AARES 53rd Annual Conference

2009

Economics of Alternative Crop Production in Arid Regions

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As water resources in arid regions decline, agricultural producers are encouraged to adopt water conserving strategies. The implementation of alternative low-water use crops is one option, but is it economically feasible? Data on current and alternative crops for this study include enterprise budgets, producer interviews, and field trials in Northwestern Nevada, USA. We use WinEPIC, a Windows-based version of the EPIC model, which synthesizes both agronomics and economics, to model yields and returns of alternative crop production under differing irrigation levels. Risk analysis or the distribution of net returns to alternative crop production is also examined. This study determined that there are alternative crops that could be feasibly substituted for alfalfa and reduce water use by at least one-half while providing net returns that meet or exceed returns from alfalfa and keep producers profitable in agriculture.

Key Words: alternative crops, arid regions, economic feasibility, irrigation, WinEPIC

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Introduction

In the western United States, hydrological cycles have changed considerably in the last fifty years, due in a large part to intervention by humans, and research predicts water supplies will reach a crisis stage (Barnett et al. 2008). As populations in western states increase, civil supply, recreation, hydropower generation, and other in-stream uses all increase competition for available supplies away from agricultural uses (Diaz and Anderson 1995). Because snowpack is the dominant source of streamflow in most of the western United States, researchers are concerned with snow-water equivalent levels and examine historical and current data for statistical trends (Kalra et al. 2008). In addition to the chronic challenge of limited water supplies, paleo-climatic records show that in the ninth through the fourteenth centuries, native American populations were subject to mega-drought conditions; a recurrence of these conditions is possible (MacDonald 2007).

Even in years with adequate or above average stream flows at the headwaters, downstream users are faced with chronic low supplies (Gaur et al. 2008). While downstream agricultural producers are able to somewhat adapt to these conditions, ecosystems do not fare as well. Studies have been conducted in the Deschutes River Basin in Oregon in two different irrigation districts on the trade-offs between ecosystem health and agricultural use, examining strategies to increase stream flows (Turner and Perry 1997). In the Rio Grande Basin, economic analyses of reducing allowable diversions to central New Mexico irrigators results in economic damage to those producers, but produces benefits to downstream users in southern New Mexico while additionally protecting critical habitat of the Rio Grande Silvery Minnow, their endangered species of interest (Ward and Booker 2006).

Policies have been used in arid climates in the west to enforce water conservation on agricultural producers utilizing irrigation such as the Groundwater Management Act of 1980 in Arizona; these policies are not always effective (Wilson and Needham 2006). Water pricing is a commonly used tool, used by both the United States Bureau of Reclamation and in other countries to reduce diversion from surface water systems (He, Tyner, and Siam 2004; Jalota et al. 2007; Martinet and Doyen 2007; Schuck and Green 2001). The goal of this policy is to make water prices reflect the social costs of using that water. Other policy strategies include fertilizer and energy taxes, pesticide taxes, and output taxes which are imposed on high water use crops such as sugar cane and rice (He, Tyner, and Siam 2004). In Spain, water law was changed to allow irrigation users to exchange water by lease-out contracts of water use rights; this has been shown to reduce economic vulnerability caused by the variation in water supply (Calatrava and Garrido 2003).

Practices imposed by policies and water managers are one side of the coin. Equally, and possibly more important, are practices adopted by the producers themselves. Planting alternative crops that use less acre feet of water is one way producers may reduce the amount of irrigation water they consume; this provides a way for producers to remain solvent in regions where water is scarce and they are under social pressure to reduce use (Gaur et al. 2008). Examples include farmers in the Punjab region of India who have replaced rice and wheat with cotton and soybeans and farmers in the Lower Rio Grande Basin of Texas who have replaced sugar cane with corn (Jalota et al. 2007; Santhi et al. 2005). This study examines the Walker Basin region in Northwestern Nevada.

Walker Lake is a rare freshwater terminal lake in northern Nevada, one of six in the world (Partners 2007). Its inflows come from the West Fork and East Fork of the Walker River, which have their origins in the Sierra Nevada of California, and join in the Mason Valley of Nevada to become the Walker River. In the last one hundred and fifty years, water has been diverted from these inflows for irrigation purposes at five major agricultural areas in the Basin. These diversions have resulted in dramatic drops in the level of the lake and in dramatic increases in the salinity of the lake. The increased salinity and lower lake levels are negatively impacting the habitat and populations of Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi)*, a federally recognized threatened species and the Nevada state fish (Dickerson and Vinyard 1999). Tui chubs (*Gila bicolor)* and other native aquatic life are being severely reduced in number (Marioni, Tracy, and Zimmerman 2005); some species of zooplankton, an important link in aquatic food webs, have become extirpated (Beutel et al. 2001). Walker Lake is one of few terminal lakes with an endemic trout fishery, and these changes are negatively impacting recreational use of the lake. These changes also have negative consequences on the more than two hundred species of migrating birds that visit the lake, a biannual food and rest stop on the Pacific Flyway for thousands of birds and a favorite destination of bird watchers (Partners 2007).

It is necessary to increase inflows to Walker Lake to be able to preserve this important natural resource. Agricultural production is the major source of revenue for local residents, and producers are dependent on irrigation for their livelihoods. Buying out agricultural producers and removing all irrigation from the fields without planting cover crops is not an option; leaving the ground fallow in these areas could result in these previously verdant areas becoming dust bowls. This problem has already occurred in the Swingle Bench area just north of the Walker Basin in Churchill County, where dust storms are resulting from non-productive farmland. These areas where irrigation has been removed are creating hazards to health, poor air quality, and impeding vehicle safety, among other hazards caused by wind erosion; federal and local agencies are working to alleviate the situation (Service 2004). The proposed possible solution to increasing lake levels without further economic or environment damage is for producers to plant alternative crops that consume less water.

The major crop grown in these areas is alfalfa *(Medicago sativa)*, an extremely high water user commonly irrigated by flood methods. Due to the quality of the alfalfa grown and current hay shortages, alfalfa production yields high prices and is an excellent source of revenue. In order to be able to feasibly sell water rights, producers would have to be able to grow a crop that would use less water, yet yield equal or greater profit. This alternative crop would also need to be able to thrive under the sometimes harsh conditions that exist in northern Nevada. Research was conducted to determine a number of crops that fit within these constraints. Additionally, local experts were consulted about experimental crops that are being grown in test plots in the region. A list of possible alternative crops meriting further study was then compiled from this investigation. The variety of crops under study offers producers more than one option when considering alternatives.

To determine the viability of these crops for both the region and the market, WinEPIC and SIMETAR were used. WinEPIC is a simulation model developed by researchers at Texas A & M extension that incorporates both agronomics and economics, forecasting yields under varying irrigation, weather conditions and soil types. The model is able to forecast yields for up to one hundred and fifty years. SIMETAR is a risk analysis modeling program that is able to take the yield results obtained from differing crops in WinEPIC, multiply those results with current and fluctuating market prices, and then compare the resulting amount of variance in returns between crops to determine those alternative crops that would incur the least amount of risk for producers.

Alternative Crop Choice

In order for an alternative crop to be economically feasible, it must meet several criteria: it must be able to thrive under climatic conditions that exist in northern Nevada such as aridity and high winds; it must be suitable for the soil types prevailing in the Great Basin; it must be a low or reduced water use crop when compared to alfalfa; the transition to alternative crops should have minimal impacts on investment such as equipment and machinery; it must be able to be harvested and shipped to market with no degradation in product quality; there must exist a market within shipping distance for the product; yields and market prices must be high enough to allow producers to switch crops and receive as much, if not more, profit from their efforts than from the previously planted crop. Published information of crop parameters was reviewed and numerous crops in several categories were submitted for consideration as possible alternatives.

Of the vegetables under consideration, bulb onions (*Allium cepa)* and leaf lettuce (*Lactuca sativa*) were chosen as the optimal alternatives. Bulb onions are a proven producer in the area, currently being grown on six percent of the acreage in Mason Valley. They utilize drip irrigation, using one acre foot less water than alfalfa per acre. Possible impediments to onion production are the necessary investment in costly specialized equipment, and the large amount of herbicides, insecticides, fumigants, and hand labor needed to bring the crop to harvest.

Leaf lettuce is currently grown on a small scale in the basin, but has been shown to be successful on a large scale in other arid environments (Meister 2004). It requires only one acre foot of water to be harvested as baby greens when grown using drip irrigation and commands premium prices. It requires a large amount of labor and investment in some of the same equipment used for onions; it could prove to be a good choice for rotation with onions, allocating costs over both crops.

Fruit crops that fell within the threshold limits for irrigation needs also required a large establishment investment and were susceptible to numerous changes in conditions, making them a bad risk as an alternative to alfalfa. Wine grapes (*Vitis interspecific*) however, increase in quality with decreased irrigation, using less than one-half acre foot per year per acre. Wine grapes have been grown on small scale trial plots by area producers since 1990, and the first commercial wine in Nevada was a Chardonnay produced in 2001 (Halbardier 2006). Tahoe Ridge Winery has planted over 20,000 vines to research thirty-seven cultivars since 1990, and the University of Nevada, Reno has been testing twelve trial varieties in its experimental vineyard on Valley Road in Reno since 1995 (Cramer 2008; Halbardier 2006). Preliminary investigations into the economic comparison between alfalfa and wine grapes show substantial improvements in returns from grapes (Henry 2005).

In the cereal and legumes category, teff (*Eragrostis tef*) is one of the optimal choices for numerous reasons, one of which is its ability to provide both a source of grain for human consumption, or as a pasture, hay, or silage crop (Extension 2007). A drawback of this crop is its less than optimal water use for seed production, using three acre feet. Although teff is fairly new to the United States, it has been cultivated in other parts of the world since 3359 BC (Stallknecht, Gilbertson, and Eckhoff 1993). It can be grown under a wide range of soil and moisture conditions and can produce a crop in a very short amount of time. Teff grain is most commonly made into flour. Teff is virtually gluten-free; this quality makes it highly desirable for those with wheat allergies and increases its marketability.

Two row malt barley appears to be another good choice in the cereal and legumes category. It is easily grown using the same equipment as other grain crops and most of northern Nevada is suitable for its production; malting barley has been produced in Nevada in the past

(Davison, Schultz, and Widaman 2001). It uses half of the water that alfalfa does, needing only two acre feet. Two row malting barley is grown for making malt, a main ingredient in beer production. This crop has increased demand and decreasing supply, making it a profitable prospect. From 1990 to 2003, the number of microbreweries in the United States increased by seven times and this trend is continuing, ensuring demand for malt barley as an input (Taylor, Boland, and Brester 2003). Two row is the preferred variety because of its higher extract (Schwarz and Horsley 1997). The downside of this crop is that there are high standards that it must meet, or be sold as feed barley which commands significantly lower prices. In addition, contracts should be negotiated with a brewery prior to establishment.

Great Basin wildrye (*Leymus cinereus*) is a native perennial grass that was once abundant in the region. It has been grown for seed production using only one acre foot of irrigation. The Aberdeen Plant Materials Center, Natural Resource Conservation Service branch of the USDA lists the ‘Magnar’ variety of Great Basin wildrye as one of its “plants for solving resource problems” because of its ability to be used for rangeland and forage, erosion control, mine reclamation, and critical area stabilization, as well as its lack of problems with disease and insect pests (Center 2006). Additionally, wildrye enhances wildlife habitat and acts as a competitor to invasive weeds, making it highly desirable as a major component in revegetation planting (Perryman 2006). This myriad of uses gives wildrye potential economic benefits with regard to seed production. When Great Basin wildrye was being grown in test plots in the area under study through the University system, it grew well and showed promise as a revegetation and forage alternative (Perryman 2008).

Switchgrass (*Panicum virgatum*) is under consideration as a forage and biofuel source. It is an American native that was once widespread (Wolf and Fiske 1995) in its native region east of the Rocky Mountains where precipitation is more abundant; here in the arid west it requires three acre feet of irrigation to reach its full potential. It is a very tall growing warm-season perennial grass that produces large biomass yields. Although it was not a well-known species, our growing desire for energy independence has brought it to the forefront of ongoing research. Research into its potential as biomass for ethanol production has been ongoing since approximately 2001 (Fransen, Collins, and Boydston 2006); economic studies have also been undertaken on the costs to produce the crop at a commercial level (Duffy and Nanhou 2002) . Its economic potential has also been investigated with regard to greenhouse gas emission mitigation (Schneider and McCarl 2003). In 1993, five varieties were planted in test plots at the Newlands Research Center in Fallon, Nevada; all appear to be well adapted for the climate and soils in the area (Davison 1999).

Data and Methods

In reviewing the literature to ascertain which model would best suit our purpose of determining crop yields under reduced irrigation, one model repeatedly appeared in the literature: the Environmental Policy Integrated Climate model commonly referred to as the EPIC model. The EPIC model, which was previously known as the Erosion Productivity Impact Calculator, was first developed in 1981 by researchers at the USDA as a response to the need for assessment of productivity of U.S. soils with regard to the impacts of erosion (Gassman 2005). The first major application of the model was undertaken in 1985, when it was used to evaluate one hundred and thirty five regions across the nation in an appraisal for the Resources Conservation Act (Gassman 2005). Since its inception, numerous functional additions have been made to the model including water quality, atmospheric CO_2 change, and enhanced carbon cycling routines; these additions prompted the changing of the model name to its current one while keeping the acronym intact (Gassman 2005).

Over the last twenty seven years this model has been used for numerous applications world-wide. It has been used to model crop production in arid regions of Brazil (de Barros, Williams, and Gaiser 2005); determine impacts of adopting alternative practices such as organic or sustainable farming (Archer 2006; Wicks, Howitt, and Klonsky 2006); compare yields under reduced irrigation from Georgia to France (Guerra et al. 2005; Cabelguenne, Jones, and Williams 1995) both for production of known crops such as alfalfa (Tayfur et al. 1995), and alternative crops including switchgrass (Brown et al. 2000). “This model improves water management and leads to substantial reduction of water consumed”. (Bontemps 1999)

The Blackland Research and Extension Center of the Texas Agricultural Experiment Station further developed the EPIC model and created a user friendly platform called WinEPIC for its widespread application; WinEPIC is a Windows® EPIC interface. It was designed as a comprehensive simulation model for researchers that would analyze the effects of production practices and differing cropping systems on yields, the quality of the soil, water quality, erosion from wind and water, and profits; it was developed with a focus on research applications with the ability to make multiple comparison runs (Gerik et al. 2006;Center 2006) . It has been used for varied applications: to reduce environmental damage in developing countries (Gandonou et al. 2004); by the U.S. Agricultural Resource Service to study the impacts of manure bans on nutrient losses (Torbert III 2005); for modeling wheat and corn rotation effects in China (Wang , Li, and Fan 2008); and for economic evaluations of integrated cropping systems (Martin 2005). EPIC and WinEPIC have consistently proven their abilities to be able to provide accurate projections with regard to water use and crop yields after being calibrated to regional specific weather and soils data, making WinEPIC an optimal model choice for conducting this study.

SIMETAR is a risk analysis management modeling program developed by James W. Richardson at Texas A&M in 1999 in their Ag & Food Policy Center. It became commercialized in 2005 by SIMETAR, Inc. under a licensing agreement with Texas A&M University (Richardson, 2006). It is used for risk based policy analysis at both the farm and sector levels and runs as an add-in to Excel (Richardson 2002). It uses a Monte Carlo simulation analysis to make spreadsheet models stochastic and is one of the programs developed for this purpose; others include @Risk and Crystal Ball (Richardson, 2007). Using SIMETAR in conjunction with WinEPIC allows decision makers to select possible alternative crops based on a distribution of returns rather than on a point estimate, incorporating risk into economic feasibility.

The first step in utilizing the WinEPIC model was to create a database specific to Nevada. This involved importing Nevada weather stations and soils; data were imported for forty-eight Nevada weather stations and included minimum and maximum daily air temperature, the monthly average standard deviations of those temperatures, the amount of daily precipitation, number of days with precipitation, the monthly standard deviation and skew coefficient for daily precipitation, the monthly probability of a wet day after a dry day, the monthly probability of a wet day after a wet day, the relative humidity or dew point, and the amount of solar radiation as measured in Langleys. Soil data was imported from the United States Department of Agriculture Natural Resource Conservation Services (NCRS) Soil Data Mart under Soil Survey Geographic (SSURGO) Data formatting for all counties in Nevada.

The two largest irrigated agricultural areas downstream on the Walker River are the Smith and Mason Valleys. Smith Valley has 20,400 acres in production and the Mason Valley has 38,159 irrigated acres. This study focuses on these two areas, as reducing the water use there would have the largest possible impact on raising lake levels. The weather station used for the Smith Valley simulations was Smith 6N (267612) located at an altitude of 5000 feet (38°57'N, -199°20'W); the complete weather data mentioned above has been available for this station since 1973. Yerington (269229) located at an altitude of 4378 feet, (39°00'N, -119°09'W) was used for the Mason Valley simulations. Complete weather data has been available for this weather station since 1960. Using the NCRS Web Soil Survey to map specific areas of interest of both valleys that were in agricultural production enabled the determination of the most common soils by percentage. Three representative soil types, Dithod, Eastfork, and Sagouspe, were chosen with increasing percentages of sand content. Dithod has a soil composition of 36.6% sand, 38.9% silt, and 24.5% clay in the first five feet of soil; Eastfork is 51.5% sand, 19.9% silt, and 28.6% clay; Sagouspe is 77.8% sand, 18.8% silt, and only 3.4% clay.

The next inputs necessary to the WinEPIC model were agronomic data with regards to production practices, and economic data such as equipment prices to create budgets for each individual crop under consideration. The most efficient way to assemble this data was to create enterprise budgets. Producer panels were conducted to gather information on practices and costs for those crops that were already under production in the focus areas or in the region. For those crops not currently grown by commercial enterprises, results from university experiment station test plots and/or information from enterprise budgets from similar semi-arid areas were used. This information was amassed into enterprise budgets which were reviewed by the producers or other knowledgeable individuals for completeness and accuracy before being inputted to crop budgets in the WinEPIC model (Enterprise budgets for all crops under consideration are available online through UNCE as special publications SP-08-06 through SP-08-14).

Analysis

Runs for all crops were made in both Smith and Yerington, in Lyon County, with good infiltration land conditions, with all three soil types, and with the appropriate weather station. The control record chosen for each crop was set for 100 years of simulation; starting the simulations in 1973 maximized known data, enabling the use of 34 years actual weather and 66 years of predicted weather for each crop. The combination of three soils and two locations resulted in six runs per batch for each crop. Batches were varied by irrigation amounts from 48” to 0” in intervals of 2”, resulting in twenty-five batches of six runs each per crop for a total of 1200 runs under consideration by this study.

The 100 year average yield output data from each irrigation level in WinEPIC was combined with economic data from the correlated enterprise budget for each crop to create graph and tabular data on break-even yields with all soil types at reported prices, and tabular data on break-even prices for average yields under alternative watering strategies by location, a comparison of current returns for all crops under optimal watering strategies, and a comparison of investment costs for the proposed alternative crops.

To forecast future returns and incorporate risk into the formulation, SIMETAR was used to calculate the variation in yield using output from WinEPIC, in addition to forecasting prices and variation in prices. Yields from all crops were simulated using Dithod soil and Yerington as the location for each crop using a WinEPIC run of 100 years. Yields were checked for normality of distribution and the appropriate distribution was used to generate stochastic yield variables.

In SIMETAR's terminology, a stochastic input in a Monte Carlo simulation has two component parts: the deterministic component which is that part of a variable that can be forecast with certainty such as the mean ($\hat{z}$ in Equation 1), and the stochastic component, which cannot be forecast with certainty ($\tilde{a}$ in Equation 1) (Richardson, 2006; Richardson, 2007). The stochastic component cannot be explained by the data and is the source of the risk; it is forecast by simulating values from a probability distribution (Richardson, 2007).

$$\tilde{z} = \hat{z} + \tilde{a} \tag{1}$$

After separating and quantifying these components, also known as whitening the data, stochastic residuals were created and added to mean yields to create stochastic yield variables (Equation 2).

$$\tilde{y} = \bar{y} + \tilde{e} \tag{2}$$

Stochastic residuals were created by finding the mean of y, computing the deviation from the mean, or residuals, finding the mean of the residuals and the standard deviation of the residuals, and creating a usd or uniform standard deviation (Equation 3). This function generates a random number between 0 and 1.

$$usd = uniform() \tag{3}$$

Yields and their residuals followed that of either a normal or beta distribution. For alfalfa, onions, teff, two row malt barley, and leaf lettuce, whose residuals followed a normal distribution, Equation 4 was used to create the stochastic residuals.

$$\tilde{e} = norm(mean, stdev, usd) \tag{4}$$

For Great Basin wildrye, switchgrass, and wine grapes, whose residuals followed a beta distribution, Equation 5 was used to create the stochastic residuals.

$$\tilde{e} = betainv(usd, \alpha, \beta, \min, \max) \tag{5}$$

Adding the stochastic residuals to the mean yields allowed the generation of random yields (Equation 2).

Historical pricing data was only available for alfalfa, onions and leaf lettuce. With more than minimal data lacking for a majority of crops under consideration, it was determined to forecast returns no further than 2009 to reduce the amount of error. The approach to calculating stochastic pricing for individual crops was determined by the amount of information available. For those crops with minimal pricing data available, a triangular distribution was used. This distribution uses the minimum, mid-point, and maximum known values as the boundaries for the assumed values (Equation 6).

$$\tilde{p} = triangle(\min, mid, \max, usd) \qquad (6)$$

For those crops with at least ten years of historical pricing, OLS regressions were ran to estimate the deterministic portion of price. Some crops in this category fit a trend model. Because twenty or more observations are required to prove conclusively that a distribution is normally distributed or to estimate the parameters of a distribution with a high degree of certainty (Richardson, 2006), a non-parametric empirical distribution with no function form where the shape of the distribution is defined by the data were used to create the stochastic residuals for those crops by estimating the empirical distribution and generating a random residual using actual data (Equation 7).

$$\tilde{e} = empirical(Si, F(Si), usd) \qquad (7)$$

Si represents the sorted data, and F (Si) is the probability of that sorted data.

The stochastic residuals were added to the appropriate regression to create stochastic prices (Equation 8).

$$\tilde{p} = b_0 + b_1 T + \tilde{e} \qquad (8)$$

Multiplying stochastic yields by stochastic prices resulted in stochastic total returns for all crops (Equation 9).

$$\tilde{y} * \tilde{p} = t\tilde{r} \qquad (9)$$

After total returns were calculated, costs were subtracted to determine stochastic net returns which were then simulated for 1000 iterations in SIMETAR (Equation 10).

$$t\tilde{r} - c = n\tilde{r} \qquad (10)$$

Costs were calculated by multiplying current costs from enterprise budgets by 1.066, the index of increase in farm production costs between 2007 and 2009 forecast by researchers at the USDA NASS. The results for net returns were compared using a combined cumulative distribution function graph, a stoplight chart that determines the probability of a favorable, cautious, or unfavorable outcome under lower and upper cutoff values, by analyzing stochastic dominance with respect to a function at different risk aversion levels: a decision maker with risk neutrality, and of a somewhat risk adverse decision maker, and by comparing stochastic efficiencies using a negative exponential utility weighted risk premium relative to alfalfa.

Results Overview

Yield Analysis

Alfalfa

At 48” of irrigation, alfalfa yields in the Mason Valley with an average yield of 6.66 tons per acre were much higher than those in the Smith Valley, where the average yield was only 4.81 tons per acre; at both locations, alfalfa planted to dithod soil performed slightly better than alfalfa planted on other soils. At $144.00 per ton, break-even yield was calculated at 5.93 tons/acre. Break even prices varied drastically between locations, producers in Smith need a per ton price of $177.34 to recoup expenses; producers in Yerington have a break-even price of $128.19. Net returns were consistently negative in Smith at all irrigation levels; returns did not become consistently negative at Yerington until irrigation levels were below 30 inches, substantially reducing yields. At 48” of irrigation, Sagouspe soil was the least favorable with net returns of only $74.82, which increased to $114.03 for Eastfork and $126.86 per acre for alfalfa on Dithod soil in Yerington. The large difference in alfalfa yields between locations is most likely caused by the difference in elevation; the elevation at Smith is 5000’, the elevation in Yerington is 4378’. The break-even yield price of $144 per ton was taken from 2007 information, while current National Agricultural Statistics Service prices from May 2008 show a nationwide price of $177 ton. Alfalfa produced in the Walker Basin is of premium quality and commands premium prices; prices reported by locals say producers were asking a minimum of $200.00 per ton. Average yields for each crop under consideration can be found in Table 1. Break even prices for all crops can be found in Table 2. Net returns for all crops can be found in Table 3.

[Insert Table 1 here]

[Insert Table 2 here]

[Insert Table 3 here]

Onions

At 28” of irrigation, there was no difference between yields by soil type at either location; onion yields in Smith Valley were 31.56 tons/acre and yields in Yerington in the Mason Valley were 37.81 tons/acre. Break-even yield was 31.18 tons/acre for pricing of $320.00 per ton. Break-even pricing was $52.92 higher in Smith at $319.74 compared with Yerington’s break-even price of $266.82. At this irrigation level, there was a difference between locations of close to $1980.00 in net returns; Smith’s net returns were $8.25 while Yerington had net returns of

$1989.05. Onion yields flat lined in the WinEPIC model between 48 and 12 inches of irrigation, which could erroneously cause the belief that water use could be increased or decreased with no impact on returns. However, because of quality issues, the window of marketable yields is much smaller and peaks at 28” of irrigation. This difference between actual and marketable yields for onions has been studied and documented (Henderson, 2003). When irrigation is increased, the amount of onions that result in splits or doubles increases dramatically. Splits or doubles occur when a single bulb becomes two bulbs that are joined at the sides; producers purposely select varieties that grow the largest with the least amount of splits or doubles because they are unmarketable as fresh onions. The larger the onion, the higher price per pound: decreasing the amount of irrigation results in yields of numerous smaller onions with the same weight as a few large onions (20 small as compared with 5 jumbo) which reduces available returns. Onions should not be grown on the same plot for more than two years, forcing producers to plant less profitable rotational crops. Onions appear to be the leader with regard to returns in Yerington and are slightly profitable in Smith, but have extremely high investment costs (See Table 4 for investment costs for each crop). A 400 acre farm planted to onions would require a capital investment of over $5,000,000, yet that same 400 acre farm planted with alfalfa would require slightly over $800,000 in capital input. In addition to the large amount of equipment required to grow and process onions, a large labor force is needed from land preparation through shipping, requiring the associated bookkeeping and management skills and time.

[Insert Table 4 here]

Teff

At 36” of irrigation, production of teff seed in Smith averaged 1.01 tons/acre; Yerington results were similar, with an average of 1.09 tons/acre. When producers received $760.00 per ton for seed, 0.76 tons needed to be produced for a break-even yield. Break-even prices were similar in both locations, $571.37 in Smith and slightly lower in Yerington at $530.37. In Smith, the highest net returns were with East fork soil at $200.52 and in Yerington the soil type with the highest returns was Sagouspe, with returns of $270.07 per acre. Teff is a versatile crop that can be used for pasture, hay, or a silage crop in addition to seed production and can be used as an emergency forage crop because of its short growing season of three months from planting to harvest. It can meet the needs of a growing niche market for those who have celiac disease or are allergic to wheat because of its gluten-free qualities; the flour has high protein content and contains numerous other nutrients. There are two factors that offset the aforementioned benefits: the lion's share of the market for teff seed is controlled by one buyer; additionally, at 36" of irrigation, the large amount of water teff consumes makes it less than desirable as an alternative crop for this study. Teff has lower capital investment costs than other crops under consideration because both planting and harvesting were contracted out at custom rates; the only equipment owned by the producer is a tractor, a pickup truck, and a four-wheeler.

Great Basin wildrye

At 12" of irrigation, yields varied greatly between soils and locations. The lowest yield in Smith was on Dithod, 252.88 pounds/acre and the highest yielding soil was Sagouspe with yields of 393.37 pounds/acre. Yerington followed the same pattern with Dithod yielding the lowest poundage of 309.08 per acre; Sagouspe was again the preferred soil for wildrye with yields of 468.30 pounds/acre. Average yields for Great Basin Wildrye were 318.44 pounds/acre in Smith and 384.01 pounds/acre in Yerington at 12" of irrigation. At a price of $2.50 per pound for seed, break-even yield was 327.3 pounds of seed produced per acre. Break-even prices were

$2.57 in Smith Valley and $2.13 in Mason Valley. Net returns varied between a low of ($186.04) on Dithod soil in Smith to a high of $352.51 on Sagouspe soil in Yerington for the common irrigation strategy of applying one foot of water. The WinEPIC model predicts maximum production at higher levels of irrigation; returns are predicted to be as high as $799.98 per acre. Wildrye seed yield simulation by the WinEPIC model fell within parameters of 300-450 pounds per acre as reported by the literature for 12” of irrigation. Simulation with the model additionally showed overall maximum yields and maximum returns occurred at higher levels of irrigation from 18 to 26 inches depending on soil type. A thorough review of the literature revealed no studies with Great Basin wildrye at any level of irrigation above 12”. Further production studies need to be conducted with this native crop to determine if larger yields are possible with additional irrigation. Great Basin wildrye has the lowest capital investment cost of any of the profitable crops, lower even than alfalfa’s costs of $2045.10 per acre; wildrye requires a capital investment of only $1699.95 per acre. Net returns may be even higher than reported in this study; a price of $2.50 per pound for seed was used for calculation which is one-third of both retail and price paid under contract to growers by government agencies. If producers were able to grow Great Basin wildrye and benefit economically, it would also benefit ecosystems across Nevada.

Switchgrass

At 36” of irrigation, switchgrass yields averaged 4.33 and 4.81 tons/acre in Smith and Yerington respectively. Yields would have to be 12.39 tons/acre for producers to break even at pricing of $66.00 per ton. At current yields, prices would have to be $188.90 per ton in Smith and $170.07 in Yerington for producers to break-even. Net returns were extremely negative on all soil types at both locations; the least amount of loss at Smith was on Dithod soil with net returns of ($506.09) with 22” of irrigation and at Yerington losses were minimized on Dithod soil with 20” of irrigation at returns of ($469.62). Switchgrass came under consideration as an alternative crop because of the high demand for alternative fuel sources. Switchgrass contains a large amount of biomass and therefore would be used to produce cellulosic ethanol. This crop is a viable option in the eastern United States where it could be grown on marginal lands with no additional irrigation needed, using existing precipitation. Its high water requirements, current low pricing, and lack of processing facilities make it a poor choice for the prime agricultural land in the Walker Basin.

Two row malt barley

At 24” of irrigation, malt barley yields on Dithod and Eastfork soils were almost identical in Smith at 3.37 and 3.36 tons/acre, dropping to 3.02 tons/acre on Sagouspe soil; results were similar in Yerington where malt barley yielded 3.58 and 3.55 tons/acre on Dithod and Eastfork soils and yields dropped to 3.25 tons/acre on Sagouspe soil. Yields in Smith averaged 3.25 tons/acre, less than the 3.46 tons/acre average for Yerington. At $360.00 per ton, the break-even point for yield was 2.68 tons/acre. Break-even pricing averaged over yields from all soils was $296.32 in Smith and $278.31 in Yerington. In both locations, net returns were highest on Dithod soil with returns of $250.04 for Smith and $325.75 for Yerington and lowest on Sagouspe soil with returns of $122.64 for Smith and $207.57 at Yerington. Two row malt barley appears to have potential for yield and profit with the caveat that this crop should not be undertaken prior to contracting with a maltster. Brewers have very specific desires and requirements with regard to variety; strict standards exist for characteristics including protein, moisture, and foreign material levels, skinned and broken kernel limitations, sprout damage, and color and plumpness of kernel because of the effects of these characteristics on the brewing process. Malt barley was configured with center pivot irrigation to give an alternative to those producers who currently use center pivot irrigation; center pivot irrigation is also a good choice for those downstream users who do not receive the full amount of their allocated surface rights because of the systems' reliance on ground rather than surface water. If the costs of the center pivot systems are removed from the budget, making malt barley a flood irrigated crop, per acre capital investment drops to $2149.46, making it comparable with alfalfa's investment costs of $2045.10 per acre. Water-wise it is a good choice because it requires only half the irrigation used by alfalfa. With investigation into the availability of contracts, two row malt barley could be a choice alternative crop.

Leaf lettuce

At 12" of irrigation, yields were extremely similar across soils and with regard to location; leaf lettuce yields averaged 12.17 tons/acre at Smith and 12.49 tons in the Mason Valley at Yerington. 9.80 tons/acre of production is necessary to break-even with pricing of $700 per ton. Break-even prices at simulated production levels would be $563.69 in the Smith Valley and $549.12 in Yerington. Net returns averaged over all soils were extremely high at both locations with producers in Smith receiving $1658.27 per acre and producers in Yerington netting $1884.19 per acre. Leaf lettuce commands high prices and uses minimal water. The literature suggests irrigation of 12" but this study found that leaf lettuce is at maximum production on all chosen soils in the Walker Basin with 14" of irrigation. WinEPIC predicts constant high yields at all irrigation above 12", however marketable yields follow a bell shaped curve that crests at 14” of irrigation. Lettuce that receives too much water can become easily susceptible to fungal disease or rot at high levels of applied water; additionally, over-irrigation leaches nutrients below the active root zone (Hartz, 1996). Leaf lettuce and onions would make a good rotational combination; with lettuce using 12” of irrigation and onions using 36”, splitting the available four acre feet of irrigation between two plots, two acre feet would be available to sell to leave in the river. For producers willing to incorporate hired labor into their farming practices and able to obtain funding for the necessary capital investment, leaf lettuce appears to be an optimal crop for the Walker River Basin, as it performs well in both Smith and Mason Valleys.

Wine grapes

At 4” of irrigation, yields were similar between locations, but varied widely between soil types. At this level of irrigation, Sagouspe was the preferred soil at both locations resulting in yields of 7.4 tons/acre in Smith and 7.45 tons/acre in Yerington; Dithod was the least preferred soil, yielding only 6.07 and 6.24 tons/acre. When producers receive a price of $825.00 for wine grapes, break-even yield is 5.17 tons at 4” of irrigation. Break even prices averaged over all soils were almost equal between locations; the break-even price in Smith was $572.47, for Yerington the break-even price was slightly lower at $568.65. Net returns, like break even prices, were almost equal between locations with wine grapes planted to Sagouspe soils in Smith returning $1843.07 per acre and those planted in Yerington returning $1879.87 per acre to those producers. Wine grape yields increase with additional irrigation, but deficit irrigation improves the quality of the grapes. As opposed to table grapes, where bigger are better, wine grape producers purposely aim for smaller size grapes. Smaller size grapes have a larger surface to volume ratio which increases the amount of skin on the grapes; the skin contains the color and flavor producing ingredients. Increased numbers of small size yields is a premium trait in grape production. Reduced irrigation is related to another important quality in wine grape production: alcohol content. As water levels are increased during the growing period, the alcohol level able to be obtained from the grapes in the fermentation process decreases because increasing irrigation adversely affects the amount of sugar in the harvested product. Grapes have the highest capital investment costs of any crop under consideration with per acre costs of over $17,000. They can be profitable however if the producer does all the maintenance labor, only hiring outside labor during harvest. Wine grapes, like two row malt barley, should be grown under contract as vintners are interested in certain varieties and should be consulted and contracted with prior to planting.

Forecast Analysis of Individual Crops

Alfalfa

Stochastic yields for alfalfa were multiplied by stochastic pricing drawn from a triangular distribution; after costs, net returns varied from a low of ($292.32) to a high of $702.23 per acre. Although historical pricing was available, it does not reflect the large increases in yield pricing that have recently occurred. For this reason a triangular pricing distribution was chosen with 2007 NASS Nevada pricing of $144 per ton as the minimum, May 2008 NASS data pricing for the combined United States, as current Nevada statistics are not available, of $177/ton as the midpoint, and local reported pricing of $200/ton as the maximum. The mean net return per acre was $165.90 with a standard deviation of $152.55.

Onions

Stochastic pricing for onion yields was calculated using a triangular distribution. Utilizing 10 years of NASS data for Nevada prices, the average of the last 10 years of $288 per ton was used as the minimum; $320 per ton as reported by local producers was used as the median, and $364, the price obtained by projecting the linear trend of Nevada historical data to 2009 was used as the maximum. Net returns for onions varied widely with ($960.40) as the lowest, and $4550.17 the highest net returns per acre; mean returns were $1584.27 with a standard deviation of $841.64.

Teff

A fixed price was used for teff pricing; the only pricing available for teff seed was $760/ton given to us by local producers. Even with a fixed price, the variation in yields led to negative returns in one hundred and eight of the one thousand iterations. Net returns per acre varied between ($289.87) and $558.15. The mean net return was determined to be $156.86 with a standard deviation at $126.78.

Great Basin wildrye

A triangular distribution was used to create stochastic pricing for wildrye; there was a large variance in returns from ($193.35) to $2495.20 as the low and high returns respectively. Average net return was $788.34 per acre with a standard deviation of $456.45. Current on-line pricing for retail Great Basin wildrye seed is $7.50 per pound. The input prices for the triangular distribution used with wildrye came from the conservative low used in enterprise budgets of one-third of retail at $2.50/ pound, a mid-point price of $5.00/pound, and the high of current retail at

$7.50; only two percent of the 1000 iterations resulted in negative returns. This risk analysis was conducted with 12” of irrigation, but higher yields are believed to be possible at higher irrigation levels; with higher yields this crop would be even more appealing.

Switchgrass

Fixed pricing was used for switchgrass and all returns were consistently negative; in the worst case returns had a low of ($687.89) and the best case returns were a per acre loss of ($317.11). Mean losses were ($534.84) with a standard deviation of $88.32. Switchgrass is a big loser in Northwestern Nevada. The fixed price used came from enterprise budgets where $66/ton was used, the price being paid for hay rather than the lower price of $40 to $50 that ethanol producers are currently paying for biomass. This crop may be economically viable in the eastern part of the United States where it is native but is not an economically feasible crop in the arid west.

Two row malt barley

Two row malt barley pricing was calculated by using a triangular distribution to generate stochastic prices. Minimum returns were ($409.90), maximum returns were $454.59. For malt barley, the standard deviation was larger than the mean, with a mean of ($22.49) and a standard deviation of $139.06. The poor results for this crop are a consequence of the pricing distribution. Current available pricing for two row malt barley is based on cash prices at the grain elevator which are believed to be much lower than that paid for barley grown under contract. In several NASS reports in the malting barley column was the disclaimer “price estimates not published to avoid disclosure of individual firms”. For the triangular distribution used for this analysis, the lowest cash price paid at grain elevators in Idaho on July 2, 2008, $201.16/ton was used as the minimum price; $280.00/ton, the highest cash price paid at the same location on the same day was used as the mid-point price, and reported contract prices of $360.00/ton from enterprise budgets was used as the maximum price. The large variation in returns for barley was certainly a product of the variation in input prices because yields had a small amount of variation: standard deviation was only .26 with a mean of 3.58.

Leaf lettuce

Pricing for leaf lettuce used historical data and a simple trend model to produce stochastic prices. This crop had the largest range of returns, from a low of ($1385.57) to a high of $4729.58. Net returns had a mean of $1515.56 and a standard deviation of $988.59. A simple regression trend model taking 10 years of historical pricing from NASS combined United States data was used to simulate price; the model was a good fit with significance for the constant of 0.000 and the trend variable significant at 0.04. Leaf lettuce is currently priced in enterprise budgets at $700.00/ton so the 2009 predicted stochastic range of between $626.60/ton and $773.85 seemed reasonable. This crop did not do as well as expected in this analysis perhaps due to the wide range of variation in yields; yields varied between 9.4 and 12.5 tons to the acre.

Wine grapes

In this analysis grapes had the highest potential for loss with minimum possible net returns of only ($2866.07). Maximum returns were $2548.62. Mean net returns were $532.80 with a standard deviation of $1116.82. Price was forecast using a triangular distribution; the minimum price of $725.00/ton was taken from information from a local winery, the mid-point price of $825.00/ton was from enterprise budgets, and the high of $954.00/ton was from 2007 NASS data for Washington State. Even though the mean yield was 6.26 tons per acre and median yield was 6.85 tons per acre, because the vineyard in the model did not reach maximum yields until approximately the tenth year of production, minimum yield was as low as 1.77 tons per acre. The extremely large variation in yield combined with projected high per acre costs of production at $4544.77 for 2009 made this crop one that should only be considered by those producers who are neutral to risk or who are risk loving. This fits with current area practices, as most wine grapes produced in the area are produced on 5 acres or less; this is not the only source of income for those producers.

Forecast Analysis of Crop Comparison

In scrutinizing the combined cumulative distribution function graph, switchgrass, barley, teff, and alfalfa had steep distribution slopes; wildrye was slightly less steep, with grapes, lettuce and onions having lower slopes; those crops with the least amount of variation of their net returns have the highest degree of slope (See Figure 1). Variation expresses the amount of deviation from a mean value or the range over which a value falls. Decision makers who are risk adverse prefer less variation: profits of $20 to $40 dollars are preferred to profits of $0 to $60, even though both scenarios have average profits of $30. This explains why producers in the Walker Basin are currently growing alfalfa: its cumulative distribution line has the steepest slope for any of the crops with mostly positive returns. Both lettuce and onions have mostly positive returns, but the wide variation in yields makes these crops less appealing. The steepness of the slope of the line for the distribution of switchgrass explains why, even though it is a consistent money loser, it is preferred, as also shown by the stochastic dominance tables, to either grapes, lettuce, or onions for those producers with even slight risk aversion (See Table 5). Risk adverse producers would rather lose $300 yearly than make a profit of $300 one year, losing $900 the next year.

[Insert Figure 1 here]

[Insert Table 5 here]

The stoplight chart uses values input by the user to determine the probability of an unfavorable, cautious, or favorable outcome to a chosen scenario using the metaphor of the red, yellow, or green coloration from a traffic signal to illustrate the data. Arbitrary inputs of no loss and profits of more than $250.00 per acre were chosen for analysis as these amounts seemed reasonable and comparable to producer's expectations. With an input low of $0.00 in returns and at least $250.00 in returns per acre as the desirable level, the stoplight chart predicted a more than 50% probability of a favorable outcome for grapes, lettuce, onions, and wildrye (See Figure 2). At these values, barley had a 58% chance of an unfavorable outcome and switchgrass had a 100% chance of an unfavorable outcome. Alfalfa had a 30% favorable rating and a 57% cautious rating; teff had a favorable probability of 23% with 66% probability of a cautious outcome.

[Insert Figure 2 here]

The stochastic dominance tables that are interactive in SIMETAR allow the user to input different Risk Aversion Coefficients (RAC) to analyze decision maker's choices under any level of risk. Analyzing stochastic dominance for producers who were risk neutral at a Risk Aversion Coefficient (RAC) of 0 which implies risk neutrality, the preferred order of crops to plant is:

onions, lettuce, wildrye, grapes, alfalfa, teff, barley, and switchgrass. When RAC level was raised to 1, that of a normal, or somewhat risk adverse producer, the preferred order changed to: wildrye, teff, alfalfa, barley, switchgrass, onions, lettuce and grapes.

The stochastic efficiency graph takes the stochastic dominance table a step further and shows at what level of risk aversion decision makers choices change. In analyzing stochastic efficiency, alfalfa became preferred to lettuce and preferred to onions at very small levels of risk aversion (See Figure 3). A risk adverse decision maker prefers a consistent small loss to fluctuating gains or losses. This preference for minimal variation in returns also explains why onions and lettuce drop behind wildrye, alfalfa, teff, and barley regardless of their higher profit potentials. At minimal amounts of risk aversion, grapes became the least preferred of any of the crops.

[Insert Figure 3 here]

Conclusions

The purpose of this study was to investigate the economic feasibility of low-water alternative crops for the Walker Basin region in order to reduce agricultural water use without causing economic damage to the producers in that region. Reducing agricultural water use is a necessary major component of the attempt to increase water levels in Walker Lake and avert further ecological degradation.

This study determined that there are alternative crops that could be economically feasible in Northwestern Nevada. For those producers able to obtain funding for capital investment who are willing to expand operations to include additional amounts of hired labor, growing onions and leaf lettuce under rotation would yield substantial returns for producers. For those producers desiring to farm with no additional input to labor or who lack funding for capital, this study recommends further investigation into contractual availability of growing two row malt barley or Great Basin wildrye. All of the afore mentioned crops, either solely or in rotation, use 24" or less of irrigation, half of the necessary irrigation needed for alfalfa, enabling producers to sell their water rights if they so desire. Switchgrass is not recommended as being economically feasible at this time. Teff has potential for profit, yet is not as water conserving as other crops under consideration. Wine grapes require a large outlay of capital investment and are labor intensive; they should not be attempted on a large scale by a first-time producer.

Field trials should be conducted in the region to determine if the high yields of Great Basin Wildrye seed that were predicted by our model at higher irrigation levels than those of normal production practices are possible.

Some of the limitations faced by this study were related to the model used; WinEPIC has no allowances for quality as evidenced by the results from simulation of onions and lettuce in the model. Additionally, WinEPIC does not allow for increased yields due to advances in technology or changes in yield from soil amendments other than nitrogen or phosphorus. Wine grape yields did not reach maximum yields until approximately year ten in the WinEPIC model, but local producers report full yields by the fourth year of production. Some of the limitations faced by this study were related to a lack of data; simulated yields of Great Basin wildrye were unverifiable and adequate historical pricing was not available for teff, switchgrass, Great Basin wildrye, or wine grapes.

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Table 1. Average yields for alternate watering strategies by location

			Percent of Typical Watering Strategy				
Crop	**Location**		60%	80%	100%	120%	140%
Alfalfa		Inches	28	38	48		
	Smith		4.19	4.71	4.81		
	Yerington		5.14	6.32	6.66		
Onions [1]		Inches	16	22	28	34	40
	Smith		21.69	28.73	31.21	29.15	22.54
	Yerington		25.99	34.42	37.40	34.93	27.01
Lettuce		Inches	8	10	12	14	16
	Smith		9.63	11.47	12.17	12.29	12.17
	Yerington		9.93	11.84	12.49	12.59	12.49
Grapes		Inches	2		4		6
	Smith		4.64		7.45		7.00
	Yerington		4.50		7.50		7.20
Teff		Inches	22	28	36	42	48
	Smith		0.91	0.96	1.01	1.01	1.01
	Yerington		0.98	1.04	1.09	1.07	1.08
Barley		Inches	14	20	24	28	34
	Smith		2.54	3.21	3.25	3.20	3.11
	Yerington		2.76	3.41	3.46	3.49	3.48
Wildrye [2]		Inches	8	10	12	14	16*
	Smith		162	240	318	387	450
	Yerington		216	303	384	459	521
Switchgrass		Inches	22	28	36	42	48
	Smith		4.16	4.30	4.33	4.24	4.11
	Yerington		4.58	4.70	4.81	4.79	4.74

[1] Onions, Lettuce, and Grape yields are marketable yields for a given irrigation level

[2] Optimal yield for Wildrye is at 22" of irrigation (546, 593)

All yields are averaged over all soils and are tons/acre except for Wildrye which is lbs/acre

Table 2. Break-even prices for alternate watering strategies by location*

		Percent of Typical Watering Strategy				
Crop	**Location**	60%	80%	100%	120%	140%
Alfalfa	Inches	28	38	48		
	Smith	$193.88	$176.58	$177.34		
	Yerington	$158.01	$131.65	$128.19		
Onions	Inches	16	22	28	34	40
	Smith	$457.94	$346.53	$319.74	$343.13	$444.78
	Yerington	$382.17	$289.24	$266.82	$286.35	$371.17
Lettuce	Inches	8	10	12	14	16
	Smith	$709.55	$596.88	$563.69	$558.91	$565.53
	Yerington	$688.27	$578.11	$549.12	$545.68	$550.91
Grapes	Inches	2		4		6
	Smith	$917.22		$572.47		$610.56
	Yerington	$945.76		$568.65		$593.60
Teff	Inches	22	28	36	42	48
	Smith	$632.74	$598.64	$571.37	$585.24	$593.96
	Yerington	$581.55	$551.69	$530.37	$549.24	$554.05
Barley	Inches	14	20	24	28	34
	Smith	$370.70	$298.00	$296.32	$303.48	$314.92
	Yerington	$340.89	$280.21	$278.31	$277.65	$281.24
Wildrye	Inches	8	10	12	14	16*
	Smith	$4.99	$3.39	$2.57	$1.95	$1.84
	Yerington	$3.76	$2.69	$2.13	$1.64	$1.59
Switchgrass	Inches	22	28	36	42	48
	Smith	$189.53	$186.34	$188.90	$195.71	$205.17
	Yerington	$172.17	$170.50	$170.07	$173.33	$177.85

*Optimal break-even for Wildrye is at 22" of irrigation ($1.54, $1.41)

All prices are per ton except for Wildrye which is per pound and are averaged over all soils

Table 3. Comparison of net returns for all crops under optimal watering strategies with regard to yields

	Alfalfa		Onions		Lettuce		Grapes	
	$144/ton		$320/ton		$700/ton		$825/ton	
Location & Soil Type	**Returns**	**Inches**	**Returns**	**Inches**	**Returns**	**Inches**	**Returns**	**Inches**
Smith Dithod	-$131.76	38	$8.25	28	$1,733.98	14	$739.22	4
Smith East Fork	-$147.93	42	$8.25	28	$1,733.98	14	$1,033.58	4
Smith Sagouspe	-$177.05	44	$8.25	28	$1,733.98	14	$1,843.07	4
Yerington Dithod	$130.92	44	$1,989.05	28	$1,942.53	14	$886.40	4
Yerington East Fork	$114.03	48	$1,989.05	28	$1,942.53	14	$1,143.97	4
Yerington Sagouspe	$74.82	48	$1,989.05	28	$1,942.53	14	$1,879.87	4

	Teff		Barley		Wildrye		Switchgrass	
	$760/ton		$360/ton		$2.50/pound		$66/ton	
Location & Soil Type	**Returns**	**Inches**	**Returns**	**Inches**	**Returns**	**Inches**	**Returns**	**Inches**
Smith Dithod	$179.59	34	$256.58	32	$561.66	24	-$506.09	22
Smith East Fork	$202.78	34	$253.87	22	$636.07	22	-$512.45	26
Smith Sagouspe	$192.79	36	$135.70	22	$433.67	18	-$521.38	20
Yerington Dithod	$231.81	36	$374.75	32	$659.49	22	-$469.62	20
Yerington East Fork	$254.62	36	$323.05	32	$799.98	22	-$482.27	18
Yerington Sagouspe	$270.07	36	$218.79	22	$527.33	18	-$497.43	18

Table 4. Investment costs for all crops on differing acreage

Crop	**Alfalfa**	**Onions**	**Lettuce**	**Grapes**
Acreage	400	400	400	5
Capital Investment*	$818,041.00	$5,347,469.50	$2,876,196.00	$88,390.80
P&I Annual Payments**	$65,922.98	$430,933.33	$231,782.29	$7,123.10

Crop	**Teff**	**Barley**	**Wildrye**	**Switchgrass**
Acreage	60	240	200	200
Capital Investment*	$190,004.00	$905,870.00	$339,989.00	$204,476.00
P&I Annual Payments**	$15,311.74	$73,000.81	$27,398.49	$16,477.99

*excluding housing and land

**30 years, 7% interest

Table 5. Analysis of stochastic dominance with respect to a function (SDRF) at a risk aversion coefficient (RAC) of risk neutrality and at slight risk aversion

	Efficient Set Based on SDRF at			Efficient Set Based on SDRF at	
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	Onions	Most Preferred	1	Wildrye	Most Preferred
2	Lettuce	2nd Most Preferred	2	Teff	2nd Most Preferred
3	Wildrye	3rd Most Preferred	3	Alfalfa	3rd Most Preferred
4	Grapes	4th Most Preferred	4	Barley	4th Most Preferred
5	Alfalfa	5th Most Preferred	5	Switchgrass	5th Most Preferred
6	Teff	6th Most Preferred	6	Onions	6th Most Preferred
7	Barley	7th Most Preferred	7	Lettuce	7th Most Preferred
8	Switchgrass	Least Preferred	8	Grapes	Least Preferred

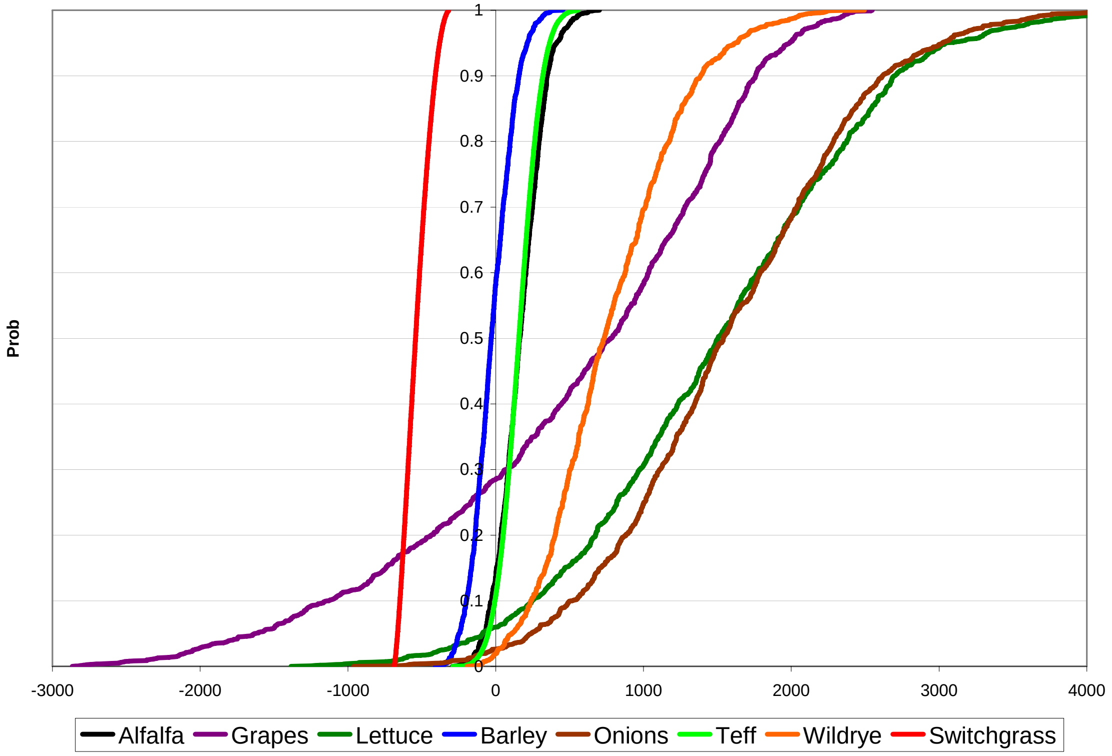

Figure 1. Combined comparative cumulative density function of net returns for all crops

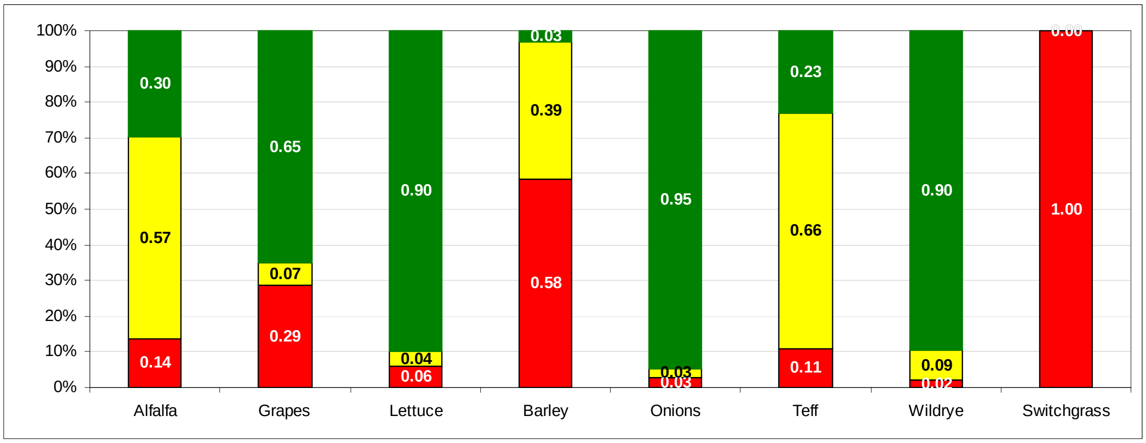

Figure 2. Probability of a favorable, cautious, or unfavorable result for returns greater than $250.00, but no less than $0.00

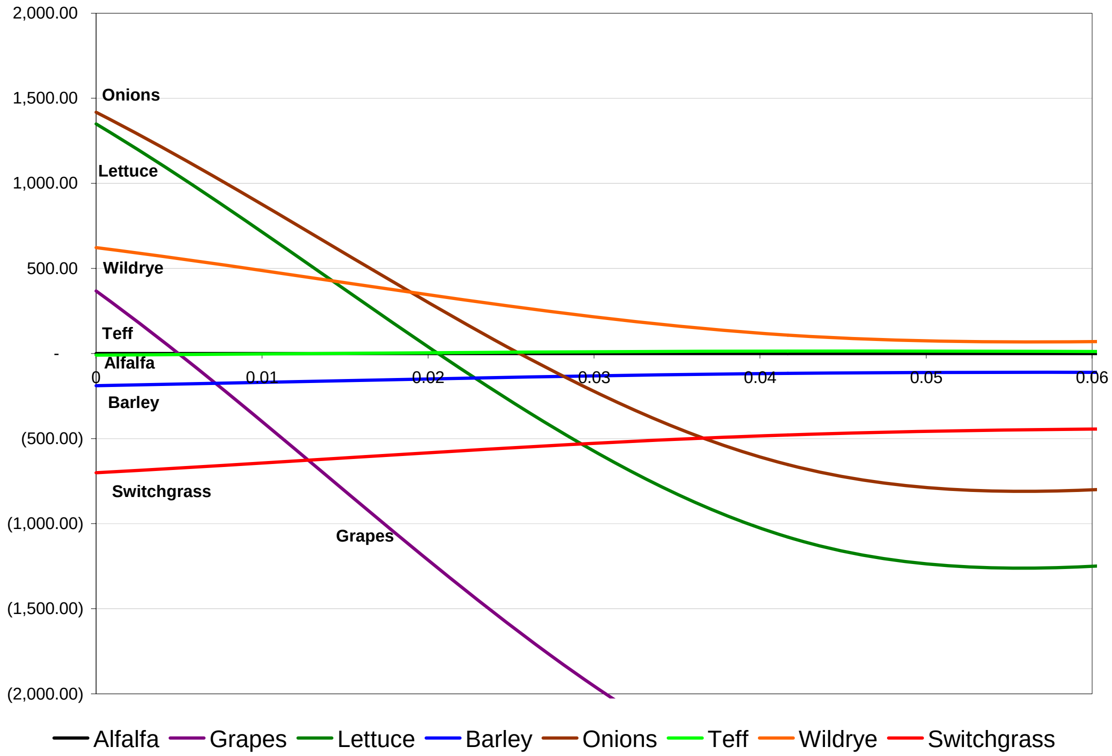

Figure 3. Risk aversion coefficient comparison between crops or SERF (Stochastic Efficiency with Respect to a Function) using a negative exponential weighted risk premium relative to alfalfa