (Ávalos-Cerdas et al., 2018). Likewise, cost-benefit analysis is an additional tool that evaluates the relationship between cost and benefits when evaluating drought management strategies in agriculture (Draper, 2003).

The relationship between the impacts of drought and the strategies employed by farmers is not widely studied. Currently, the strategies go beyond adopting efficient irrigation systems, purchasing feed, or leasing grazing land. For this reason, it is completely justified to carry out research studies about these issues, especially for Indians reservations, who have one of the main economic income from agriculture. Thus, the objective of this study was to analyze the economic impacts and drought management strategies focused on native Americans reservations in the southwest United States. This study analyzes each reservation's main strategies to cope with drought in their hay and livestock enterprises. Looking to the future, this analysis allows livestock farmers and policymakers to clearly understand the economic implications of different drought management strategies, thus seeking that policies and assistance programs can focus on sustainable initiatives for drought and improve the economies of Indian reservations in the southwestern United States.

2. BACKGROUND – LITERATURE REVIEW

2.1. Southwest Indian reservations

Most of the crops in the southwest are irrigated. The water is taken mainly from the Colorado River and the Rio Grande. Among the Southwest's main crops are fiber cotton, alfalfa, cereals, and sorghum, and livestock is the main activity, especially in New Mexico, Arizona (Sinha & Singh, 2014).

The southwest has many native Americans reservation in the United States, the Navajo Nation, where its members are distributed across Arizona, New Mexico, and Utah. Other Indian reservations include the Zuni, Laguna Pueblo, Piute, Shoshone, and Uintah and Ouray Ute, etc. However, this region has not been greatly benefited in economic terms. That is, while the median annual income of an American household is $55,322, the annual income for an American Indian family is $ 38,502 (United States Department of Agriculture, 2012). This difference is even more accentuated putting in terms of annual agricultural sales, since the average annual sales of an Indian farm is $40,331, which represents only 1/3 of the United States average (United States Department of Agriculture, 2012)

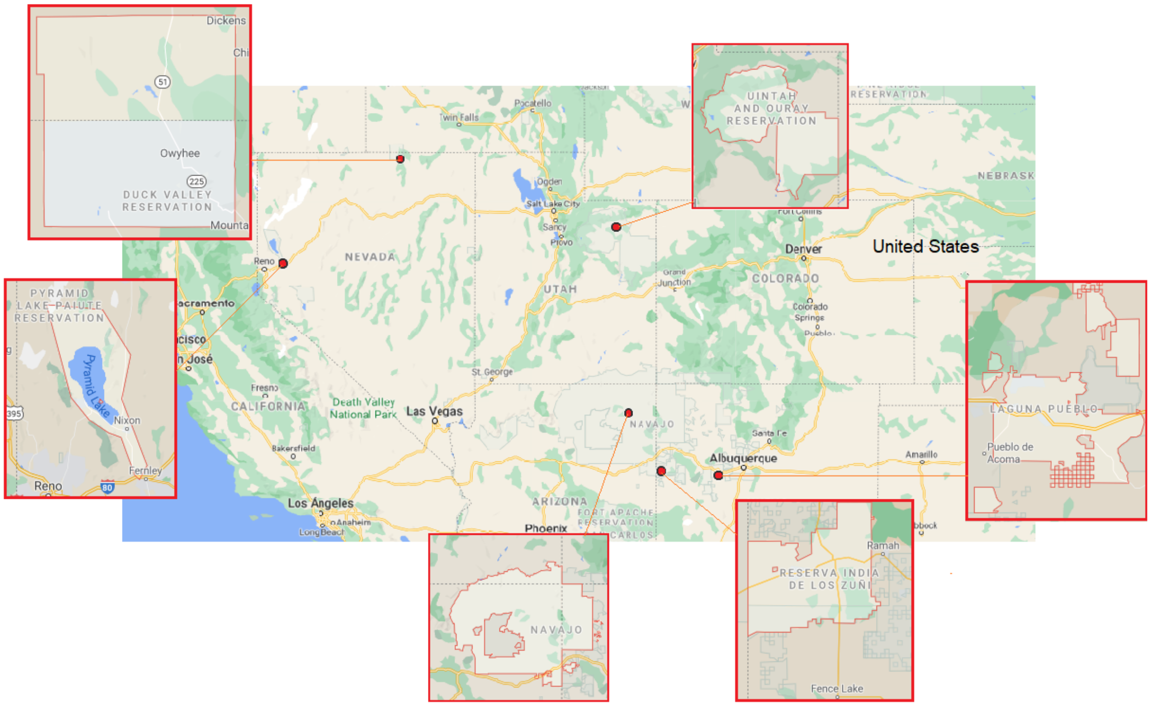


Figure 1 Indian Reservations in the Southwestern United States (elaborated by author)

2.1.1. Navajo Nation

Navajo Nation was established in 1868 after the treaty between Navajo leaders and the federal government, it is the largest reservation than any other community in the country. It has an area of 70,000 km², and the main economic activity of them includes agriculture, mining, production and sale of pottery and jewelry fabrics (BBC, 2014). The Navajo nation is considered an organized indigenous reservations, it has a self-government system that allows them to have autonomous management of their resources. (Necefer et al., 2015).

A case study Necefer et al., (2020) on the Navajo nation's cultural identity, they believe that the main belief is to maintain the connection with the land and its culture and that this is opposed to a large-scale transformation by industries. In Navajo Nation, one of the main problems, in addition to access to water resources for irrigation, is the state of the irrigation infrastructure. The infrastructure in many places on the Navajo Nation is severely deteriorated due to lack of maintenance, making it obsolete and, in some cases, useless. Leading to decreases in crop yields (Averyt et al., 2010; United States Department of Agriculture, 2012)

2.1.2. Zuni Indian Reservation

Unlike the Navajo, culturally, the Zuni consider themselves lonely and isolated located on New Mexico and Arizona, and they are one of the few tribes that maintain the native way of life through the years (Native, 2018). They are considered a peaceful and traditional people whose main activity to subsist is agriculture and livestock. They are cautious with these activities, so they try to conserve the natural resources as much as possible; this practice has been successful in their economy. Currently, some Zuni depends on tourism and especially the sale of handicrafts. Their main crops are corn, squash, and beans, but little by little, they have been transferred to livestock (Native, 2018).

2.1.3. Laguna Pueblo

The organization of the Laguna Pueblo Indian reservation is a composition of different towns in central New Mexico. It has this name because of the presence of the lagoon in its territory that historically was more extensive than today when developing efficient agriculture and having the resources. They focused their activities on religion and handicrafts (Grugel, 2012) At present, some members manage the economy; they still practice agriculture and cattle raising. However, they also have salaried work, businesses, and programs paid for by the government.

2.1.4. Pyramid Lake Reservation

The information regarding the activities of the Pyramid Lake reservation, located reservation in northwestern Nevada, is scarce. The community has reported an employment rate of 56%, with an economy focused on fishing and tourism activities (careerbuilder, 2017). However, some members of the tribe are part of the cooperative association of cattlemen that allows these members to raise livestock in the open air in the reservation. The tribe is in charge of monitoring the native aquatic species due to the great impact that man has caused this ecosystem (Brandon, 2007).

2.1.5. Duck Valley Indian Reservation

This reservation located in high desert country, for the most part, is split in half between Nevada and Idaho. The combination of green valleys, rock formations, streams, and water reservoirs (McNeel, 2018). Despite this, tourism is exclusive from the point of view that it has not been promoted. The main economic activity is livestock and agriculture, along with fishing (McNeel, 2018).

2.1.6. Uintah and Ouray Indian Reservation

The Uintah and Ouray Reservation located in northeastern Utah is the second-largest Indian reservation in the United States. More than half of the tribe members of this reservation live within it. (Utah Department of Heritaga & Arts, 2018) Indian Tribe has a strong tribal economy and plays an important role in the regional and state economy. The tribe leases about 400,000 acres for oil and gas development (Ute Indian Tribe, 2019). Around 7,000 wells produce 45,000 barrels of oil a day. Energy development funds their government, and the services they provide to their members provide thousands of jobs, household energy supplies, and support their tribal, regional, and national economies (Ute Indian Tribe, 2019).

2.2. Drought Management Strategies

Drought is a threat because of its impact on both developed and developing countries. It affects food security and people's livelihoods, especially those who inhabit arid and semi-arid lands or areas prone. to drought (Ndiritu, 2019). One of the sectors that receives the most impact from the drought is agriculture. This sector absorbs more than 80% of the direct impact of droughts, affecting water availability, agricultural production, rural livelihoods, and food security. According to FAO, (2017) there are almost 1,300 million people who depend on agriculture as their main source of income.

Different types of drought are known, meteorological, hydrological, and agricultural and each type of drought has a socio-economic implication (Enenkel et al., 2015). Traditionally, there have been many ways of dealing with drought; from the point of view of agriculture, it is very common to take momentary measures to be able to stop the serious consequences of drought. The strategies reported in the literature can be found purchasing feed/hay, leasing grazing land, reduction in head of cattle, changing to an efficient irrigation system, and changing to a drought resistant variety. This literature review briefly shows the literature reported on these measures by ranchers and farmers for drought.

2.2.1. Depopulation of animals

Livestock reduction is a management strategy that can be used to manage drought, in livestock operations, Ndiritu (2019) argues that this practice assures farmers that the animals that remain in the herd have a higher weight and will bring a higher price when. In fact, many farmers take advantage of this onset of drought to be able to sell animals, to reduce the amount of feed to maintain their breeding herd (Salmoral et al., 2020).

A study carried out by Smith & Foran (1992) shows that the strategy of reducing the number of cattle by 20% and up to 40% during the drought guarantees a stable permanence of the herd and projects a better economic performance (with a projection of 10 years). Those who do not carry out the reduction of livestock, assure that the reduction of livestock by 20% guarantees an optimal response during the first year. However, if the drought continues, the sensible percentage to be profitable is 40%. The main advantage reported is that it allows the farmer to ensure a quality of life in his animals and remain in the livestock business. Of the strategies evaluated by Díaz-Solís et al., (2009), the strategy of selling cattle was the best in terms of maintaining body condition and weight in the cattle that remain. Still, they warn that a reduction in young animal stock for a significant period may not allow the farm to survive economically.

Among the reasons why this practice is not so accepted, or is not the first option to face droughts, is because many producers are reluctant to sell their herds since they would have to lose much of the genetic improvement they have developed and acquired. After the drought passed, the risk of diseases increases in the cattle herd, which could trigger losses much greater than those caused by the drought (Díaz-Solís et al., 2009), Also these authors warn that in this option, the sale number of cows during drought generally coincides with low market prices, and repopulation of the herd post drought usually coincides with high market prices. That is, they sell cheap and buy high. Morton & Barton (2002) propose that, either at the highest point of the drought cycle or when the animals are already in poor body condition (that more than a reduction in livestock would be a rescue) or at the beginning of the drought, it is necessary for the government and other external agencies to facilitate and create incentives so that producers can sell their animals or at least not have limitations when marketing them during drought.

2.2.2. Purchase of feed/hay

The purchase of feed is the most common way for farmers to respond in the short term to the impacts of drought. They also use stored supplies from wintertime or accumulate hay to feed their animals (Salmoral et al., 2020). In times of drought, production costs tend to be variable, but this cost can be compensated. Some farmers report an increase in the cost of their production from 20% to 25% due to buying feed, and that on many occasions, this causes them to accumulate debt in the form of credit from their suppliers. On the other hand, those farmers who accumulate or have an excess supply of feed benefit from the increase in prices in times of drought (Salmoral et al., 2020).

Purchasing feed, like depopulation in the herd, always has financial consequences. Studies show that buying feed has a negative result when it is done at the drought peak (Tigner & Dennis, 2020), but if farmers buy the feed in the valley, it shows a more positive performance against the depopulation of the herd. However, it is more preferred to the technique of depopulation of the animals since buying feed/hay, or leasing grazing has the disadvantage of the uncertainty of the duration of the drought. That is, hay must be constantly bought until the drought ends, while depopulation is done only once and no matter how long the drought lasts (Tigner & Dennis, 2020). The best option may be to combine the sale of cattle with the purchase of feed. Cows that do not have grass consume half a ton of hay per month, which can cost between $100 and $200 per ton (Bailey et al., 2018). One of the factors that influence the price of hay is the impact of drought on hay fields. This causes nitrate levels in the forage to increase and does not make it viable to commercialize or convert it into silage (Bailey et al., 2018).

Although studies show that purchasing feed is less profitable and may causes economic losses, the study carried out by Muzanarwo, (2017) shows that 40% of farmers prefer the use of this silage and the purchase of hay, within of the strategies evaluated by the same study, the practice of giving molasses to make the stubble more palatable is also considered by the minority of farmers (this practice is the one with the least positive cost-benefit ratio). However, the study also ensures that the surveyed farmers are unaware of best silage practices or testing different species for supplementary feeding that may become more economically viable.

2.2.3. Leasing grazing land

The land has a powerful influence on the value of a product, on the ratio of exchange of goods between groups, on the use of resources, on education, distribution of science and general social production, likewise, the land and the leasing relationship of it is strongly influenced by these factors (Tskhadadze, 2019)

Prasad (2006) shows that when there are institutional prerequisites that allow stability in the leasing of agricultural land, in the long term, it creates stability and security in agriculture and other sectors. In addition to this, Czyżewski & Matuszczak (2016) assure that the rent of land in sustainable agriculture is due to the intrinsic utility that said rented land has. This generates that the expected productivity of capital is greater than other sectors of the Agroindustry.

Despite this, the farmers motivated by land's economic benefits tend to over-exploit it, cultivating crops that are not suitable for the characteristic of said rented land, and the use of chemical pesticides and pesticides that significantly cause the land to deteriorate (Rondhi et al., 2018). Authors defend that the sale and purchase of agricultural land are better than renting it since with the sale of the land, property rights are transferred, the person who is going to get or buy the land has better access to credit and makes a constant investment on the land, which protects it from bad actions by tenants. However, the literature reports that it seems more important to rent than to buy an agricultural area (Ciaian et al., 2009), and this makes the land rent is competitive due to a large number of demanders and few suppliers, which in the long term generates a disadvantage in agricultural production and its profits

2.2.4. Improved water management (Efficient Irrigation)

The adoption of efficient irrigation systems is widely known and especially beneficial in crop production. The development of irrigation systems and their modernization help alleviate poverty, create employment opportunities, reduce food prices, increase agricultural production stability, and increase rural incomes, which generates a greater demand for goods and services (de Fraiture et al., 2010). It has been shown that the best long and short-term response to drought by producers is to increase the availability of water supply. This includes the connection of hydroelectric water pipes in the farms to the purchase of reservoirs or lakes as a method of future protection (Salmoral et al., 2020).

Thomas, (2008) showed that supplying a limited amount of water to crops during the drought and water stress in critical stages of plant growth such as lentils, chickpeas, and barley increases water productivity measured in kg of biomass. The best form of action for this system is to improve the capacity for adaptation and efficient response to changes in the demand for water, the implementation of these risk systems requires renewing water policies, adequate training for farmers, and financing (Iglesias & Garrote, 2015).

Studies carried out by FAO (Bruinsma, 2009) projected that by 2050 the land equipped with risk systems would expand by 32 million hectares worldwide. In this same study, they predicted that the increase would be mainly in developed countries due to the slow improvement that these showed in water use and projected that the water withdrawals for risk would have a languid pace. However, in 2012 an study by the FAO (Alexandratos & Bruinsma, 2012) showed that irrigated areas in the world had reached 47 million hectares, they also mentioned that the potential for irrigation expansion was limited.

The central pivot system consists of a lateral pipe mounted on motorized structures with wheels that aid its movement. The machine rotates around a pivot point in the center of the field. The sprinkler outlets are installed on top of a pipe supported by steel trusses between the tower structures. According to Evans (no date), this method of applying water is highly adaptable and has become popular around the world in the past: 1) its potential for consistent and highly efficient water applications, with the correct design, water is applied evenly and efficiently, 2) its high degree of automation requires less labor than most other irrigation methods; 3) great coverage, and 4) its ability to economically apply water and water-soluble nutrients in a wide range of soil conditions.

Alfalfa and vegetable crops can and have been successfully irrigated with center pivot water application systems in a wide range of conditions

2.2.5. Drought resistant varieties

Among the main reasons for reductions in crop yields are antibiotic stress, drought, high and low temperatures, soil health, and toxic metals. These factors often reduce crops productivity between 50% to 80%. By 2050 it is projected that to satisfy the world population's food demand, food production must increase by at least 70%. Currently, 38% of the world's land and 70% of fresh water is used in agriculture. Therefore, it is necessary to develop stress-resistant crops that allow stable yields with minimal water and land use (Zhang et al., 2018).

A study carried out in Namibia with FAO's participation gave farmers access to genetically improved and drought resistant varieties. As a result, their crop were more productive in a shorter growing period (Mikhailova, 2019). Similar to this study, in Zimbabwe, another study showed that horticulturists who grow drought-tolerant maize at harvest get up to 600 kg more grain per hectare in the dry season (Kropff, 2020). Thus, drought tolerant varieties improve the efficiency of water use and combat or mitigate the impacts of climate change (Iglesias & Garrote, 2015).

The main reason why drought resistant varieties are needed is that few farmers have the tools or strategies to significantly reduce the physical effects in a short time of the growing season, the sowing date, the space between plants, and sowing rates are adjustable, as is the available water. But these factors are always subject to or are dependent on the crop environment and the characteristics of the field and soil (McFadden, 2019).

Luo et al. (2019) mentions that a common difficulty for research on resistance to drought is the lack of precise results under varying field conditions. Very rarely do studies that give an accurate estimate of the traits of resistance to drought in the field. Although crop producers can enroll in various federal programs to protect yields through insurance and obtain compensation payments for loss in drought conditions. These federal crop insurance programs generally do not fully compensate tor financial losses (McFadden, 2019).

2.3. Economic Evaluation of Drought Strategies

Economically, droughts have become one of the costliest natural hazards in the world. In the United States from 1988 to 1989 it caused losses in crops valued at $15,000 million dollars, for 2001 and 2002 the losses reached $2,000 million dollars in crops and $553 million dollars in livestock activities, in addition to these losses, increased the costs of pumping groundwater by $1.3 billion dollars (Kuwayana, 2019). In 2015, in other parts of the world, such as China, droughts caused economic losses of 289,000 million yuan, in 2016, which corresponds to 15.6% of the total economic losses related to meteorological disasters (Zhao et al., 2020). Another study carried out by Medellín-Azuara et al. (2016) showed that about 1785 direct full-time jobs were lost during the drought of 2016 in the Central valley in California, United States, the loss of their jobs plus other areas such as loss in the sale of gross production reached $247 million dollars of losses.

For calculating the possible economic outcomes of different drought management strategies is increasingly feasible due to the availability of agricultural data. Both in the United States and other countries, the network of these reliable data allows for statistical simulations that illustrate the economic returns to each drought management strategy (Antle & Stöckle, 2017). Several authors have demonstrated the importance of economic studies in drought management. For example Lalani et al., (2017) showed that comparing the cash flows between two agricultural cultivation systems allowed to know short-term benefits. These benefits depend on the mixture of crops or the cost of opportunities according to the strategies evaluated by them, other authors like Medellín-Azuara et al., (2016) projected that the contribution of the gross product would decrease by 180 million dollars contributed by the state of California and 4,700 full-time jobs will be lost due to the need to reduce costs in times of drought.

3. DATA AND METHODS

3.1. Drought Management in Livestock Operations

3.1.1. Partial Budget Analysis

An enterprise budget is the estimate of all the economic costs and revenues projected to accrue from a certain agricultural business activity or enterprise (in this case, the raising of livestock and production of forage) over a time period enterprise budget are the potential profit and loss stage for an agricultural business. The importance of budgets lies in the collection of information on certain specific resources used in the production process. Budgets help to provide weight in the decisions to be made, analyze the potential profitability production. They essentially provide projections for producers before they commit their resources (Whittaker et al., 2006). According to Curtis et al. (2005), partial budget analysis provides an overview of the various budget options for agricultural production. The enterprise budget is built on an annual basis and includes all incomes and costs associated with a particular commodity, with the main use of comparing alternative agricultural organizations under different cropping or production patterns and estimating the profitability of the farm plan. It is done following the guidelines of the article Connolly & Painter (2015).

Partial budgets are used to evaluate the financial impact of a management strategy. It examines the changes in costs, revenues or both for one change to the operation, such as switching from leased grazing land to purchasing hay for livestock feed. All other aspects of the operation remain the same (Reyes Hernández, 2001). This will provide stakeholders with a simple analysis of the financial impacts of implementing a single annual change drought management strategy.

For these scenarios that we analyze, the costs related to each of the strategies were taken into consideration. This is: 1) reduction in feed costs and other variable costs, and reduction in income for the strategy of reducing head of cattle, 2) increasing feed costs related to the purchase of hay, 3) finally, increasing feed costs related to leasing grazing.

As this study looks at Indian reservations (with limited access to information), the partial budgets for each farm/ranching operation by reservation/area were collected from Extension resources in Utah (USU, 2019), Nevada, New Mexico, and Arizona (Johnson et al. (2018). Partial budgets were developed for each drought management strategy with data collected from online and local input distributors.

To perform the partial budget analysis for livestock operations on the Indian reservations, the geographic location of the most important Indian reservations in the southeastern United States were taken into account since the budget information on Indian reservation is very limited. We used livestock budgets for the regional location of each reservation.

For the Navajo Nation, an enterprise budget from the Plateau region in northern Arizona was used, due to its proximity to Navajo Nation. The budget used in this region corresponds to a ranch of 400 head of cattle. It should be noted that each region has different characteristics in terms of the origin of the feed type, as well as climate characteristics and growing situation. According to the study by Johnson et al. (2018), in the Plateau region of northern Arizona, livestock feed comes from public grazing lands. Table 1 shows the main costs and quantities used to do the partial budget analysis in the region.

Table 1 Initial Costs and Quantities for Northern Arizona

Reseravation	Location	Herd Size	Item	Detail	Quantity	Price per unit/pound	Total Cost	Source
Navajo Nation	Arizona Plateau Region	400	Steer Calves		160.00	$ 1.77	$ 141,600.00	(Johnson et al., 2018)
			Heifer Calves		120.00	$ 1.37	$ 78,090.00	(Johnson et al., 2018)
			Cull Cows		37.00	$ 0.89	$ 29,637.00	(Johnson et al., 2018)
			Cull Bulls		1.00	$ 1.10	$ 1,375.00	(Johnson et al., 2018)
			Hay	Tons	45.00	$ 162.00	$ 7,290.00	(USDA, 2020)
			BLM	AUM	534.22	$ 1.35	$ 721.20	Author Calculations
			State	AUM	2,185.46	$ 2.09	$ 4,567.60	Author Calculations
			USFS	AUM	582.79	$ 1.35	$ 786.76	Author Calculations
			Private (owned)	AUM	1,068.45	$ -	$ -	Author Calculations
			Private (leased grazing)	AUM	485.66	$ 10.00	$ 4,856.57	Author Calculations

For the Zuni and Laguna Pueblo Indian Reservations, are used enterprise budgets that correspond to the northern region of New Mexico since this is where these Indian reservations are located. The budgets they use correspond to cattle ranches of 170 and 450 heads. Similar to Arizona farms, the main source of livestock feed comes from public grazing lands in this state according to Johnson et al. (2018). Table 2 shows the main costs and quantities used to do the partial budget analysis in the region.

Table 2 Initial Costs and Quantities for the Northern New Mexico Region

Reseravation	Location	Herd Size	Item	Detail	Quantity	Price per unit/pound	Total Cost	Source
Zuni, Laguna Pueblo	New Mexico North	450	Steer Calves		187.00	$ 1.96	$ 190,590.40	(Johnson et al., 2018)
			Heifer Calves		119.00	$ 1.90	$ 111,919.50	(Johnson et al., 2018)
			Cull Cows		68.00	$ 0.74	$ 46,948.56	(Johnson et al., 2018)
			Cull Bulls		1.00	$ 0.84	$ 1,008.00	(Johnson et al., 2018)
			Hay	Tons	23.00	$ 162.00	$ 7,290.00	(USDA, 2020)
			BLM	AUM	0.00	$ -	$ -	Author Calculations
			State	AUM	2,477.01	$ 3.53	$ 8,735.59	Author Calculations
			USFS	AUM	1,926.56	$ 1.74	$ 3,352.22	Author Calculations
			Private (owned)	AUM	1,100.89	$ -	$ -	Author Calculations
			Private (leased grazing)	AUM	0.00	$ -	$ -	Author Calculations

For the Pyramid Lake and Duck Valley Indian Reservations located in Nevada, we use the enterprise budgets to the county where these Indian reservations are located. Namely, the Pyramid Lake Indian Reservation is located in Lyon County, and the Duck Valley Indian Reservation is located in Elko County. The budgets you use for your analysis in Elko County are for ranches of 400 and 600 head of cattle. For Lyon county, the budget used is 350 head of cattle. In these counties the majority of feed Particularly comes from public grazing lands, similar to Arizona and New Mexico. However, there is less use of owned land to feed livestock, and increased use of hay, grains, and alfalfa for feed (Johnson et al., 2018). Table 3 shows the main costs and quantities for the partial budget analysis for Elko County, where the Duck Valley Indian Reservation is located, and the main costs and quantities for Lyon County, where the Pyramid Lake Indian Reservation is located.

Table 3 Initial Costs and Quantities for Elko and Lyon Counties.

Reseravation	Location	Herd Size	Item	Detail	Quantity	Price per unit/pound	Total Cost	Source
Duck Valley Indian Reservation	Nevada Elko	400	Steer Calves		117.00	$ 2.39	$ 160,787.25	(Johnson et al., 2018)
			Heifer Calves		111.00	$ 2.22	$ 123,210.00	(Johnson et al., 2018)
			Cull Cows		40.00	$ 0.81	$ 32,400.00	(Johnson et al., 2018)
			Cull Bulls		2.00	$ 0.99	$ 2,970.00	(Johnson et al., 2018)
			Hay	Ton	516.32	$ 81.17	$ 41,909.79	Author Calculations
			Grain	Ton	16.50	$ 197.65	$ 3,260.74	Author Calculations
			alphalfa	Ton	41.24	$ 161.16	$ 6,646.85	Author Calculations
			BLM	AUM	3,500.00	$ 1.35	$ 4,725.00	(Johnson et al., 2018)
Pyramid Lake Indian Reservation	Nevada Lyon	350	Steer Calves		138.00	$ 2.39	$ 189,646.50	(Johnson et al., 2018)
			Heifer Calves		58.00	$ 2.22	$ 70,818.00	(Johnson et al., 2018)
			Cull Cows		52.00	$ 0.75	$ 42,900.00	(Johnson et al., 2018)
			Cull Bulls		3.00	$ 0.94	$ 4,230.00	(Johnson et al., 2018)
			Hay	Ton	451.89	$ 81.17	$ 36,679.51	Author Calculations
			Molasses Tubs	Ton	25.00	$ 213.64	$ 5,341.00	Author Calculations
			alphalfa	Ton	50.00	$ 136.99	$ 6,849.50	Author Calculations
			BLM	AUM	3,000.00	$ 1.35	$ 4,050.00	(Johnson et al., 2018)

Finally, the Uintah and Ouray Indian Reservations is located in Duchesne County, Utah. The budget corresponding to the central Utah has 96 head of cattle. This region has livestock operations very similar to the regions analyzed in Nevada, where there is an absence of owned land for grazing and greater use of hay and alfalfa for feed (Larsen, 2019). In Duchesne County, the budget used 200 head of cattle. In this county, it should be noted that most of the livestock feed comes from leasing private land, little public land or self-owned land is needed. There is also a greater use of hay and alfalfa for livestock feed (Johnson et al., 2018). Table 4 shows the major costs and quantities used to do the partial budget analysis for Duchesne County and Central Utah, where the Uintah and Ouray Indian Reservations are located.

Table 4 Initial Costs and Quantities for Duchesne County and Central Utah Region

Reseravation	Location	Herd Size	Item	Detail	Quantity	Price per unit/pound	Total Cost	Source
Uintah and Ouray Reservation	Utah Duchesne County	200	Steer Calves		90.00	$ 1.98	$102,465.00	(Johnson et al., 2018)
			Heifer Calves		90.00	$ 1.82	$ 87,633.00	(Johnson et al., 2018)
			Cull Cows		20.00	$ 0.79	$ 17,380.00	(Johnson et al., 2018)
			Cull Bulls		2.00	$ 0.96	$ 3,552.00	(Johnson et al., 2018)
			Grass Hay	Ton	200.00	$ 97.00	$ 19,400.00	(USDA, 2020)
			Alfalfa Hay	Ton	193.00	$ 137.00	$ 26,441.00	(USDA, 2020)
			Private Pasture Lease	AUM	1,484.00	$ 24.55	$ 36,432.20	(Johnson et al., 2018)
Uintah and Ouray Reservation	Utah Central Region	96	Steer Calves		40.94	$ 1.58	$ 35,576.86	(Larsen, 2019)
			Heifer Calves		28.98	$ 1.45	$ 21,010.50	(Larsen, 2019)
			Cull Cows		9.20	$ 0.55	$ 5,566.00	(Larsen, 2019)
			Cull Bulls		1.05	$ 0.55	$ 805.00	(Larsen, 2019)
			Alfalfa Hay (Good Feede	Ton	47.22	$ 137.00	$ 6,469.32	(USDA, 2020)
			Grass Hay	Ton	105.11	$ 97.00	$ 10,195.24	(USDA, 2020)
			Private Meadow Pasture	AUM	201.80	$ 22.00	$ 4,439.61	(Larsen, 2019)
			State Range	AUM	198.55	$ 6.28	$ 1,246.87	(Larsen, 2019)
			Federal Range	AUM	397.09	$ 1.41	$ 559.90	(Larsen, 2019)

The strategies used to manage droughts in livestock operations are depopulation of herd, purchasing supplementary feed, and leasing grazing private land to feed cattle.

For this study, we assumed that due to the drought, the production of food from the land was reduced by 21%, This 21% reduction in forage was calculated with the counties' hay yield data where the Indian reservations are in each State. These data were retrieved from the USDA website (2020). The annual hay yield by state was averaged for the calculation, and the annual variation was calculated. Afterward, the biggest negative variation in yield by state in the last 10 years was identified, and finally, these variations were averaged among the four states. Due to this forage reduction, the amount of food available from public and private lands is not the same as in a year without drought.

To evaluate the depopulation of herd strategy and based on the enterprise budgets obtained from the study of Johnson "*An Economic Analysis of Cattle Numbers and Feed Sources in the USDA Basin and Range Region*" (2018), I adjusted the number of cows and bulls according to the amount of feed available. This adjustment was made keeping the cows to bull ratio that initial study had. For example, in the Plateau Region of Northern Arizona, in a year without drought, the herd size is 400 head of cattle, of which 25 are bulls and 375 are cows, for a ratio of 15 cows for each bull (Johnson et al., 2018). As there is a reduction in feed available due to the drought, the herd would have to be reduced to 315 head of cattle, of which 20 are bulls, and 295 are cows. This quantity of cows and bulls keeps the same proportion of 15 cows for each bull. When adjusting the herd size, it is expected that the quantity available for sale of steer calves, heifer calves, cull cows, and cull bulls will also be reduced; thus, the revenues will also be smaller.

To analyze the strategy of purchasing supplementary feed/hay, we kept the scenario in which, due to the drought, the availability of feed from land (public and private lands) is reduced. However, to keep the herd's size as it was initially, I calculated the amount of supplementary feed (hay) that would need to be purchased to feed the entire herd. After calculating the amount of feed needed, I simulated the scenario where all the additional feed needed would be obtained from purchasing additional tons of hay. This scenario implies a reduction in the costs of buying AUMs from public land (BLM, State Lands, and Federal Lands) and private lands; since the availability of AUMs from these lands is low. At the same time, this scenario implies higher costs in obtaining additional supplementary feed such as hay. We are considering that the amount of cattle available for sale remains similar to a year without drought, but feed costs would increase due to the additional supplementary feed purchased.

Finally, to assess the strategy of leasing additional grazing land, we started from the drought scenario, in which the availability of feed or AUMs from public and private lands is reduced. Like the previous strategy, I calculated the amount of feed needed to feed all the livestock without reducing the herd. After calculating the additional feed needed to feed all cattle, we assumed that the additional feed would come from leasing private grazing land; Therefore, we calculated the additional costs that would result.

This scenario implies that there would be a reduction in feed costs from public lands (BLM, State Lands, and Federal Lands), supplementary feed costs (hay, alfalfa, and grains) are constant, and the costs of leasing private grazing land would increase. The number of cattle available for sale would be the same as in a year without drought, but feed costs from private lands would increase. Additionally, buying AUMs on private land may increase more than proportionally since prices per AUM would increase due to over demand.

3.2. Drought Management in Hay Operations

3.2.1. Cost-benefit analysis

The cost-benefit analysis is an additional tool that can be used to evaluate the costs and the benefits when choosing a strategy to cope with drought in crop production. The importance of carrying out cost-benefit analysis stems from the need to make decisions which impact the economic viability on the operation. The strategy which least negatively impacts the operation is the chosen (Draper, 2003).

The analysis is calculated by adding the present values for the benefits received from an investment minus the costs of implementation an operation. The importance of the calculation lies in the future since the benefits may exceed the investment costs in the long term. For the analysis and to give effective weight to the cost and benefits and have a meaningful comparison of the strategies, calculating Net Present Value (NPV) is necessary. Conceptually, the NPV assumes that the variance of the profit values in the present and future costs are zero and variance matters a lot when making real investment decisions (Basher & Raboy, 2018). In theory, the calculation of NPV is carried out using the following formula:

$$NPV = \sum_{t=0}^{T} \frac{B_t}{(1+\delta)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+\delta)^t}$$

Equation 1: *Calculation for NPV*

Where T is the useful life of the project, *t* is the number of years projected in the future for the cost-benefit, δ discount rate, B*t* total benefits for a given year, and C*t* total costs for the same year. In this study, the NPV for the selected strategies was calculated under the baseline variables' parameters as a robustness check of the selected strategy, showing its validity in the results for a variety of economic situations.

Drought negatively impacts crops producers. Here the proposed strategies to deal with drought by producers are to implement a more efficient irrigation system or to use drought resistant varieties. The analysis will focus on alfalfa production. Therefore, information on the behavior of alfalfa price is needed (shown in Table 5), where 36 consecutive months on data we used in the regions where Indian reservations are located.

Table 5 Price behavior by state

	Utah*			Nevada*		
	2020	**2019**	**2018**	**2020**	**2019**	**2018**
Jan	185	185	140	180	180	190
Feb	175	185	145	185	180	180
Mar	180	185	150	180	180	185
Apr	175	185	150	185	180	180
May	170	185	150	180	165	180
Jun	175	185	160	185	170	180
Jul	185	180	160	180	170	175
Aug	180	180	170	180	170	170
Sep	190	175	175	180	170	170
Oct		185	175		180	175
Nov		185	175		175	165
Dec		190	180		180	170

*** USDA Quick Stats Alfalfa Price (2020)**

After this, alfalfa yields were obtained from the counties where the Indian reservations are located. For the Uintah and Ouray Indian Reservations, alfalfa production yields were obtained in Carbon, Duchesne, Uintah, and Wasatch counties. Yields per acre were taken from the USDA website (USDA, 2020). Similarly, alfalfa production yields were obtained for Washoe, Douglas, and Lyon counties, near where the Pyramid Lake Indian Reservation is located. The descriptions of the yields are shown in table 6.

Table 6 Alfalfa Yield per Acre by state

	Utah*	Nevada*
Mean	3.4	4.4
Mode	3.1	4.9
Stand. dev.	0.4	0.7
Max	4.1	5.4
Min.	2.7	3.4

*** USDA Quick Stats Alfalfa field (2020)**

3.2.2. Use of efficient irrigation systems

As we discussed previously, center pivot irrigation system offers several benefits in terms of optimization of water use, uniformity in water application, and reduction in costs related to water irrigation. In Utah the pivot system's installation cost varies between $600 and $1000 per acre (Scherer, 2018). For the practical case of this document, the selected price is $800 dollars per acre. The irrigation system was evaluated on a 100-acre farm, for a total system cost of $80,000. Additionally, the alfalfa seed was calculated at $5,160 for 100 acres, the seed is changed every 5 year (Welter Seed, 2020). The price of a ton of alfalfa for Utah was adjusted to its best distribution in @Risk according to the last 36 months of pricing data (Table 5). This showed that the triangular distribution is the best fit to prices behavior (Figure 2). Simultaneously, the average yield of alfalfa in Central Eastern Utah is shown in Table 6.

When assessing the best distribution in @Risk, it was found that the normal distribution is the best distribution that fit for the yield data. (Figure 3).

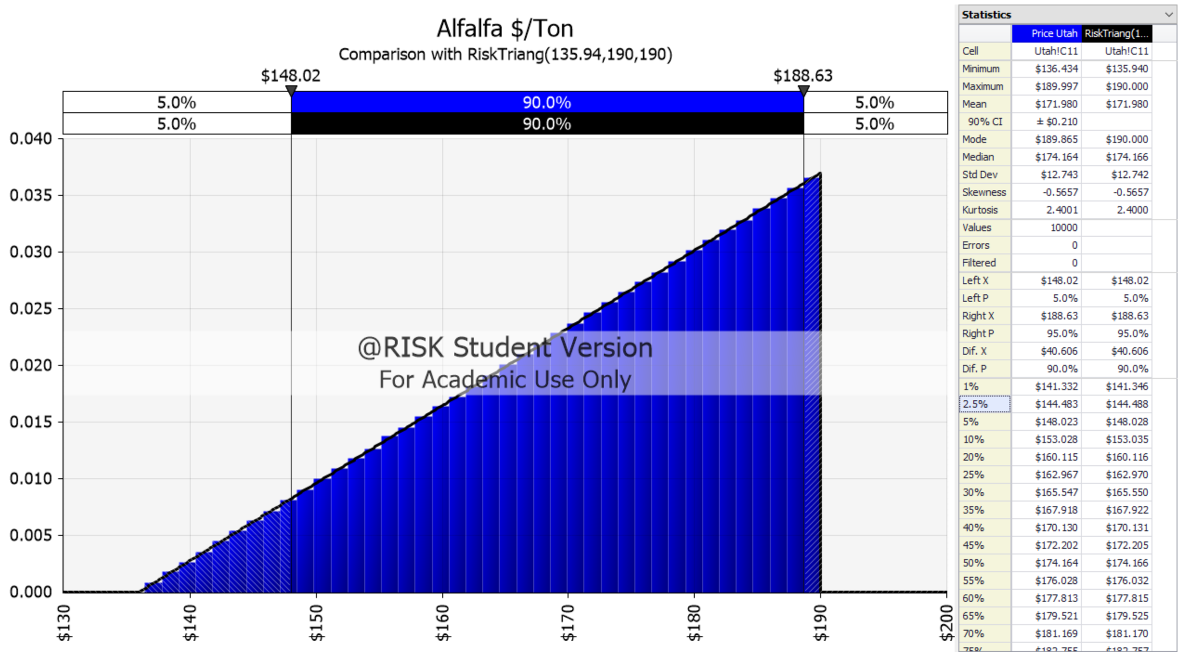


Figure 2 Alfalfa Price Distribution in Utah

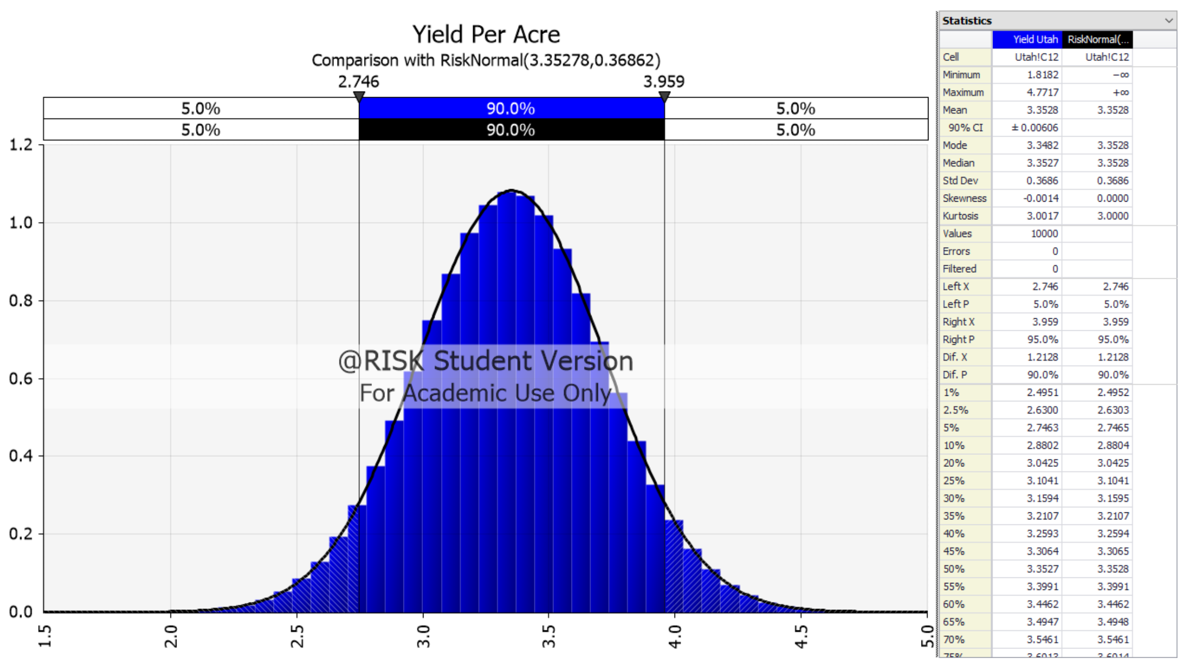


Figure 3 Alfalfa Yield Distribution in Central Eastern Utah

According to the literature consulted, alfalfa production may improves slightly with the implementation of the center pivot system (McKnight, 1983). Being that literature reviewed do not show any precise data about the increase yield, we assume that crop yield increase slightly by 3% in the simulation. The variable and fixed costs are shown in Table 7, taken from the business budget "*Defense Against Drought*" (Yost et al., 2019). The costs related to irrigation are modified by the fact of using a different irrigation system than shown in the enterprise budget.

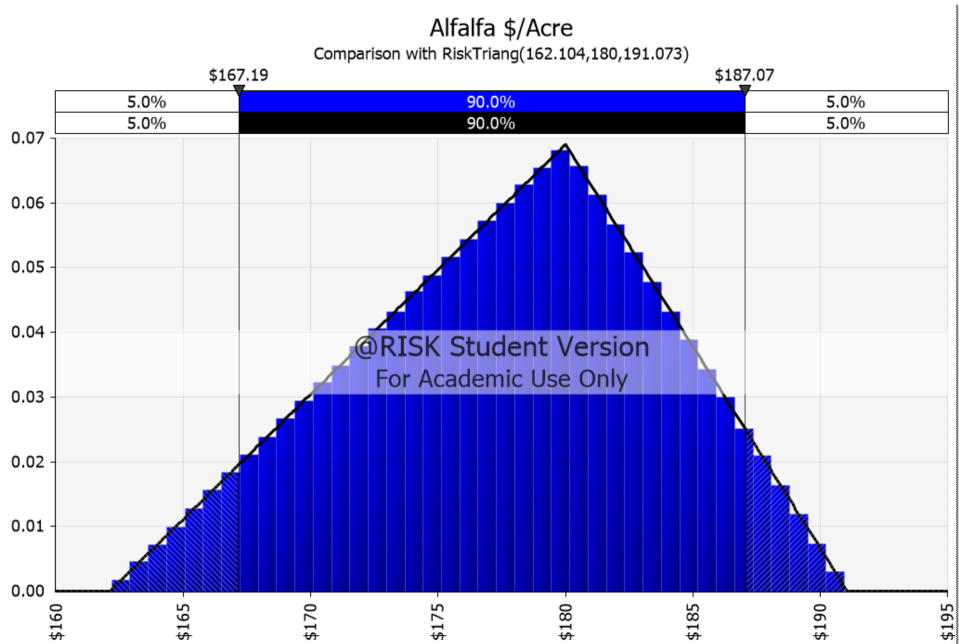
Table 7 Variable and Fixed Costs of Alfalfa Production, Utah

Variable Costs			
	Total Value	Value or Cost/Acre	Source
Fertilizer	$ 6,000.00	$ 60.00	(USU, 2019)
Application	$ 600.00	$ 6.00	(USU, 2019)
Herbicide	$ 600.00	$ 6.00	(USU, 2019)
Application	$ 600.00	$ 6.00	(USU, 2019)
Insecticide	$ 400.00	$ 4.00	(USU, 2019)
Application	$ 600.00	$ 6.00	(USU, 2019)
Crop Insurance	$ 250.00	$ 2.50	(USU, 2019)
Operator Labor	$ 7,500.00	$ 75.00	(USU, 2019)
Fuel	$ 6,479.00	$ 64.79	(USU, 2019)
Repairs & Maintenance	$ 5,944.13	$ 59.44	(USU, 2019)
Interest	$ 275.00	$ 2.75	(USU, 2019)
Twine	$ 2,225.00	$ 22.25	(USU, 2019)
Other	$ 500.00	$ 5.00	(USU, 2019)
Total Variable costs*	**$ 31,973.13**	**$ 319.73**	
Irrigation			
Water Cost	$ 1,875.00	$ 18.75	Autor Calculations
Irrigation Labor	$ 1,000.00	$ 10.00	Autor Calculations
Pivot Maintenance	$ 3,200.00	$ 32.00	Autor Calculations
Total Irrigation Variables costs**	**$ 6,075.00**	**$ 60.75**	
TOTAL VARIABLE COSTS	**$ 38,048.13**	**$ 380.48**	
Fixed Cost			
FIXED COSTS***	$ 23,797.58		(USU, 2019)
Irrigation insurance	$ 293.04		Autor Calculations
Total	**$ 24,090.62**		
TOTAL COSTS	**$ 94,111.87**		

* Total Variable costs excluding Costs related with irrigation
** Total variable costs related with irrigation
*** Total fixed cost excluding center pivot system insurance costs

By using a more efficient irrigation system, center pivot, costs related to irrigation can be reduced since it reduces water consumption and as well as costs related to labor. According to Brown (2008), labor may decrease up to 90% depending on how automated the irrigation system is. For this simulation we are assuming that the more efficient irrigation system is not fully automated, thus we will assume a 40% decrease in labor related to irrigation. Maintenance costs may increase since it is calculated that the annual maintenance cost of this irrigation system can be between 2% to 5% of the total cost of implementing the irrigation system (USDA, 2020). For this scenario we assume 4% of maintenance.

In the case of Nevada, the same installation price for the new irrigation system is assumed, $800 per acre. The irrigation system was evaluated on a 200-acre farm, for a total system cost of $160,000. The alfalfa seed for this 200-acre farm was calculated at $10,320 (Welter Seed, 2020), and it is changed every 5 years. The price of a ton of alfalfa for Nevada adjusted to its best distribution in @Risk according to the 36 months of pricing data (Table 8); showing that the triangular distribution is the best fit to observed prices (Figure 4).



Statistics

	Price NV	RiskTriang(1...
Cell	Nevada!C11	Nevada!C11
Minimum	$162.177	$162.104
Maximum	$190.961	$191.073
Mean	$177.726	$177.726
90% CI	± $0.0982	
Mode	$179.814	$180.000
Median	$178.204	$178.204
Std Dev	$5.968	$5.968
Skewness	-0.2232	-0.2231
Kurtosis	2.4004	2.4000
Values	10000	
Errors	0	
Filtered	0	
Left X	$167.19	$167.19
Left P	5.0%	5.0%
Right X	$187.07	$187.07
Right P	95.0%	95.0%
Dif. X	$19.878	$19.878
Dif. P	90.0%	90.0%
1%	$164.380	$164.381
2.5%	$165.700	$165.704
5%	$167.190	$167.195
10%	$169.302	$169.304
20%	$172.286	$172.287
25%	$173.488	$173.489
30%	$174.573	$174.575
35%	$175.573	$175.574
40%	$176.504	$176.504
45%	$177.376	$177.378
50%	$178.204	$178.204
55%	$178.989	$178.990
60%	$179.741	$179.741
65%	$180.476	$180.477
70%	$181.263	$181.263
75%	[illegible]	[illegible]

Similarly, it was found that the best distribution that fits the alfalfa yield data in Central Western Nevada (Table 6) is the triangular distribution (Figure 5).

Figure 4 Alfalfa Price Distribution in Nevada

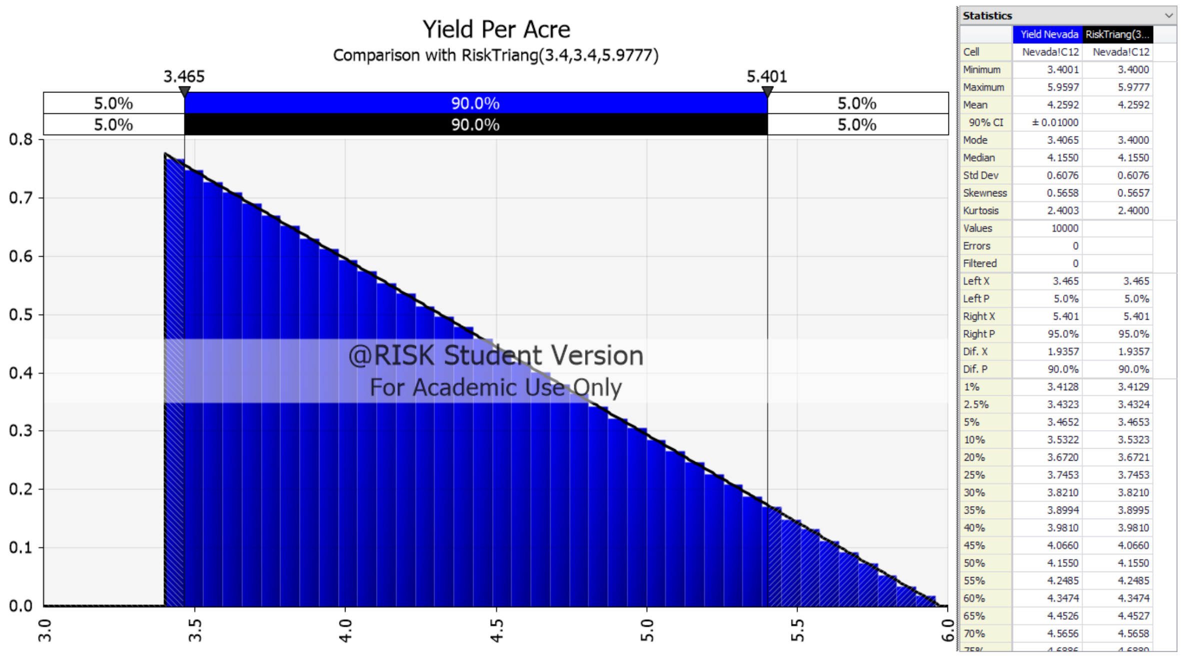


Figure 5 Alfalfa Yield Distribution in Central Western Nevada

The variable and fixed costs are shown in Table 8 are taken from "*Northwestern Nevada Alfalfa Hay Establishment, Production Costs and Returns, 2008*" (2010). Since the operating costs found correspond to 2008, some prices were adjusted for inflation, and some others were adjusted with information found on the internet. The costs related to irrigation were modified due to use an irrigation system different from that in the enterprise budget. As in the exercise carried out in Utah, yields are expected to improve slightly, so production was calculated with an increase of 3%.

Table 8 Variable and Fixed Costs for Alfalfa Production, Central Western Nevada

Variable Costs			
	Total Value	Value or Cost/Acre	Source
Insecticide	$ 3,780.00	18.9	keystone pest solutions (2020)
Herbicide	$ 3,460.00	17.3	keystone pest solutions (2020)
Accounting & Legal	$ 2,600.00	13.0	(Curtis, Kobayashi, & Bishop, 2008)
Fuel & Lube	$ 14,987.08	74.9	Global Petrpl Price (2020)
Maintenance	$ 7,364.50	36.8	(Curtis, Kobayashi, & Bishop, 2008)
Utilities	$ 4,524.00	22.6	(Curtis, Kobayashi, & Bishop, 2008)
Miscellaneous	$ 2,080.00	10.4	(Curtis, Kobayashi, & Bishop, 2008)
Operating Capital Interest	$ 5,014.64	25.1	(Curtis, Kobayashi, & Bishop, 2008)
Operator Labor	$ 35,150.00	175.8	U.S. BUREAU OF LABOR STATISTICS (2020)
Total Variable costs*	**$ 78,960.21**		
Irrigation			
Water Cost	$ 2,250.00	11.3	Autor Calculations
Irrigation Labor	$ 1,200.00	6	Autor Calculations
Pivot Maintenance	$ 6,400.00	32	Autor Calculations
Total Irrigation costs**	$ 9,850.00		
TOTAL	**$ 88,810.21**		
Fixed Cost			
FIXED COSTS***	$ 61,681.67		(Curtis, Kobayashi, & Bishop, 2008)
Irrigation insurance	$ 586.08		Autor Calculations
Total	**$ 62,267.75**		
TOTAL COSTS	**$ 151,077.96**		

* Total Variable costs excluding Costs related with irrigation
** Total variable costs related with irrigation
*** Total fixed cost excuding center pivot system insurance costs

The same assumptions used to evaluate this strategy in Central Eastern Utah were used in Central Western Nevada including a decrease in water consumption up to 50% according to Tiusanen (n.d.), however, for this analysis we are simulating with a water reduction of 25%. According to Brown (2008), labor may decrease up to 90% depending on how automated the irrigation system is, for this analysis we are simulating labor reduction of 40% in water irrigation activities. Finally, we are assuming 4% annually of the total cost on the new irrigation system in maintenance as we discussed previously.

3.2.3. Use of drought-resistant varieties

L.A. Hearne Company offers a modified seed that, according to the producer of the seed, is ideal for very dry climates and restricted access to water. The seed producer's recommendation suggests 25-30 pounds per acre be used (Hearne Company, 2020). Using the seed producer's recommendation, it was calculated that with the maximum use of seeds per acre, the price of the seed per acre would be $4.8, for a total seed change investment of $ 14,400 on a 100-acre farm in Central Eastern Utah. And a $28,800 investment in a 200-acre farm in Central Western Nevada. Rodman (2011) argues that the use of drought-resistant plant varieties could present between 7% and 10% more yield than other varieties of alfalfa under drought conditions. Therefore, for this analysis, it is assumed that alfalfa production increases by 8%. For this analysis, the prices and returns described in Tables 5 and 6 were used. Likewise, the price and yield distributions described above were maintained.

Table 9 describes the fixed and variable costs in Central Eastern Utah. The costs of water in this table were adjusted since the implementation of this strategy may change the use of water. Similarly, in Table 10, the Central Western Nevada farm costs are described. Some of the costs of this farm were updated with information found on the internet, and some other costs were adjusted for inflation.

Table 9 Variable and Fixed Costs for Alfalfa Production, Utah

Variable Costs			
	Total Value	Value or Cost/Acre	Source
Fertilizer	$ 6,000.00	$ 60.00	(USU, 2019)
Application	$ 600.00	$ 6.00	(USU, 2019)
Herbicide	$ 600.00	$ 6.00	(USU, 2019)
Application	$ 600.00	$ 6.00	(USU, 2019)
Insecticide	$ 400.00	$ 4.00	(USU, 2019)

Application	$ 600.00	$ 6.00	(USU, 2019)
Irrigation			
Water Cost	$ 2,125.00	$ 25.00	(USU, 2019)
Irrigation Labor	$ 2,500.00	$ 25.00	(USU, 2019)
Crop Insurance	$ 250.00	$ 2.50	(USU, 2019)
Operator Labor	$ 7,500.00	$ 75.00	(USU, 2019)
Fuel	$ 6,479.00	$ 64.79	(USU, 2019)
Repairs & Maintenance	$ 6,302.00	$ 63.02	(USU, 2019)
Interest	$ 275.00	$ 2.75	(USU, 2019)
Twine	$ 2,225.00	$ 22.25	(USU, 2019)
Other	$ 500.00	$ 5.00	(USU, 2019)
Total Variable Costs	**$ 37,331.00**		
Indirect Cost			
Buildings, Equipment, & Improvements	$ 4,500.62		(USU, 2019)
Machinery & Vehicles	$ 17,820.00		(USU, 2019)
Taxes & Insurance	$ 846.00		(USU, 2019)
General Overhead	$ 750.00		(USU, 2019)
TOTAL FIXED COSTS	**$ 23,916.62**		
TOTAL COSTS	**$ 61,247.62**		

Table 10 Variable and Fixed Costs for Alfalfa Production, Central Western Nevada

Variable Costs			
	Total Value	Value or Cost/Acre	Source
Insecticide	$ 3,780.00	$ 18.90	keystone pest solutions (2020)
Herbicide	$ 3,460.00	$ 17.30	keystone pest solutions (2020)
Irrigation	$ 5,100.00	$ 30.00	(Curtis, Kobayashi, & Bishop, 2008)
Operator Labor	$ 36,350.00	$ 181.75	U.S. BUREAU OF LABOR STATISTICS (2020)
Accounting & Legal	$ 2,600.00	$ 13.00	(Curtis, Kobayashi, & Bishop, 2008)
Fuel & Lube	$ 14,987.08	$ 74.94	Global Petrpl Price (2020)
Maintenance	$ 7,364.50	$ 36.82	(Curtis, Kobayashi, & Bishop, 2008)
Utilities	$ 4,524.00	$ 22.62	(Curtis, Kobayashi, & Bishop, 2008)
Miscellaneous	$ 2,080.00	$ 10.40	(Curtis, Kobayashi, & Bishop, 2008)
Operating Capital Interest	$ 5,014.64	$ 25.07	(Curtis, Kobayashi, & Bishop, 2008)
Total Variable Costs	**$ 86,160.21**		
Indirect Cost			
Liability Insurance	$ 2,080.00		(Curtis, Kobayashi, & Bishop, 2008)
Office & Travel	$ 1,820.00		(Curtis, Kobayashi, & Bishop, 2008)

Annual Investment Insurance	$ 3,884.45		(Curtis, Kobayashi, & Bishop, 2008)
Annual Investment Taxes	$ 5,392.50		(Curtis, Kobayashi, & Bishop, 2008)
Buildings, Improvements, & Equipment	$ 12,088.47		(Curtis, Kobayashi, & Bishop, 2008)
Machinery & Vehicles	$ 36,416.25		(Curtis, Kobayashi, & Bishop, 2008)
TOTAL FIXED COSTS	**$ 61,681.67**		
TOTAL COSTS	**$ 147,841.88**		

4. RESULTS

4.1. Livestock operations

4.1.1. Navajo Nation Strategies

Depopulation of animals-results

The first strategy used for the Navajo Nation (northern Arizona) was the depopulation of the animals. This strategy was carried out based on a control group and a modified group. According to food availability, the herd's size was reduced keeping a ratio of 1 male to 15 females. Due to the reduction of food available due to a drought, the reduced herd presents fewer costs related to feeding, however, it also presents less gross income. After evaluating the factors of production income, feeding costs, and variable costs, as can be seen in Table 11, the strategy of reducing the herd represents a decrease of 21.2% in returns above variable costs. Naturally, this reduction is due to the reduction of animals available for sale.

Table 11 Navajo Nation Strategies Results

		STRATEGIES							
				Reducing herd		Purchasing feed/hay		Leasing Grazing Land	
		Control		Modif.		Modif.		Modif.	
Population (Bull-Cow)		400		315		400		400	
		Bull	Cows	Bull	Cows	Bull	Cows	Bull	Cows
		25	375	20	298	25	375	25	375
TOTAL VALUE PRODUCED									
Average Value		$250,702.0		$200,561.6		$250,702.0		$250,702.0	
Value per cow		$626.8		$630.7		$626.8		$626.8	
FORRAJE CONSUMPTION									
Hay	Tons	45.0		45.4		442.7*		45.0	
Public Land	AUM	3302.5		2608.9		2608.9		2608.9	
Private (own)	AUM	1068.4		844.1		844.1		844.1	
Private (Leased Grazing)	AUM	485.7		383.7		383.7		1403.5	
FEED COST									
Subtotal Feed Cost		$38,994.9		$32,513.7		$101,135.1		$49,705.0	
Subtotal Value Per Cow Average		$97.5		$81.3		$252.8		$124.3	
OTHER VARIABLE COSTS PRICE COST HIGH LOW									
Subtotal Other Variable Cost		$67,321.4		$53,520.5		$67,321.4		$67,321.4	

Subtotal Value Per Cow Average	$168.3	$168.3	$168.3	$168.3
RETURNS ABOVE VARIABLE COSTS				
Average Value**	$140,535.7	$110,677.3	$78,395.4	$129,825.5
Value per cow**	$351.3	$276.7	$196.0	$324.6

*The price of the ton of hay for this state was set at $162.00 taken from (USDA, 2020)

**Returns exclude fixed costs and operational costs

Purchasing feed/hay results

For the simulation of this strategy, the control group was not modified in terms of the number of animals. However, the feeding costs have a significant rise, $38,994.9 for the control group, and $101,135.1 for the purchasing feed group (Table 11). The number of tons of hay needed to supply the amount of feed needed during a drought is quite high, resulting in a wide gap between both groups as a result of returns.

Leasing grazing land results

As the last strategy of livestock operations, the control group and the modified group also have changes in the information on feed costs. By leasing more grazing land and therefore buying more AUMs at a lower unit cost than the previous strategy, the feeding costs increase compared to the control group. Although the returns above variable costs are less than the control group, the returns for this strategy may be higher than the other two strategies reviewed.

By presenting the three strategies results, one next to the other (shown in table 11), leasing grazing land generates the highest returns than the other two strategies. Depopulation of animals could be the second-best strategy, despite having a small herd. The supplementation with hay generates low profits due to the high increase in expenses for hay purchasing.

4.1.2. Zuni Indian Reservation and Laguna Pueblo Strategies

Depopulation of animals-results

Similarly than Navajo Nation, for the Zuni Indian Reservation and Laguna Pueblo (northern New Mexico) the depopulation of the animals was carried out based on a control group and a modified group. According to food availability, the herd's size was reduced keeping a ratio of 1 male to 20 females. Due to the reduction of food available due to a drought, the reduced herd presents fewer costs related to feeding, however, it also presents less gross income. After evaluating the factors of production income, feeding costs, and variable costs, as can be seen in Table 11, the strategy of reducing the herd represents a decrease of 22.23% in returns above variable costs. Naturally, this reduction is due to the reduction of animals available for sale.

Table 12 Zuni Indian Reservation and Laguna Pueblo Strategies Results

		STRATEGY							
				Reducing herd		Purchasing feed/hay		Leasing Grazing Land	
		Control		Modif.		Modif.		Modif.	
Population (Bull-Cow)		450		315		450		450	
		Bull	Cows	Bull	Cows	Bull	Cows	Bull	Cows
		21	429	17	340	21	429	21	429
TOTAL VALUE PRODUCED									
Average Value		$362,966.5		$200,561.6		$362,966.5		$362,966.5	
Value per cow		$806.6		$630.7		$806.6		$806.6	
FORRAJE CONSUMPTION									
Hay	Tons	23.0		26.0		473.8*		23.0	
Public Land	AUM	4403.6		3478.8		3478.8		3478.8	
Private (own)	AUM	1100.9		869.7		869.7		869.7	
Private (Leased Grazing)	AUM	0.0		0.0		0.0		1155.9	
FEED COST									
Subtotal Feed Cost		$46,454.4		$37,961.1		$116,948.2		$57,787.3	
Subtotal Value Per Cow Average		$103.2		$106.3		$259.9		$128.4	
OTHER VARIABLE COSTS PRICE COST HIGH LOW									
Subtotal Other Variable Cost		$88,673.7		$70,347.8		$88,673.7		$88,673.7	
Subtotal Value Per Cow Average		$197.1		$197.1		$197.1		$197.1	
RETURNS ABOVE VARIABLE COSTS									

Average Value**	$223,879.3	$174,102.0	$153,385.6	$212,546.5
Value per cow**	$497.5	$487.7	$340.9	$472.3

*The price of the ton of hay for this state was set at $162.00 taken from (USDA, 2020)

**Returns exclude fixed costs and operational costs

Purchasing feed/hay results

For this strategy the control group was not modified in terms of the number of animals. However, the feeding costs have a significant rise, $46,454.4 for the control group, and $116,948.2 for the purchasing feed group (Table 12). The number of tons of hay needed to supply the amount of feed needed during a drought is quite high, resulting in a wide gap between both groups as a result of returns and a reduction in returns of 31.5%

Leasing grazing land results

As the last strategy of livestock operations, the control group and the modified group also have changes in the information on feed costs. By leasing a greater amount of grazing land and therefore buying more AUMs at a lower unit cost than the previous strategy, the feeding costs increase by 24.4% compared to the control group. Although the returns above variable costs are less than the control group, the returns for this strategy may be higher than the other two strategies reviewed.

After analyzing the three strategies results, shown one next to the other in table 12, leasing grazing land generates the highest returns than the other two strategies. Depopulation of animals could be the second-best strategy, despite having a small herd. And purchasing feed/hay generates low profits due to the high increase in expenses for feed/hay purchasing.

4.1.3. Duck Valley Indian Reservation

Depopulation of animals-results

For Duck Valley Indian Reservation, in Elko County, Nevada. We set a depopulated group simulating a herd reduction. The herd's size was reduced according to food availability, keeping a ratio of 1 male to 15 females. Due to the reduction of food available due to a drought, the reduced herd presents fewer costs related to feeding, however, it also presents less gross income. After evaluating the factors of production income, feeding costs, and variable costs, as can be seen in Table 13, the strategy of reducing the herd represents a decrease of 27.2% in returns above operational costs. Naturally, this reduction is due to the reduction of animals available for sale.

Table 13 Duck Valley Indian Reservation Strategies Results

		STRATEGY							
				Reducing herd		Purchasing feed/hay		Leasing Grazing Land	
		Control		Modif.		Modif.		Modif.	
Population (Bull-Cow)		400		328		400		400	
		Bull	Cows	Bull	Cows	Bull	Cows	Bull	Cows
		25	375	21	307	25	375	25	375
TOTAL VALUE PRODUCED									
Average Value		$366,287.3		$310,782.8		$366,287.3		$366,287.3	
Value per cow		$915.7		$947.5		$915.7		$915.7	
FORRAJE CONSUMPTION									
Hay	Tons	516.3		512.5		812.5		516.3	
Public Land	AUM	3500.0		2765.0		2765.0		2765.0	
Private (own)	AUM	0.0		0.0		0.0		0.0	
Private (Leased Grazing)	AUM	0.0		0.0		0.0		760.0	
FEED COST									
Subtotal Feed Cost		$61,318.0		$59,156.2		$84,368.7		$70,935.3	
Subtotal Value Per Cow Average		$153.3		$180.4		$210.9		$177.3	
OPERATIONAL COSTS									
Subtotal Other Variable Cost		$119,966.3		$117,005.9		$119,966.3		$119,966.3	
Subtotal Value Per Cow Average		$299.9		$356.7		$299.9		$299.9	
RETURNS ABOVE OPERATIONAL COSTS									
Average Value		$185,003.0		$134,620.7		$161,952.3		$175,385.6	

Value per cow	$497.5	$336.6	$404.9	$438.5

*For this state, the price of the ton of hay is $81.17 taken from (Johnson et al., 2018)

Purchasing feed/hay results

For this strategy the control group was not modified in terms of the number of animals. However, the feeding costs have a significant increase, $61,318 for the control group, and $84,368.7 for the purchasing feed group (Table 13). This strategy shows a in decrease of returns of 12.4% compared to the control group.

Leasing grazing land results

As the last strategy of livestock operations, the control group and the modified group also have changes in the information on feed costs. In this case, the enterprise budget used for this region did not report the use of leasing grazing land, so we simulate a scenario where ranchers lease grazing land and therefore buy AUMs. In this simulation, the feeding costs increase compared to the control group. Although the returns above operational costs are less than the control group, the returns for this strategy may be higher than the other two strategies reviewed.

The results of the three strategies results (Table 13), leasing grazing land strategy seems to generate the highest returns than the other two strategies. Contrary to the previous Indian Reservation evaluated, purchasing feed/hay could be the second-best strategy. Finally, depopulation of animal is the less profitable option in this Indian reservation.

In states where the reduction of livestock is better than purchasing feed/hay and vice versa, the combination of these two strategies proposed by Bailey et al. (2018)could be evaluated, who consider that the best option is to combine the sale of cattle with purchasing feed/hay.

4.1.4. Pyramid Lake Indian Reservation

Depopulation of animals-results

In Pyramid Lake Indian Reservation, the depopulation of the animals was carried out based on a control group and a modified group. According to food availability, the herd's size was reduced keeping a ratio of 1 male to 15 females. Due to the reduction of food available due to a drought, the reduced herd presents fewer costs related to feeding, however, it also presents less gross income. After evaluating the factors of production income, feeding costs, and variable costs, as can be seen in Table 13, the strategy of reducing the herd represents a decrease of 34.1% in returns above operational costs. Naturally, this reduction is due to the reduction of animals available for sale.

Table 14 Pyramid Lake Indian Reservation Strategies Results

		STRATEGY							
				Reducing herd		Purchasing feed/hay		Leasing Grazing Land	
		Control		Modif.		Modif.		Modif.	
Population (Bull-Cow)		350		328		350		350	
		Bull	Cows	Bull	Cows	Bull	Cows	Bull	Cows
		22	328	18	265	22	328	22	328
TOTAL VALUE PRODUCED									
Average Value		$326,914.5		$277,568.3		$326,914.5		$326,914.5	
Value per cow		$934.0		$980.8		$934.0		$934.0	
FORRAJE CONSUMPTION									
Hay	Tons	451.9		448.1		669.6*		451.9	
Public Land	AUM	3000.0		2370.0		2370.0		2370.0	
Private (own)	AUM	0.0		0.0		0.0		0.0	
Private (Leased Grazing)	AUM	0.0		0.0		0.0		651.0	
FEED COST									
Subtotal Feed Cost		$58,981.3		$56,566.9		$81,679.8		$67,218.8	
Subtotal Value Per Cow Average		$168.5		$199.9		$233.4		$192.1	
OPERATIONAL COSTS									
Subtotal Other Variable Cost		$101,829.0		$99,131.7		$101,829.0		$101,829.0	
Subtotal Value Per Cow Average		$290.9		$350.3		$290.9		$290.9	
RETURNS ABOVE OPERATIONAL COSTS									

Average Value	$185,003.0	$121,869.7	$143,405.7	$157,866.7
Value per cow	$497.5	$430.6	$409.7	$451.0

*For this state, the price of the ton of hay is $81.17 taken from (Johnson et al., 2018)

Purchasing feed/hay results

For this strategy the control group was not modified in terms of the number of animals. However, the feeding costs have a significant rise, $58,981.3 for the control group, and $81,679.8 for the purchasing feed group (Table 14). The number of tons of hay needed to supply the amount of feed needed during a drought is quite high, resulting in a wide gap between both groups as a result of returns and a reduction in returns of 22.5%

Leasing grazing land results

Similarly to Duck Valley Indian reservation, the enterprise budget used for this region did not report the use of leasing grazing land, so we simulate a scenario where ranchers lease grazing land and therefore buy AUMs. In this simulation, the feeding costs increase compared to the control group. Although the returns above operational costs are less than the control group, the returns for this strategy may be higher than the other two strategies reviewed.

After analyzing the three strategies results, shown one next to the other in table 14, leasing grazing land generates the highest returns than the other two strategies. The second-best strategy is purchasing feed/hay. Finally, depopulation of animal generates the lowest returns.

4.1.5. Uintah And Ouray Indian Reservation

Depopulation of animals-results

The first strategy used for Uintah And Ouray Indian Reservation (Duchesne County) was the depopulation of the animals. This strategy was carried out based on a control group and a modified group. According to food availability, the herd's size was reduced keeping a ratio of 1 male to 25 females. Due to the reduction of food available due to a drought, the reduced herd presents fewer costs related to feeding, however, it also presents less gross income. After evaluating the factors of production income, feeding costs, and variable costs, as can be seen in Table 15, the strategy of reducing the herd represents a decrease of 50.5.2% in returns above variable costs. Naturally, this reduction is due to the reduction of animals available for sale.

Table 15 Uintah And Ouray Indian Reservation Strategies Results

		STRATEGY							
				Reducing herd		Purchasing feed/hay		Leasing Grazing Land	
		Control		Modif.		Modif.		Modif.	
Population (Bull-Cow)		202		137		202		202	
		Bull	Cows	Bull	Cows	Bull	Cows	Bull	Cows
		8	194	5	132	8	194	8	194
TOTAL VALUE PRODUCED									
Average Value		$211,030.0		$141,917.2		$211,030.0		$211,030.0	
Value per cow		$1,044.7		$702.6		$1,044.7		$1,044.7	
FORRAJE CONSUMPTION									
Hay	Tons	200.0		201.1		321.4*		200.0	
Public Land	AUM	0.0		0.0		0.0		0.0	
Private (own)	AUM	0.0		0.0		0.0		0.0	
Private (Leased Grazing)	AUM	1484.0		1172.4		1172.4		1484.0	
FEED COST									
Subtotal Feed Cost		$82,694.9		$75,011.0		$92,577.1		$89,981.3	
Subtotal Value Per Cow Average		$409.4		$371.3		$458.3		$445.5	
OTHER VARIABLE COSTS									
Subtotal Other Variable Cost		$95,561.2		$84,798.0		$105,443.5		$102,847.7	
Subtotal Value Per Cow Average		$473.1		$419.8		$522.0		$509.1	
RETURNS ABOVE VARIABLE COSTS									
Average Value**		$115,468.8		$57,119.2		$105,586.5		$108,182.4	
Value per cow**		$571.6		$282.8		$522.7		$535.6	

**Returns exclude fixed costs and operational costs

Purchasing feed/hay results

For this strategy the control group was not modified in terms of the number of animals. However, the feeding costs have a significant rise, $82,694.9for the control group, and $92,577.1 for the purchasing feed group (Table 15). The number of tons of hay needed to supply the amount of feed needed during a drought is quite high, resulting in a wide gap between both groups as a result of returns and a reduction in returns of 8.6%

Leasing grazing land results

As the last strategy of livestock operations, the control group and the modified group also have changes in the information on feed costs. By leasing a greater amount of grazing land and therefore buying more AUMs at a lower unit cost than the previous strategy, the feeding costs increase by 8.8% compared to the control group. Although the returns above variable costs are less than the control group, the returns for this strategy may be higher than the other two strategies reviewed.

The results of the three strategies results (Table 15), leasing grazing land strategy seems to generate the highest returns than the other two strategies. Contrary to Arizona's and New Mexico's Indian Reservation, purchasing feed/hay could be the second-best strategy. Finally, depopulation of animal is the less profitable option in this Indian reservation. In the case of Utah, the reduction of livestock is the least profitable option, since from obtaining $115,468.8 they will have $57,119.2, generating a large gap in profits, the reason for this result can be demonstrated by the study of (Díaz-Solís et al., (2009) who warn that a total reduction in the existence of young animals would not allow small businesses survive economically, and Utah's state control herd is relatively small with just 200 animals.

4.1.6. Central Utah

Depopulation of animals-results

In this region we set a depopulated group simulating a herd reduction. The herd's size was reduced according to food availability, keeping a ratio of 1 male to 23 females. Due to the reduction of food available due to a drought, the reduced herd presents fewer costs related to feeding, however, it also presents less gross income. After evaluating the factors of production income, feeding costs, and variable costs, as can be seen in Table 16, the strategy of reducing the herd represents negative returns by $2,308.9 after total costs.

Table 16 Central Utah Strategies Results

		STRATEGY							
				Reducing herd		Purchasing feed/hay		Leasing Grazing Land	
		Control		Modif.		Modif.		Modif.	
Population (Bull-Cow)		96		82		96		96	
		Bull	Cows	Bull	Cows	Bull	Cows	Bull	Cows
		4	92	4	78	4	92	4	92
TOTAL VALUE PRODUCED									
Average Value		$62,958.4		$54,121.5		$62,958.4		$62,958.4	
Value per cow		$565.5		$563.8		$565.5		$565.5	
FORRAJE CONSUMPTION									
Hay	Tons	105.1		105.1		150.8*		105.1	
Public Land	AUM	595.6		466.4		466.4		466.4	
Private (own)	AUM	0.0		0.0		0.0		0.0	
Private (Leased Grazing)	AUM	201.8		158.0		158.0		328.1	
FEED COST									
Subtotal Feed Cost		$24,072.5		$22,547.7		$29,972.8		$27,901.8	
Subtotal Value Per Cow Average		$250.8		$234.9		$312.2		$290.6	
OTHER VARIABLE COSTS									
Subtotal Other Variable Cost		$25,164.5		$23,140.7		$25,164.5		$25,164.5	
Subtotal Value Per Cow Average		$262.1		$248.7		$262.1		$262.1	
RETURNS ABOVE TOTAL COSTS									
Average Value		$1,145.3		-$2,308.9		-$4,754.9		-$2,684.0	
Value per cow		$11.9		-$50.9		-$49.5		-$28.0	

*For the state of Utah, the price of a ton of hay is $97.00 taken from (USDA, 2020)

Purchasing feed/hay results

For this strategy the control group was not modified in terms of the number of animals. The feeding costs increase, from $24,072.5 for the control group, and $29,972.8 for the purchasing feed group (Table 16). This strategy shows negative returns by -$4,754.9.

Leasing grazing land results

As the last strategy of livestock operations, the control group and the modified group changes a little in the information on feed costs, $24,072.5 for the control group, and $27,901.8 for the modified group. The returns above total cost for this strategy is negate by -$2,684.0.

By presenting the three strategies results, one next to the other (Table 16), all the three strategies represent negative returns. However, the strategy that generates fewer negative returns is the depopulation is animal, followed by leasing grazing land. Purchasing feed/hay may be the worst strategy to manage a drought in this region being that generates more losses than the other two strategies. This ranch may be highly affected by a drought due to its size, as smaller the herd is, higher are the losses by drought. The reduction of herd was ranked first just in one region as the best strategy, which is contradictory to the study of Ndiritu, (2019) wherein 52% of the evaluated herds adopt this strategy.

4.2. Hay Operations

4.2.3. Uintah and Ouray Reservation

Efficient Irrigation System results

After simulating the scenario where a more efficient irrigation system is implemented, it can be seen that after evaluating the project at 15 years, the useful life of the Pivot Center irrigation system, the probability of having negative returns is 88.5% (Figure 6) on 100-acre farms, as is the case in Utah.

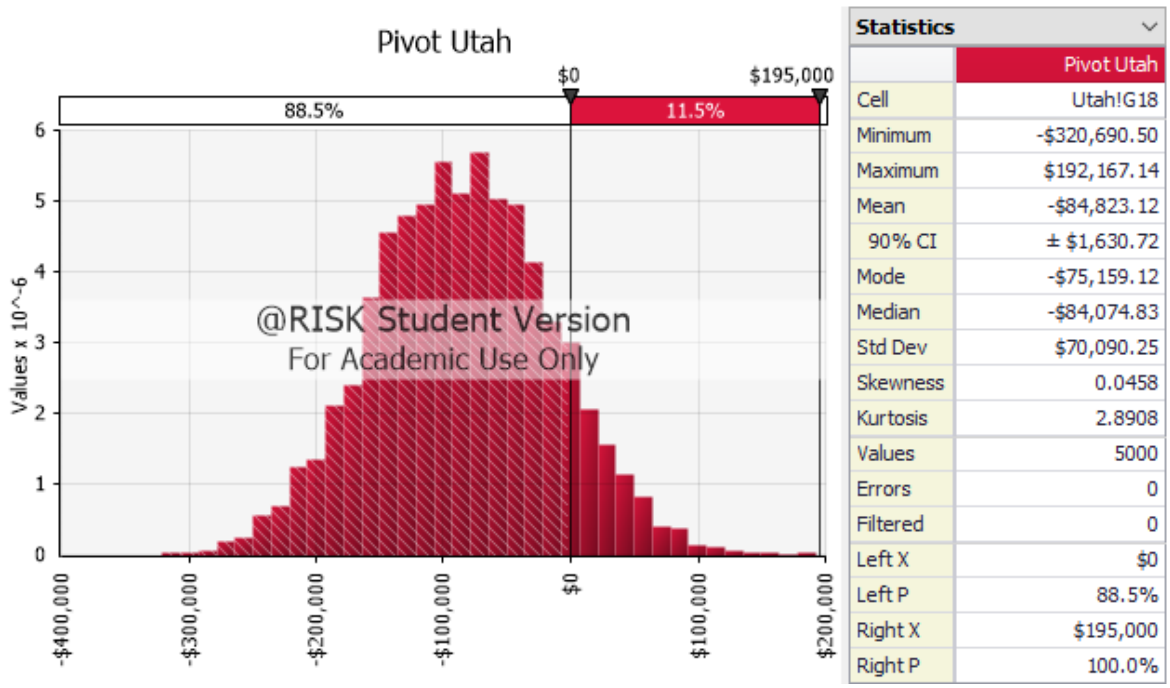
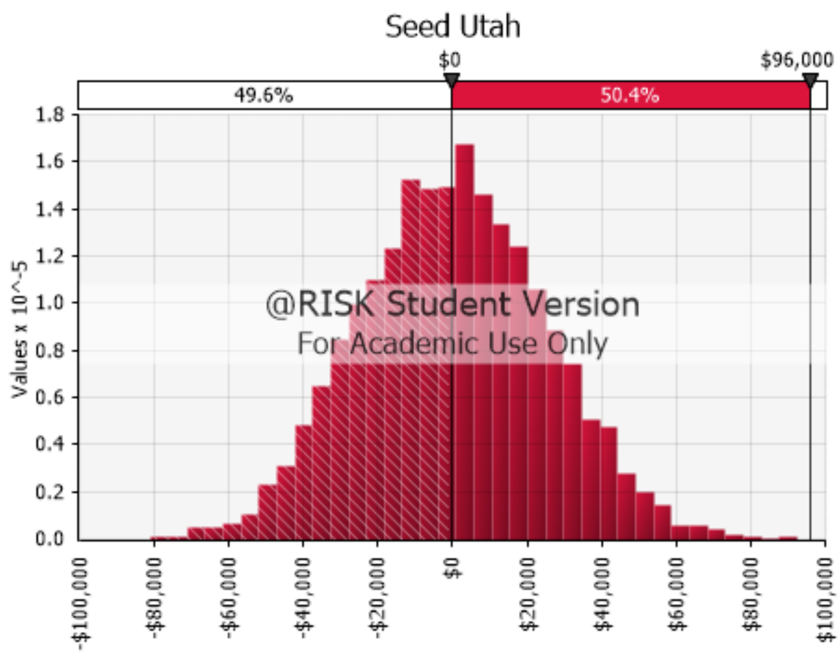


Figure 6 Center Pivot NPV Probability Density Function in Utah

Drought Tolerant Varieties results

At the same time, after evaluating the strategy of changing to drought tolerant variety, it was found that the probability of having negative returns is reduced by adopting this strategy. The probability of having negative returns under this strategy is reduced to 49.6% (Figure 7). It should be clarified that the strategy of changing varieties was evaluated at three years since, according to the seed producer it is recommended to change the seed between 3 to 5 years when the crop was planted (Hearne Company, 2020). Likewise, the seed producer affirms that the most productive years are the first three years, and after that time yields tend to decrease.



Statistics	Seed Utah
Cell	Utah!G74
Minimum	-$80,858.53
Maximum	$92,424.35
Mean	$228.93
90% CI	± $577.99
Mode	$1,136.74
Median	$258.39
Std Dev	$24,842.78
Skewness	0.0479
Kurtosis	2.8176
Values	5000
Errors	0
Filtered	0
Left X	$0
Left P	49.6%
Right X	$96,000
Right P	100.0%

Figure 7 Drought Tolerant Variety NPV Probability Density Function in Utah

Although implementing an efficient irrigation system can reduce other operational costs such as water use and the amount of labor required for irrigation, these cost reductions are not enough to offset the increase in irrigation system maintenance, generating a probability of having 63.3% negative returns each year.

On the other hand, adopting the strategy of adopting drought tolerant variety offers certain benefits in terms of yields per acre since it can increase yields between 9% and 11%. However, this strategy would not reduce operational costs. Also, changing the seed has a probability of negative annual returns of 43.8%.

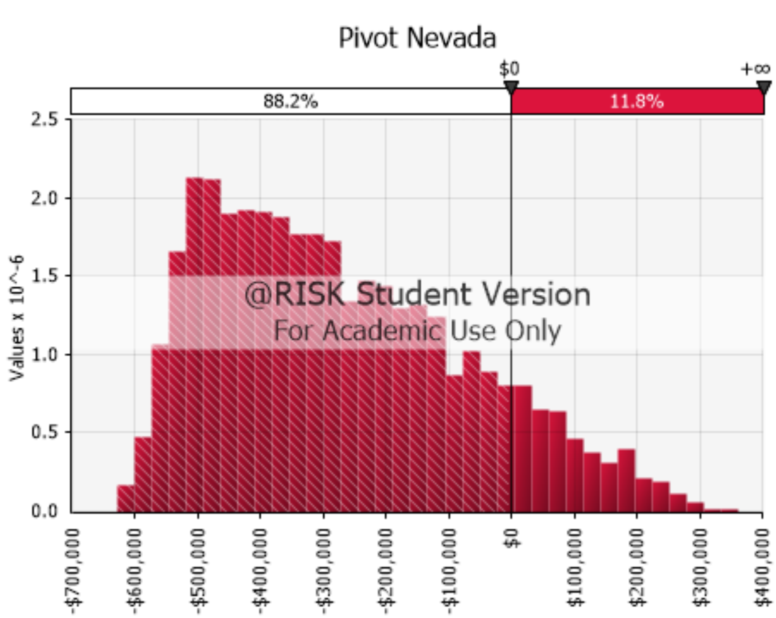
In terms of investment, each strategy has their advantage and disadvantages, the main disadvantage of implementing a more efficient irrigation system is the heavy initial investment that must be made, since, in this exercise, it was estimated that the initial investment would be $80,000 for a 100-acre farm. However, given the irrigation system's useful life, 15 years, the total investment for this period of time is not comparatively very high for the drought resistant variety strategy. Given that the seed has to be replaced every three years to obtain the maximum yields, in the same 15 years, the initial investment of $14,400 must be made 5 times, which would give a total cost of the seed of $ 72,000; not counting the change in the price of the seed over the years.

For Uintah and Ouray Reservation, the strategy that costs less and has more financial benefits in the short term is adopting drought resistant varieties. This strategy requires a less initial investment and has the potential to increase the yield. At the same time, this strategy is the one that has less probability of having negative returns or less risk.

4.2.2. Pyramid Lake Indian Reservation

Efficient Irrigation System results

In Pyramid Lake Indian reservation case, the scenario where a more efficient irrigation system is implemented, it can be observed that after evaluating the project, the probability of having negative returns is 88.2% (Figure 8) in farms of 200 acres, such as the Nevada case.

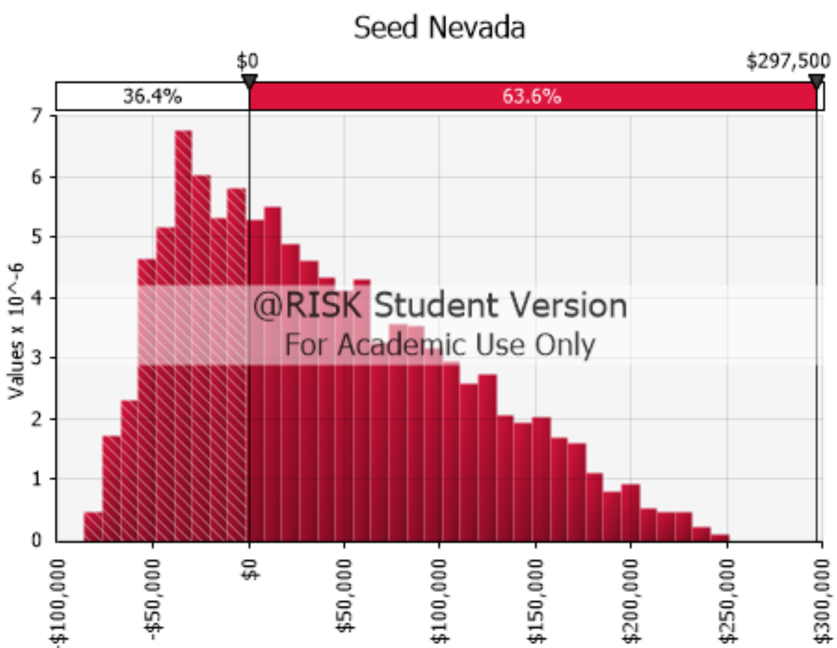


Statistics	Pivot Nevada
Cell	Nevada!G18
Minimum	-$629,809.80
Maximum	$362,646.00
Mean	-$275,073.38
90% CI	± $4,734.05
Mode	-$502,710.58
Median	-$307,456.12
Std Dev	$203,474.59
Skewness	0.5562
Kurtosis	2.5035
Values	5000
Errors	0
Filtered	0
Left X	$0
Left P	88.2%
Right X	+∞
Right P	100.0%

Figure 8 Center Pivot NPV Probability Density Function in Nevada

Drought Tolerant Varieties results

At the same time, after evaluating the strategy of drought resistant variety more resistant to droughts, it was found that the probability of having negative returns is reduced by adopting this strategy. The probability of having negative returns under this strategy is reduced to 36.4% (Figure 9)



Statistics	Seed Nevada
Cell	Nevada!G69
Minimum	-$85,909.54
Maximum	$251,070.25
Mean	$38,246.60
90% CI	± $1,665.36
Mode	-$28,791.48
Median	$25,384.94
Std Dev	$71,578.78
Skewness	0.5731
Kurtosis	2.5174
Values	5000
Errors	0
Filtered	0
Left X	$0
Left P	36.4%
Right X	$297,500
Right P	100.0%

Figure 9 Drought Tolerant Seed NPV Probability Density Function in Nevada

Similar to the Utah case, the strategy of implementing a pivot center irrigation system can reduce other operational costs of water consumption and the amount of labor required for irrigation, but these cost reductions are not enough to compensate for the increase in maintenance of the irrigation system; which could generate a probability of having 48.2% negative returns each year. Adopting the strategy of changing the seed offers has certain benefits that were already discussed previously. Additionally, changing the type of seed has a probability of having negative annual yields of 30.2%.

For Pyramid Lake Indian reservation, the strategy that is more efficient, costs less and has more financial benefits in the short term is adopting drought resistant varieties. This strategy requires a less initial investment and has the potential to increase the yield. At the same time, this strategy is the one that has less probability of having negative returns or less risk.

Drought-resistant variety are obtained by plant breeding techniques or biotechnology; currently, studies on them continue to increase (Ngumbi, 2019). There are still challenges to improve drought-tolerant crops, testing the seeds in different locations and accurately characterizing the traits that can take many years yet require several different studies as discussed by Ngumbi, (2019). Significant investment is needed to have drought-tolerant crops available to all farmers in different locations. McFadden (2019) shows that some researchers are aware that variety resistant to drought do not show a statistically significant difference in yields compared to varieties that have not been designed for drought. These previous observations by the authors could answer the low profit produced by implementing a drought-resistant seed system. While it is true, changing the type of seed is a more viable strategy than implementing a complex irrigation system such as the center pivot. As science and genetic improvement of seeds advances, it is possible to advance in the productivity per acre of the seed, which will generate a higher profit and achieve a great advantage over non-resistant seeds, but for the moment, it continues being a not very viable strategy.

5. CONCLUSIONS

Sixty five percent of the United States has been covered by drought. In 2012 (the strongest drought in the last decade) generated agricultural losses that exceeded $30,000 million dollars (Rippey, 2015). This thesis search to improves knowledge concerning climate risk management, especially for drought. It contributes to understand decision-making related to risk management in times of drought on southwest Indian reservations.

In livestock operations, it cannot be said that just one strategy serves to manage droughts. The strategies to manage droughts depend on different factors such as geographic location, size of the herd, access to different food sources, etc.

For livestock operations of the Indian reservation located in Arizona and New Mexico, the strategy that stood out was leasing grazing land. However, it should be noted that the land available for grazing is limited. In these regions, where most of the feed for livestock comes from public and private lands, purchasing feed/hay turns out to be the worst strategy, since the cost of this kind of feed is very high compared to purchasing AUMs.

In the Indian reservations located in Nevada, a great option is purchasing additional tons of feed/hay since the Indian reservations in this region base a large part of the feeding on purchasing supplementary feed/hay. In the particular case of Utah, it is evident that small herds are more susceptible to droughts, and in this case, the best strategy is to reduce livestock.

For alfalfa production, in both cases, of the Indian reservations located in Nevada and Utah, the strategy that stood out over the other was to switch to a drought-resistant variety. Under this strategy, there is more probability of having positive returns every year and even at the end of the three years when the seed must be re-sown. However, it should be noted that there is still a lot of inconclusive information that could validate these results. For example, there is still uncertainty if droughts resistant varieties require less water, and if so, how much less this seed can tolerate without affecting its production.

Finally, it is necessary for the government and private institutions to greatly improve their support for individual farmers, ranchers, and land managers, to facilitate a systematic collection and organization of information as a basis for programs and related to drought. Brown (2017) states that collaboration of institutions and agricultural producers can improve institutional and individual learning and mitigate the impacts of drought for both agricultural producers and the economy.

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