Potential Impact of Innovations in Production and Ginning Technologies on Relative Profitability of Pima and Upland Cotton in the U.S. Southwest

Pratima Bhandari, Ram N. Acharya, J. Idowu, and Carlos B. Armijo

This study examines the impact of recent innovations in production and ginning technologies on the profitability of growing Pima and upland cotton in the Southwest. Pima cotton produces higher quality and more durable fabrics than the upland cotton due to its longer fiber and attracts higher lint prices than the upland cotton. However, it is more expensive to produce because of its longer growing season, higher management costs, lower yields, and high ginning costs. For these reasons, upland cotton is the dominant variety grown in the region.

However, recent varietal improvements and ginning technologies may enhance the relative profitability of producing Pima cotton. Moreover, the changing climate and increased production of Pima cotton may significantly heighten the demand for irrigation water and other scarce resources. Given these scenarios, this study combines publicly available state-level cost of production and yield data with experimental crop yield and ginning cost observations to evaluate the relative performance of two cotton varieties produced in the region. Also, the impact of changing the varietal mix and climate change will be simulated under different water supply and cotton demand scenarios. The preliminary results indicate that grower's varietal choice will heavily depend on the availability of irrigation water.

Keywords: cotton varieties, farm profitability, Monte Carlo simulation, climate change.

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Introduction and History:

Cotton is one of the most important textile fiber in the world which accounts for about 13 percent of all fibers produced. The USA is world's largest cotton producer, ranking third after China and India and is the leading exporter in the world cotton market. US export accounts for one third of the global trade in raw cotton (agmrc.org, 2017)

Two major varieties of cotton produced in the US are Upland cotton (*Gossypium hirsutum)* and Pima cotton *(Gossypium barbedense)*. Of these two varieties, upland cotton is the predominant one, of the total acreage of 10.5 million acres of cotton harvested in 2018 upland cotton covered 10.2 million acres. The average yield of upland cotton for 2018 was 821 lb/acre. 17.5 million bales of upland cotton were ginned in 2018 and received a price of 0.75$/lb. The major upland cotton producing states by volume are Texas, Georgia, Mississippi, Arkansas and California. Another variety planted is the pima cotton also known as Extra-long staple (ELS) cotton, pima cotton covers about 5% of the total cotton production in the USA. The average yield of pima cotton for 2018 was 1540 lb/acre. 7.94 million bales of pima cotton were ginned in 2018 and received a price of 1.10 $/lb (NASS, 2018)

Pima cotton is a higher end type of cotton which have a longer fiber than upland cotton. Pima cotton fiber measures between 1.4 to 2 inches in length, while upland cotton measures upto 1.1 inches long. According to the cotton product manufacturers, pima cotton products have 50% longer life expectancy than other cotton products (Authenticity50, 2018). Though the pima cotton has high premium price it is not cultivated as commonly as upland cotton because of it being limited to the regions which are capable of accommodating its long growing seasons (>200) days due to its indeterminate nature. Therefore, it is confined to California, Arizona, West Texas and New Mexico (Unruh and Silvertooth 1996).

Comparison of Pima and Upland cotton under various conditions:

Response to Irrigation and Fertilization:

As the two varieties have a difference in the yield factors they also respond differently to the practices such as irrigation and fertilization. Pima cotton has traditionally received different irrigation management as compared to upland cotton. it is stressed more for irrigation as compared to the upland cotton. An experiment conducted to see the response of the cultivars of these two varieties showed that, pima cotton obtained higher lint at one increment of the drier irrigation than upland cotton. It was observed that whenever there was reduction on the lint yield by frequent irrigation, pima cotton yield was reduced more than the upland cotton and conversely, when lint yield decreased by water deficiency, upland cotton was affected more than pima cotton. Dry treatments were found to reduce the fiber lengths for upland cotton but not for pima cotton (Kittock 1979).

Under the California production system, N is generally considered to be a limiting factor and is added to meet crop demand. Average N fertilizer applied by California cotton growers increased considerably since the late 1970s from about 120 to 200 kg ha^{-1} in the mid-1990s. there might be some link between the increase of N fertilizer and the development of new cotton varieties. The modern cotton cultivars are more determinate and early maturing, set and fill bolls over a shorter period of time and respond more strongly to N application than the obsolete varieties. Both the Acala and Pima dry matter production increased in response to N. The different pattern of response to the N treatment suggested that N fertilization in Pima should not be simply based on the experience gained with Acala (Fritschi, Roberts et al. 2003).

Nutrition Partitioning:

Other studies were also conducted for the comparison between the upland and pima cotton for the growth, yield and nutrition uptakes. In the past, pima cotton cultivars typically yielded less than the upland cotton cultivar during 1996 the dominant pima cultivar was S-6 which was a relatively indeterminate cultivar and was comparable to the dominant upland cultivar Deltapine 90. The results of the experiment showed that there was a higher vegetative growth of upland cotton as compared to the pima cotton and the balance between the reproductive and vegetative growth between two cultivars was similar. Though the balance between the vegetative and reproductive growth was similar, there was a wide difference between the production of lint as a function of reproductive/vegetative dry matter ratio (RVR). The results showed that for each unit increase of RVR there was an increase of 190 g lint/m^2 in DPL 90 as compared to 92 g lint/m^2 for S-6(Unruh and Silvertooth 1996). In addition to the RVR, the lower yield of Pima S-6 relative to the DPL 90 were apparently due to the smaller total biomass and less efficient portioning of dry matter into reproductive organs. There was not any significance difference in the uptake of nutrients by the two cultivars but pima cotton required slightly more N, P, and K per unit of lint production(Unruh and Silvertooth 1996).

Effect of Irrigation:

The fiber length and the strength are the major determining quality for any cotton variety and there are many cultural operations which add up to maintaining the innate fiber quality of the cotton varieties. This led to the experiments in the shortening of the duration of plantation and irrigation application in cotton. The need for shortening of growing season was sought because there is was a high loss of cotton production due to the insect infestation in addition to the loss in production, more cost for management and environmental risk is also implied (Kittock, Henneberry et al. 1981). In addition to the cost for insect management, the full season utilization for growing the cotton crop has other problems associated with it which are increased water cost, limited water availability (major areas of desert southwest) and nutritional needs extended to full season. The results of the experiments to reduce the planting season and irrigation requirements showed that early planting is critical to ensure the optimum yield potential for full maturity of upland and pima cotton. An average yield increase of 83lb lint/acre and 118 lb lint/acre for upland and pima cotton respectively was found for irrigation termination after the development of second fruiting cycle. Results also showed that termination prior to the rise of late-season insect pressure provided the best management strategy for maintaining lint quality and yield potential (Unruh and Silvertooth 1997).

Dryland Cotton Production:

Cotton has been produced on the fine-textured soils in the southern Great Plains where, after the intensive use of irrigation water, the underground water supplies are being depleted and the places where the saturation of aquifer was thin, have reverted to dryland. These circumstances indicate that, researches are needed to evaluate alternative dryland cropping and tillage system, which will simultaneously provide erosion control, save water and maintain farm profits (Harman, Michels et al. 1989). The 50% of the acreage of cotton in the Texas Southern Great Plains was irrigated through the non-recharging Ogallala aquifer and the decreasing well yields and increased pumping costs have increased which led to the increase of dryland acreage.

An experiment on the moisture deficit effect on different vegetative and reproductive traits of cotton observed that, irrigated condition increased the lint yield 35% over the yield of dryland treatment. Though the yield was numerically higher, irrigation did not significantly affect the lint yield (Pettigrew 2004).

Research Methodology:

a. **Analysis Tools**

Monte Carlo Simulation:

Monte Carlo simulation offers business analysts and investors an economical means of conducting risk-based economic feasibility studies for new investment and a non-destructive means of stress testing existing business under risk. Monte Carlo simulation provides decision makers with extreme values of relevant key output variables and favorable outcomes. In addition to analysis of risk and how it affects the feasibility of a project, simulation model can be used to analyze the alternative management plans if the investment is undertaken.

It is a simulation technique that formulates the probability distribution of the possible outcomes of the decisions which we would make. This process allows the decision makers to assess the probability of risks that comes with a decision that they make so that they can select the decision that provides the best balance of benefit against risk (vosesoftware.com, 2019).

The greatest benefit of a Monte Carlo simulation feasibility analysis is that the methodology explicitly incorporates risk faced by investors. By incorporating probability factors for variables that investors cannot forecast with certainty, the analyst can develop realistic probabilistic forecasts of Key Output Variables. The additional benefits of the methodology include the decision maker's ability to see the range of KOVs as well as the probabilities of the unfavorable outcomes. The simulation methodology can be used for the feasibility study for a wide range of agribusinesses (Richardson, Herbst et al. 2007).

Monte Carlo programming involves random sampling from all feasible plans within the boundary of constraints relevant to the farm (Dent and Byrne 1969).

Monte Carlo simulation is a widely used tool whenever the uncertainty is expressed in the form of probability distributions. Usually, the uncertain parameters are given in the form of specific probability distribution. Mathematical programming and Monte Carlo can be combined whenever the nature of dominance is stochastic.

Stochastic Dominance:

A very popular way to rank alternative risk management strategies consistent with the Expected Utility Hypothesis (EUH). All the stochastic dominance techniques are ways to rank alternative strategies consistent with EUH. The EUH is one of the most commonly used model to guide decision making under uncertainty. Several applications of stochastic dominance have demonstrated innovations that could be of great use to the agricultural risk analysis. Techniques has been developed that allow for threshold risk preferences to be identified, that measure the value of information for risk management (Cochran 1986).

There is a number of stochastic dominance application for determining efficient and inefficient choices within agricultural economics. The second degree stochastic dominance is distribution free and relies only on the available data, it makes no ancillary assumptions about a super population that generated the data (H. Dennis, 1988).

Using stochastic dominance to select the most efficient strategies relies on comparing cumulative probability distributions of possible incomes of each strategy. Stochastic dominance does not require that the underlying distribution is normal and, therefore is more flexible than other analysis. Stochastic dominance is consistent with the expected utility hypothesis as a general model for guiding the decision making process under uncertainty. The stochastic dominance with respect to a function (SDWRF) is a generalized version of the commonly used first and second degree stochastic dominance criteria and, at the same time is more flexible and discriminating and does not require the specification of the decision maker's utility function (Williams 1988).

Stochastic dominance is a popular tool for discrete choice efficiency analysis. It makes pairwise comparisons of probability distributions, Fi and Fj from a finite set of choices in order to determine if one is inefficient and should be discarded from the efficient set (Kramer and Pope 1981). Stochastic dominance is a popular method for the analysis of agricultural data, it provides a way of ranking risky alternatives without the detailed knowledge of decision-maker preferences(McCarl 1990).

It is an analytical technique which enables one to rank two cumulative distributions in terms of risk preference. The process has been used by various researchers for different experiments some of them being, analyzing alternative commodity programs, evaluating various crop insurance strategies etc. (Zacharias and Grube 1984).

b. Data Source

The data for this study were obtained from various primary and secondary sources. The production cost of cotton for each state was derived from the openly available state-level crop budgets and the experimental yield data of different varieties of cotton in the various locations of New Mexico. The crops budget for New Mexico was obtained from the Cost and Return Estimates (CARE) 2019, from NMSU and the crop budget for Texas was obtained from the publicly available cotton budgets from Texas A&M. The budget for Arizona and California was derived by the Producers Price Indexing of the state budgets available. The budgets consist of cost associated with land preparation, planting, growing and harvesting cotton. Budget for each state has the variables related to the crop revenue, variable cost, fixed cost and overhead costs per acre for the Upland and pima cotton.

The yield data for different cotton varieties of both upland and pima cotton were obtained from the experiments in the popular varieties of both cotton cultivars on Las Cruces and Artesia.

Yield/ Acre for different states:

	Upland (dryland)	Upland (irrigated)	Pima (irrigated)
NM		977	812
TX	547	954	933
CA		1910	1662
AR		1319	943

(NASS, 2018)

Yield/ Acre of Upland and pima varieties in New Mexico:

Pima lb/acre			Upland lb/acre		
Cultivars	**Las Cruces**	**Artesia**	**Cultivars**	**Las Cruces**	**Artesia**
DP 348	929.02	1825	16R 346 B3XF	1112.98	1271
PHY 881 RF	974.37	1941	16R 341 B3XF	1368.43	1176
PHY 841 RF	1007.68	2014	DP 1549 B2XF	1185.91	1212
PHY 802 RF	837.36	1196	DP 1612 B2XF	1536.82	1197
PHY 805 RF	601.61	1778			

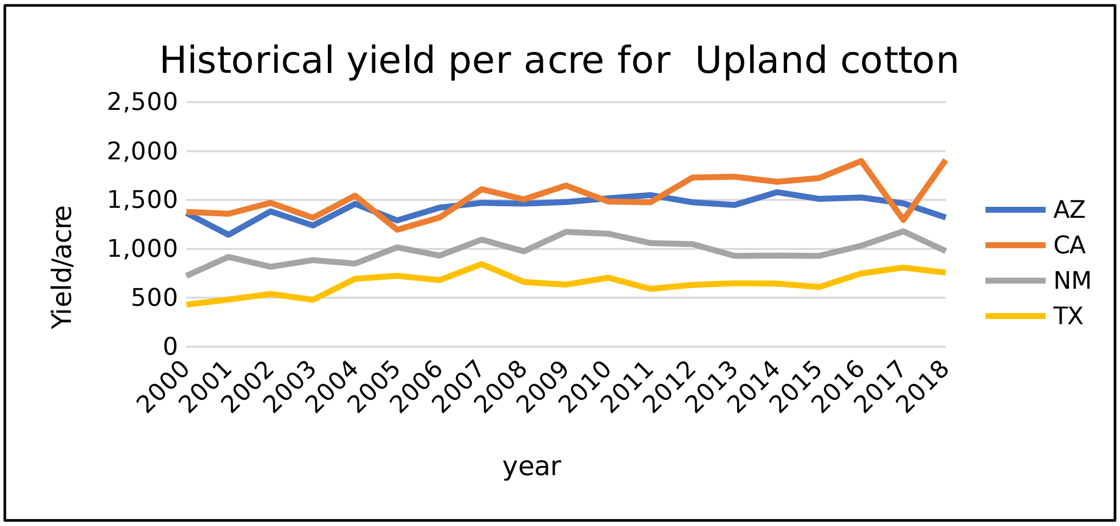
(Cotton newsletter, 2018)

3. Results and Discussions

a. Empirical Results:

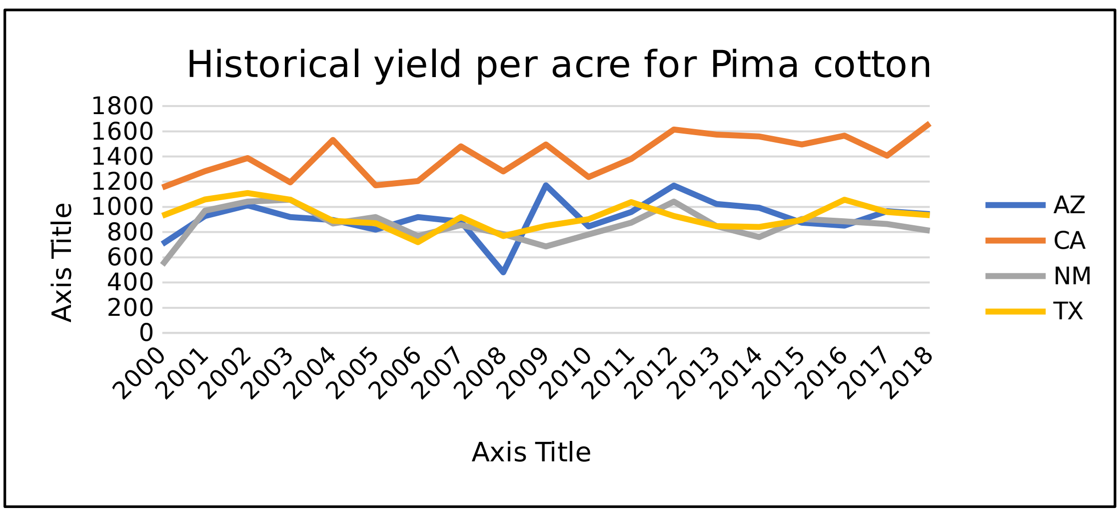
The cotton budgets from all the four states showed that the highest net returns above the cost of production was for the irrigated pima cotton in California, whereas the lowest return was found for the irrigated Upland cotton in New Mexico. For Upland cotton, highest net return was found in Texas and lowest was in New Mexico and for pima cotton, highest return was for California and lowest was for New Mexico.

The historical yield data for both varieties of cotton showed that per acre yield for both the cotton is highest for California whereas the lowest yield of upland cotton was for Texas and lowest for Pima was in New Mexico.



(Source: Quickstat NAAS, 2019)

Figure 1: Historical yield (lb/acre) for irrigated upland cotton in all the four states of the study area.



(Source: Quickstat NAAS, 2019)

Figure 2: Historical yield (lb/acre) for irrigated pima cotton in all the four states of the study area.

b. Simulation Results:

The historical yield of the cotton varieties from 2000 to 2018 were simulated in the cotton budgets. Simulation was carried out for 1000 iterations and the comparison was carried out for within states and between states. The simulation for the irrigated upland cotton showed that AZ has the highest probability of making profit from the production of Upland cotton given the current budget scenario. Results show that Arizona has 98.2% probability of making profit by producing irrigated upland cotton, followed by New Mexico, California and Texas. Texas have only 17.4% chances of making a positive return for producing upland cotton.

Whereas, for pima cotton the probability of getting the high net return was highest for Texas having 94.8% chances of getting returns above zero followed by New Mexico, California and Arizona. Arizona have 61.0% chances of getting positive returns for producing pima cotton.

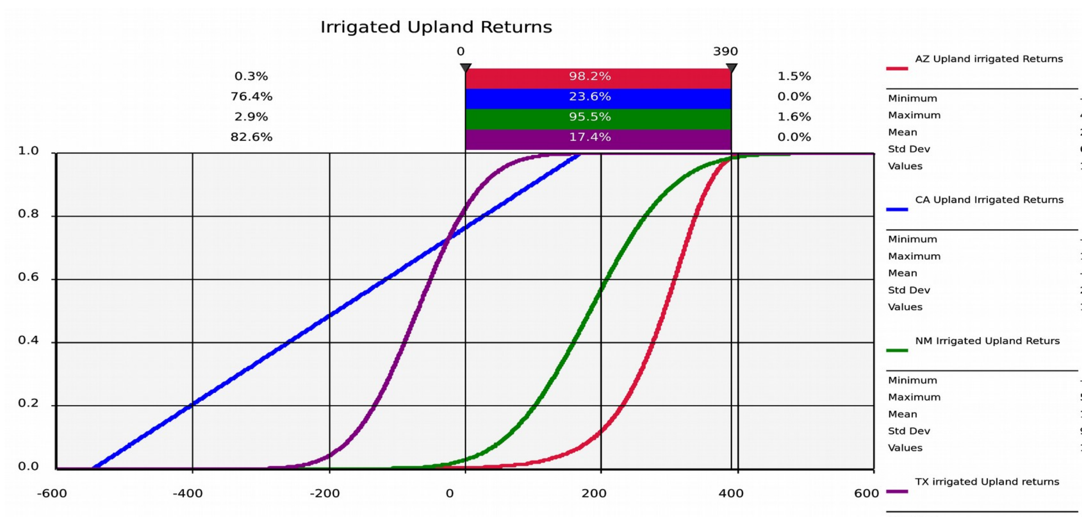


Figure 3: Simulated net returns for irrigated Upland cotton in AZ, CA, NM and TX.

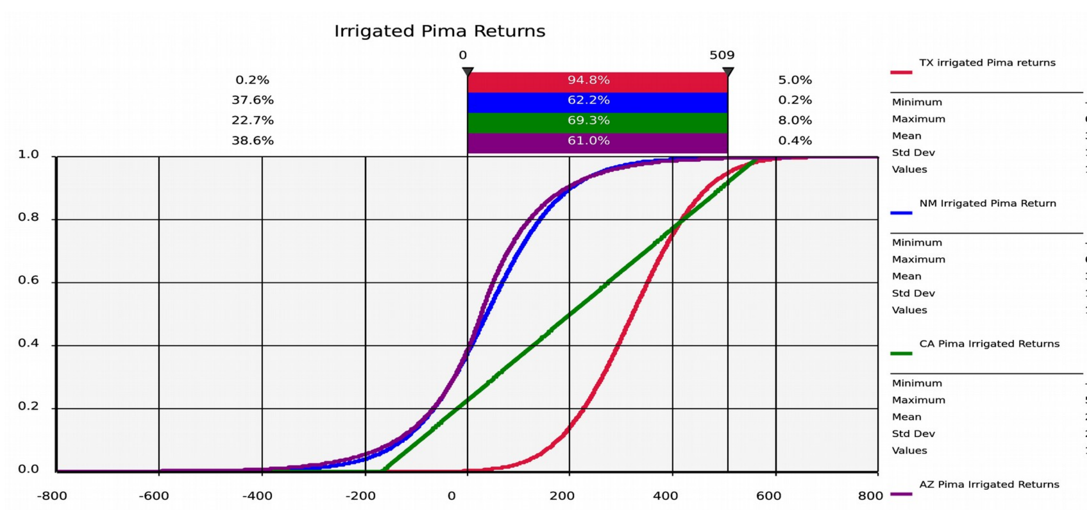


Figure 4: Simulated net returns for irrigated pima cotton in AZ, CA, NM and TX.

Yield Comparison for each state:

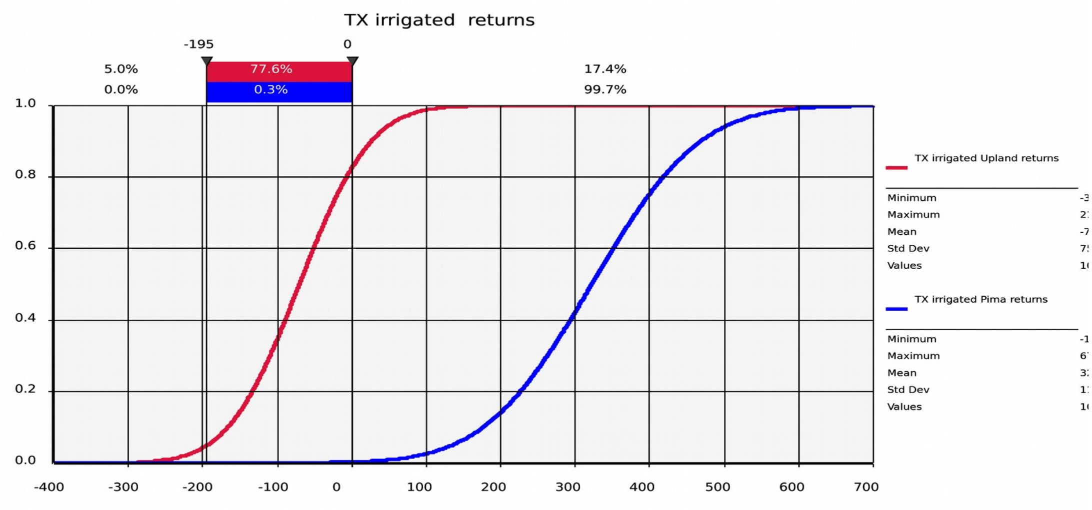


Figure 5: Simulated net returns for irrigated cotton in TX.

The comparison between both the varieties of cotton in Texas shows that producing pima cotton is more profitable than producing upland cotton. Texas have 99.7% chances of making profit from producing Pima cotton whereas the chances are 17.4% for upland cotton.

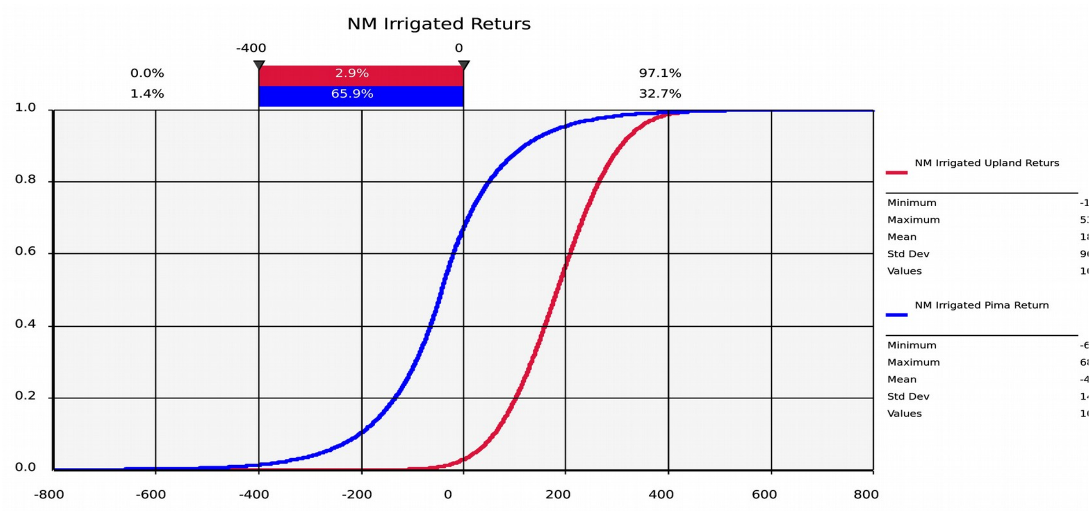


Figure 6: Simulated net returns for irrigated cotton in NM.

The comparison between both the varieties of cotton in New Mexico shows that producing upland cotton is more profitable than producing pima cotton. New Mexico have 97.1% chances of making profit from producing upland cotton whereas the chances of profit are 32.7% for pima cotton.

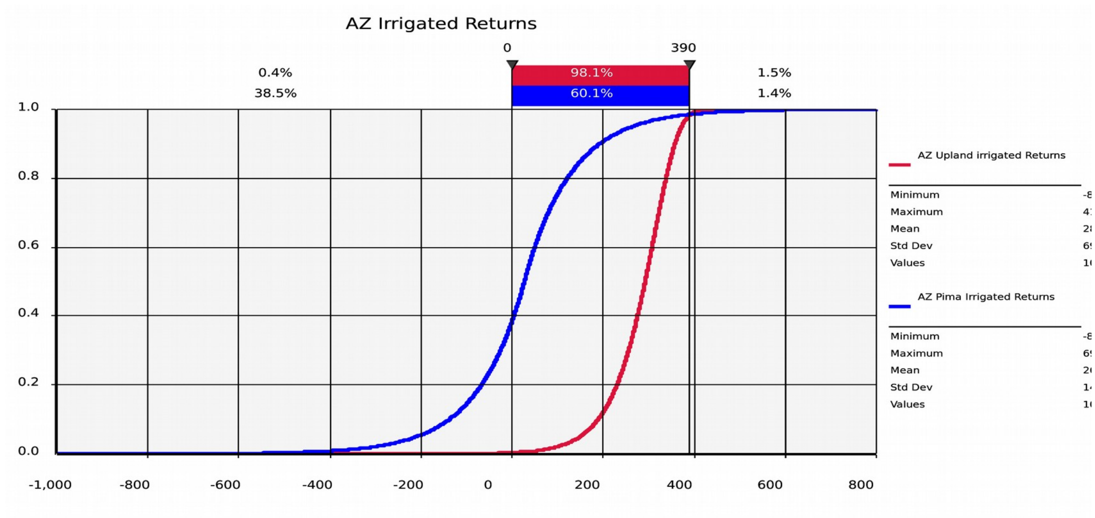


Figure 7: Simulated net returns for irrigated cotton in AZ.

The comparison between both the varieties of cotton in Arizona shows that producing upland cotton is more profitable than producing pima cotton. Arizona have 98.1% chances of making profit from producing upland cotton whereas the chances of profit are 60.1% for pima cotton.

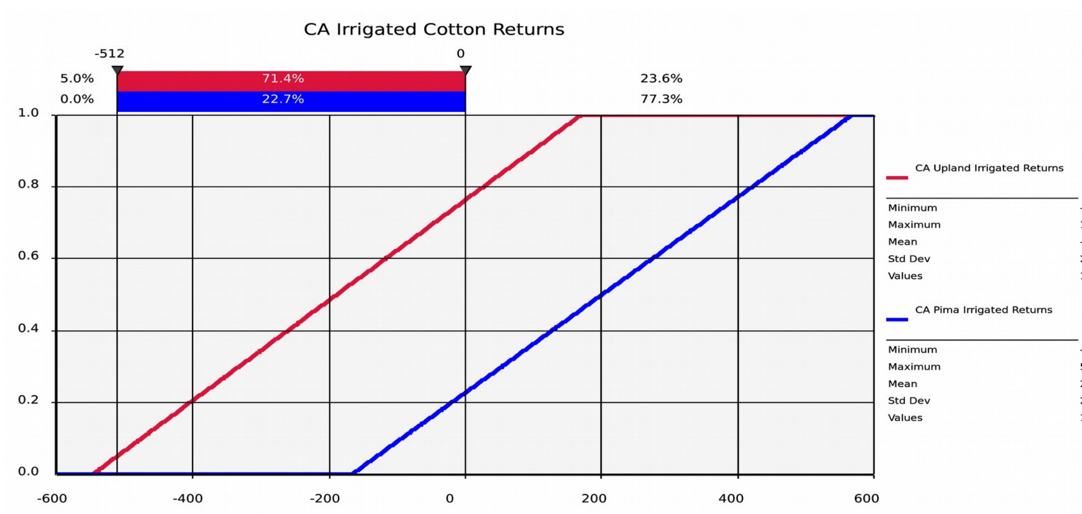


Figure 8: Simulated net returns for irrigated cotton in CA.

The comparison between both the varieties of cotton in California shows that producing pima cotton is more profitable than producing upland cotton. NM have 71.4% chances of making profit from producing pima cotton whereas the chances of profit are 22.7% for upland cotton.

4. Conclusion:

From the empirical results of the cotton budgets and the simulation analysis, we can see that there are differences in the cost of production in each four states of the study area and so are the yields. From the cotton budgets and the simulation results we can say that the production of pima cotton is profitable in Texas whereas the production of upland cotton is more profitable in Arizona. Though the simulation has these results, the production of pima cotton is highest in California more than any other state and have the highest yields also.

References:

Agricultural marketing resource center. (2017, September). Retrieved January 12, 2020, from agmrc.org: https://www.agmrc.org/commodities-products/fiber/cotton

Cochran, M. J. (1986). Stochastic dominance: The state of the art in agricultural economics.

Dent, J. B. and P. Byrne (1969). "Recent Developments in Farm Planning: Investment Planning by Monte Carlo Simulation." Review of Marketing and Agricultural Economics **37**(430-2016-30984): 104-120.

Fritschi, F. B., et al. (2003). "Response of irrigated acala and pima cotton to nitrogen fertilization." Agronomy Journal **95**(1): 133-146.

Harman, W., et al. (1989). "A conservation tillage system for profitable cotton production in the central Texas high plains." Agronomy Journal **81**(4): 615-618.

Kittock, D. (1979). "Pima and Upland Cotton Response to Irrigation Management 1." Agronomy Journal **71**(4): 617-619.

Kittock, D., et al. (1981). "Fruiting of Upland and Pima Cotton with Different Planting Dates 1." Agronomy Journal **73**(4): 711-715.

Kramer, R. A. and R. D. Pope (1981). "Participation in farm commodity programs: a stochastic dominance analysis." American Journal of Agricultural Economics **63**(1): 119-128.

McCarl, B. A. (1990). "Generalized stochastic dominance: an empirical examination." Journal of Agricultural and Applied Economics **22**(2): 49-55.

Pettigrew, W. (2004). "Moisture deficit effects on cotton lint yield, yield components, and boll distribution." Agronomy Journal **96**(2): 377-383.

Richardson, J. W., et al. (2007). "Including risk in economic feasibility analyses: the case of ethanol production in Texas." Journal of Agribusiness **25**(345-2016-15144): 115-132.

Unruh, B. L. and J. C. Silvertooth (1996). "Comparisons between an Upland and a Pima cotton cultivar: I. Growth and yield." Agronomy Journal **88**(4): 583-589.

Unruh, B. L. and J. C. Silvertooth (1996). "Comparisons between an Upland and a Pima cotton cultivar: II. Nutrient uptake and partitioning." Agronomy Journal **88**(4): 589-595.

Unruh, B. L. and J. C. Silvertooth (1997). "Planting and irrigation termination timing effects on the yield of Upland and Pima cotton." Journal of production agriculture **10**(1): 74-79.

usda.gov. (2018). Retrieved November 2018, from National Agricultural Statistics Service: https://quickstats.nass.usda.gov/

Williams, J. R. (1988). "A stochastic dominance analysis of tillage and crop insurance practices in a semiarid region." American Journal of Agricultural Economics **70**(1): 112-120.

Zacharias, T. P. and A. H. Grube (1984). "An economic evaluation of weed control methods used in combination with crop rotation: a stochastic dominance approach." North Central Journal of Agricultural Economics: 113-120.