PROJECT G: ECONOMIC ANALYSIS OF WATER CONSERVATION PRACTICES FOR AGRICULTURAL PRODUCERS

ECONOMIC ANALYSIS OF ALTERNATIVE WATER-CONSERVING CROPS FOR THE WALKER RIVER BASIN

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ABSTRACT

Walker Lake is facing critical water shortages and becoming excessively saline due to surface water withdrawals from its sources, endangering its ecosystem and economic resources. Water diverted from surface inputs for agricultural use is one cause of this shortage. Unless agricultural water use can be reduced, the ecology of Walker Lake will be altered. This study examined alternative crops that would enable producers to remain economically viable while using less water. A combination of a crop yield model, WinEPIC, and a risk simulation model, SIMETAR, were used to analyze and answer the agronomic and economic questions. 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.

INTRODUCTION

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, terminating at Walker Lake. In the last one hundred and fifty years, water has been diverted from these inflows for irrigation purposes at five major agricultural areas along the rivers. 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. The Walker Basin Project, funded by Congress through Public Law 109-103, Section 208 in November 2005, is involved in purchasing water rights from agricultural producers in order to be able to leave this previously appropriated water in the rivers where it will make its way downstream to the lake. 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 a sensible option; leaving the ground fallow in these areas could result in these previously verdant areas becoming sources of 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). A 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 while continuing to grow crops, producers would have to be able to grow a crop with less water, yet yield equal or greater profit. An alternative crop would 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 university and extension faculty 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 alternative crops under study fall into differing categories: onions, an annual market crop already grown in the region; leaf lettuce, an easily marketable annual; wine grapes, a high-end market perennial; teff, a specialty annual grain used for market or forage; two-row malt barley, an annual used in the niche market of beer brewing; Great Basin wild rye, a native perennial grass that can be used for restoration or forage; and switchgrass, a native perennial grass with potential as a biofuel. 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. Yields can be compared for the same crop using flood, sprinkler or drip irrigation. The model has been calibrated to use data from long-term existing weather stations in northern Nevada, and uses soil data from the USDA Natural Resources Conservation Service for the areas under consideration. 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.

The results of this study will be useful not only to area producers and those involved in the Walker Basin Study, but also to producers in other areas of the West. Water is an increasingly scarce commodity in the west, and as more water is diverted from agricultural use to residential and industrial purposes, producers in other areas will be facing similar challenges.

RELATED LITERATURE

Water Availability

In the western United States, hydrological cycles have changed considerably in the last fifty years, due in a large part to anthropogenic intervention, and research predicts water supplies will reach a crisis stage (Barnett et al. 2008). As populations in western states increase, municipal 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).

Reducing Water Use

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). Farmers in the Punjab region of India have replaced rice and wheat with cotton and soybeans while farmers in the Lower Rio Grande Basin of Texas have replaced sugar cane with corn (Jalota et al. 2007; Santhi et al. 2005). We offer in this study several alternatives to alfalfa that reduce water consumption.

Alternative Crops

In order for an alternative crop to be considered economically feasible by this study, 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; and 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. The categories of crops under consideration were vegetables, herbs, fruits, cereals and legumes, and industrial crops and grasses. Allowing for climate and market considerations, a potential optimal crop was chosen from each category.

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.

Of the herbs under consideration, none were chosen, as the growing conditions in northern Nevada were not conducive to any of the crops researched due to either temperature or water use limitations.

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, but can be added as a thickener to soups, stews, and gravies, added to various types of baked goods, made into porridge, or used to make home-brew (Stallknecht 1998). Teff is virtually gluten-free; this quality makes it highly desirable for those with wheat allergies and increases its marketability. It has a high protein content and a high calcium content along with high levels of other trace minerals (Stallknecht, Gilbertson, and Eckhoff 1993). Teff can be ready for harvest as soon as fifty days after planting (Extension 2007). Because it is able to be grown in such a short amount of time, it can act as a high quality emergency hay crop. Few disease or pest problems are associated with teff and it can be planted and harvested with conventional forage equipment, eliminating the costs of new equipment investment. Teff can be stored for a minimum of three years and up to five years with no loss of viability (Stallknecht, Gilbertson, and Eckhoff 1993) and has been modeled for its production potential (Yizengaw and Verheye 1994).

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). Many former barley producers switched to corn when prices increased for that crop and maltsters are currently facing shortages, increasing prices (Hildebrant 2008). 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). It was widely introduced to the public when President George W. Bush mentioned it in his 2006 state of the union address as a source of bio-based fuel for transportation (Bush 2006). Switchgrass has been modeled to verify mean yields at sites in the southern United States (Kiniry et al. 2005), and its potential production has been modeled under both current and greenhouse-altered climatic conditions (Brown et al. 2000). 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).

Cropping Practices

Changing cropping systems or water usage on agricultural fields can potentially have adverse effects on yields, soil productivity, or environmental quality; practices therefore, are an important consideration when evaluating suggested changes in production. Soil quality is a large determinant of yield; should soil modification to improve soil structure and root growth be a consideration? While soil modification increases yields on small plots, studies of large plots have found that it does not improve yields of irrigated forages and is not feasible on a commercial scale (Greenwood et al. 2006). Increasing the amount of nitrogen in the soil does result in increased crop vigor, but also increases total water use with a slight increase in water efficiency due to decreased evaporation (Norton and Wachsmann 2006); this trade-off needs to be considered when determining amounts of applied nutrients.

One practice which is beneficial with regard to environmental considerations and in optimizing water use is no-till cropping. In sandy loam soils, which are prevalent in the study area, no-till cropping was found to increase soil carbon storage and soil aggregation (Grandy et al. 2006). Carbon storage has become an important issue with the advent of global warming; tilling soil releases carbon into the air and reduced tillage, also known as conservation tillage, has been estimated by the USDA to increase carbon storage by eight million metric tons a year in the United States (Comis, Becker, and Stelljes 2001). Soil aggregation, or clumping of particles of different sizes, allows for pores to form between the particles which results in the ability of well aggregated soil to store air, water, nutrients, microbes, and organic matter and makes these soils less vulnerable to erosion (Australia 2004). No-till practices have been found to considerably increase the amount and diversity of soil macroinvertebrates, decrease run-off and nitrogen loss, and increase soil moisture due to greater water infiltration (Gregory, Shea, and Bakko 2005). Conservation tillage has been found to greatly enhance water conservation, especially in semi-arid regions (Unger et al. 1991). Because no-till practices are an optimal choice with no apparent disadvantages, we have incorporated them for all crops under consideration.

DATA AND METHODS

Model Choice

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, abstract, 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.

Nevada Database

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.

Areas of Focus

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.

WinEPIC Model Setup

Many of the alternative crops of interest were not in the WinEPIC database so other crops were used as a template for these missing crops and the parameters were adjusted based upon the recommendations of the staff agronomist at the Blackland Research Center (Blackland 2007). Teff was created from spring wheat, spring onions from winter onions, and Great Basin wildrye from western wheatgrass by altering price, seed cost, plant population, seeding rate, biomass energy ratio, leaf area index decline factor, lower limit of harvest index, maximum leaf area index, minimum temperature for plant growth, optimal temperature for plant growth, and yield decrease by salinity increase parameters in the WinEPIC crop data screen under data/setup.

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.

The irrigation type selected for each crop varied and was chosen based on common production practices (Curtis et al. various 2008). Alfalfa, teff, Great Basin wildrye and switchgrass budgets were chosen to use flood irrigation. Onions and leaf lettuce budgets use a combination of sub-surface or buried drip irrigation and set spot sprinklers. Set spot sprinklers are used for germination of crops and used as primary irrigation until plant roots are sufficiently long to reach the buried drip tape; as the crop grows they are used to apply chemicals and liquid fertilizers. Wine grapes use solely surface and sub-surface drip irrigation. Two-row malt barley was chosen to use center pivot irrigation with Low Energy Precision Application, as some producers in the region utilize center pivots to grow alfalfa and it was desirable to be able to offer them an alternative with the same irrigation system. All irrigation types with the exceptions of center pivot for two row malt barley and drip irrigation for wine grapes use surface water as their irrigation source. Irrigation amounts followed producer and research recommendations (Curtis et al. various 2008). Alfalfa was given 48” of irrigation, onions, teff and switchgrass were irrigated with 36”, however 8” of the water allotted to onions was for its cover crop of winter wheat; the actual irrigation applied to onions was 28”. Two-row malt barley received 24” of irrigation, Great Basin wildrye and leaf lettuce were irrigated with 12” of water, and wine grapes were simulated with only 4” of irrigation.

Alfalfa was run with six years of alfalfa production followed by a year of winter wheat production which is a common practice in the region; returns from winter wheat were not included in this analysis. Onions, which are an annual crop, were intercropped with winter wheat which was later sprayed out. Teff, another annual, was double-cropped with winter wheat as teff has a growing season of only three months. As with alfalfa, returns from winter wheat were not included in this analysis, however, as this analysis was conducted with growing teff for seed production, returns from the chaff produced as a function of seed production were included in returns. Great Basin wildrye was grown on a seven year rotation with harvesting occurring during six years of the rotation. Switchgrass is grown on an eleven year rotation; the first year consists of land preparation, the second year is an establishment year, and the switchgrass is harvested during the next nine years. Two-row malt barley and lettuce are both annuals that could be grown with winter cover crops, but that practice was not considered in this study. Wine grape vineyards of interspecific grapes have an expected production cycle of thirty-five years; no harvest occurs in the first two years with a small harvest in the third year continuing to build to maximum production at approximately ten years.

WinEPIC Validation and Simulation

The WinEPIC model was validated using known yields from Churchill County and 40 years of actual weather data from the weather station in Fallon to verify the efficacy of the model. The model correctly predicted known alfalfa yields for Churchill County. National Agricultural Statistics Service (NASS) records show that alfalfa yields in Lyon County are consistent with those in Churchill County which was used as the baseline for yield validation. Planting dates and amounts, irrigation regimes, amount and timing of fertilizer applications, and other budget inputs were altered to produce verifiable yields under simulation for all crops using actual weather conditions. Prior to simulation, all crops were put through a 'pre-run' of twelve years beginning in 1960 to set up the soil properties, allowing them to be adjusted by the local climate and cropping practices. Pre-run also considers the number of years that the location has been in cultivation, which affects soil parameters.

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.

Analysis

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 data on break-even yields with all soil types (Curtis, various 2008). 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 (marketable yield adjusted), 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. Dithod soil was chosen due to its prevalence in Mason Valley/Yerington area. Yerington was chosen as it has more area dedicated to agricultural production in the Walker River Basin. Similar analysis could be conducted over other soils and for Smith Valley, but would likely be trivial to the discussion.

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 uniform standard deviation (Equation 3). This function generates a random number between 0 and 1.

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

Yields and their residuals as determined by the data, following 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.

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

Alpha and Beta parameters for the beta distributions were as follows: Great Basin wildrye (1.478, 2.261), switchgrass (1.401, 2.072), and wine grapes (2.198, 0.774). 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).

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

For those crops with at least ten years of historical pricing, ordinary least squares (OLS) regressions were run to estimate the deterministic portion of price. Some crops in this category fit a trend model. 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, where the shape of the distribution is defined by the data was used to create the stochastic residuals for those crops by estimating the empirical distribution and generating a random residual using actual data (Equation 7).

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

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 based upon the pricing data (*T*) (Equation 8).

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

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

$$\tilde{y} * \tilde{p} = \tilde{tr} \quad (9)$$

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

$$\tilde{tr} - c = \tilde{nr} \quad (10)$$

In order to simulate through 2009, 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 NASS (USDA-NASS 2007a). 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

<u>Alfalfa</u>

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 (Figure 1).

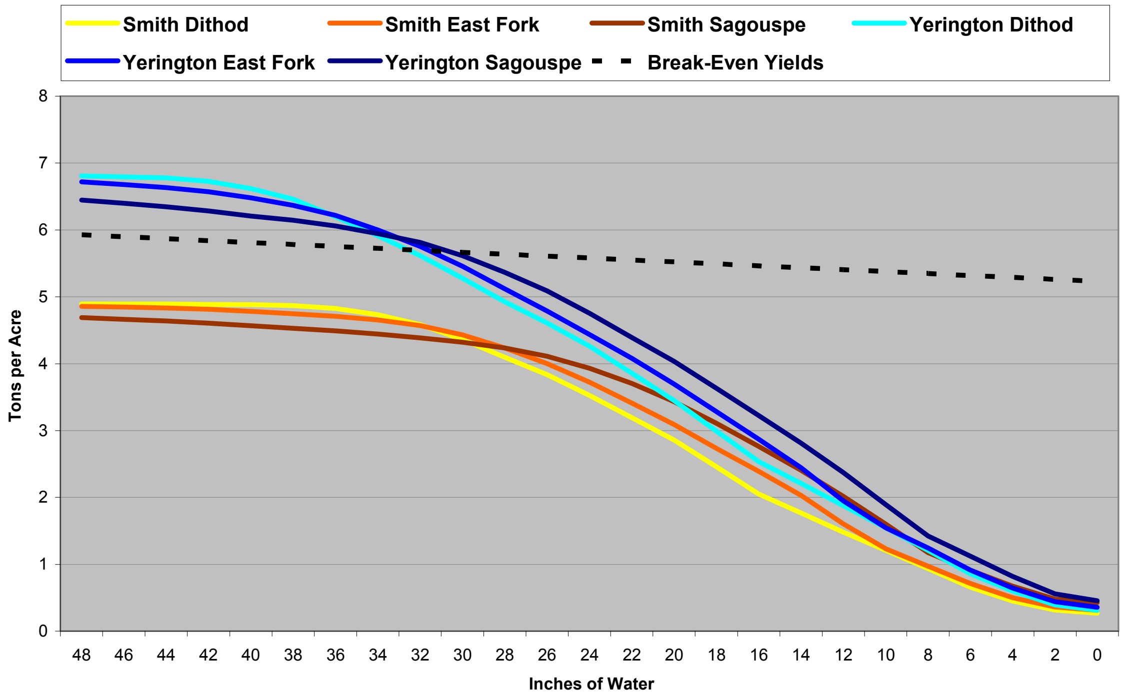

Figure 1. Alfalfa yields for all soil types and both locations under all irrigation regimes.

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 (Table 1).

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'.

Table 1 Break-even prices for alternate watering strategies by location.*

Crop	Location		Percent of Typical Watering Strategy 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

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 (Figure 2).

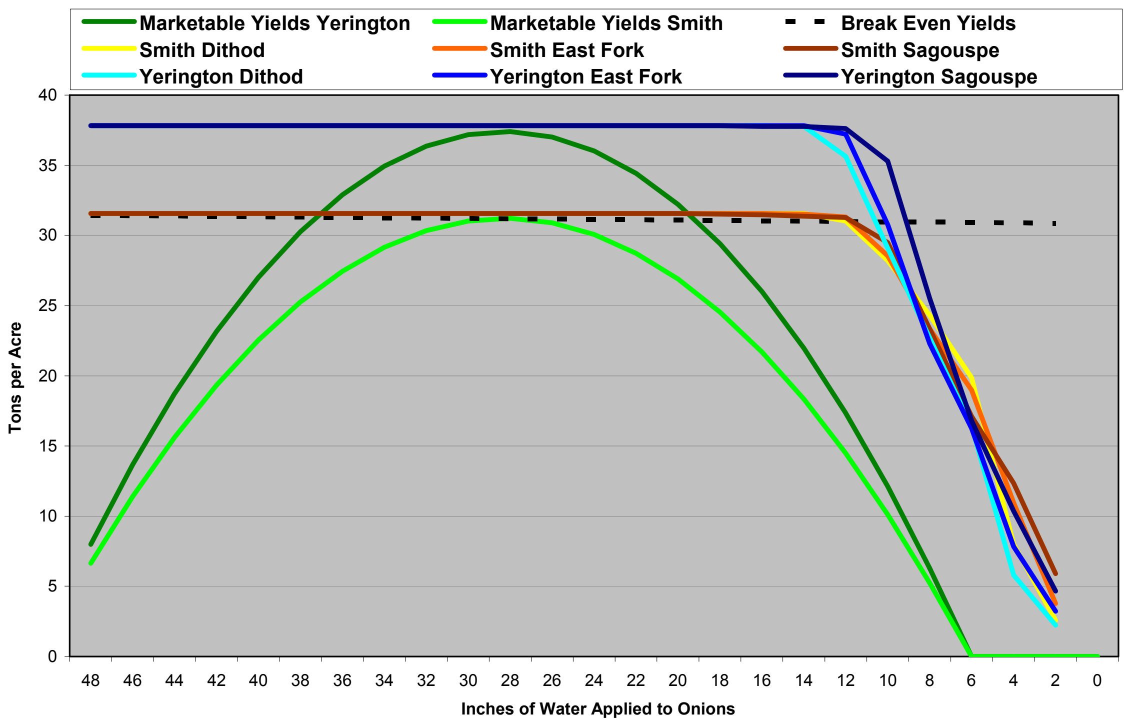

Figure 2. Onion yields for all soil types and both locations under all irrigation regimes.

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 (Table 1). 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 (Table 2).

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 (Table 3).

Table 2. 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 3. 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
Principal & Interest 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
Principal & Interest Annual Payments**	$15,311.74	$73,000.81	$27,398.49	$16,477.99

*excluding housing and land
**30 years, 7% interest

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.

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 (Figure 3).

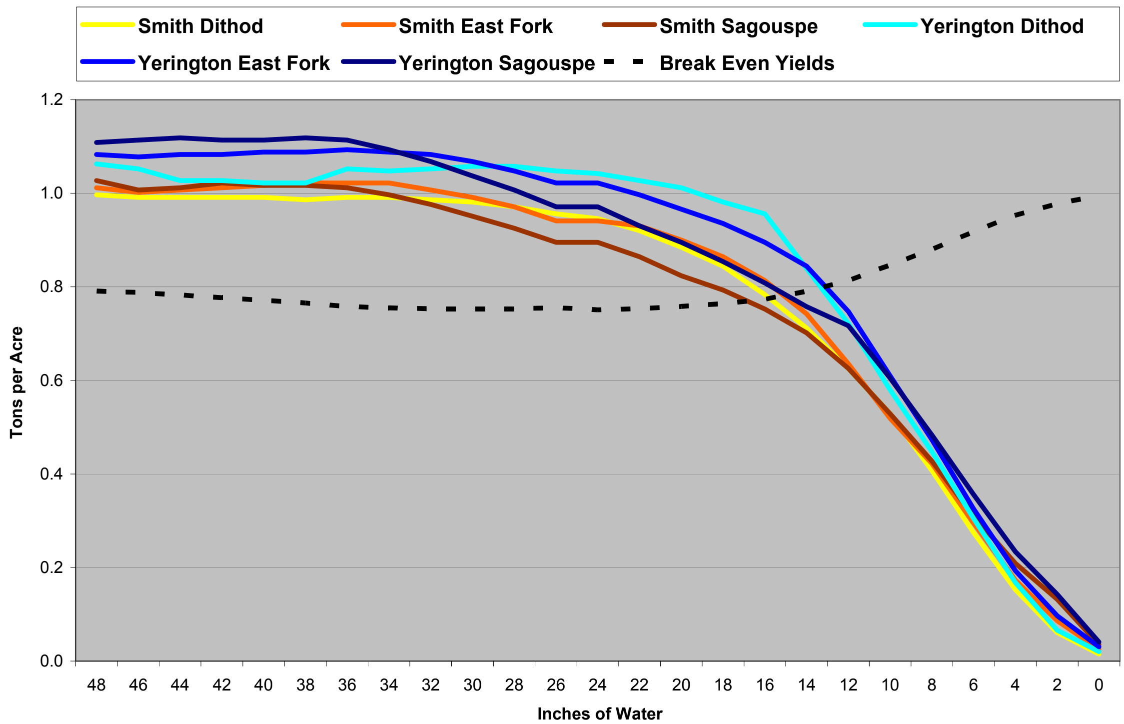

Figure 3. Teff seed yields for all soil types and both locations under all irrigation regimes.

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 (Table 1). In Smith, the highest net returns were with Eastfork 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 (Table 3).

<u>Great Basin wildrye</u>

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 (Figure 4).

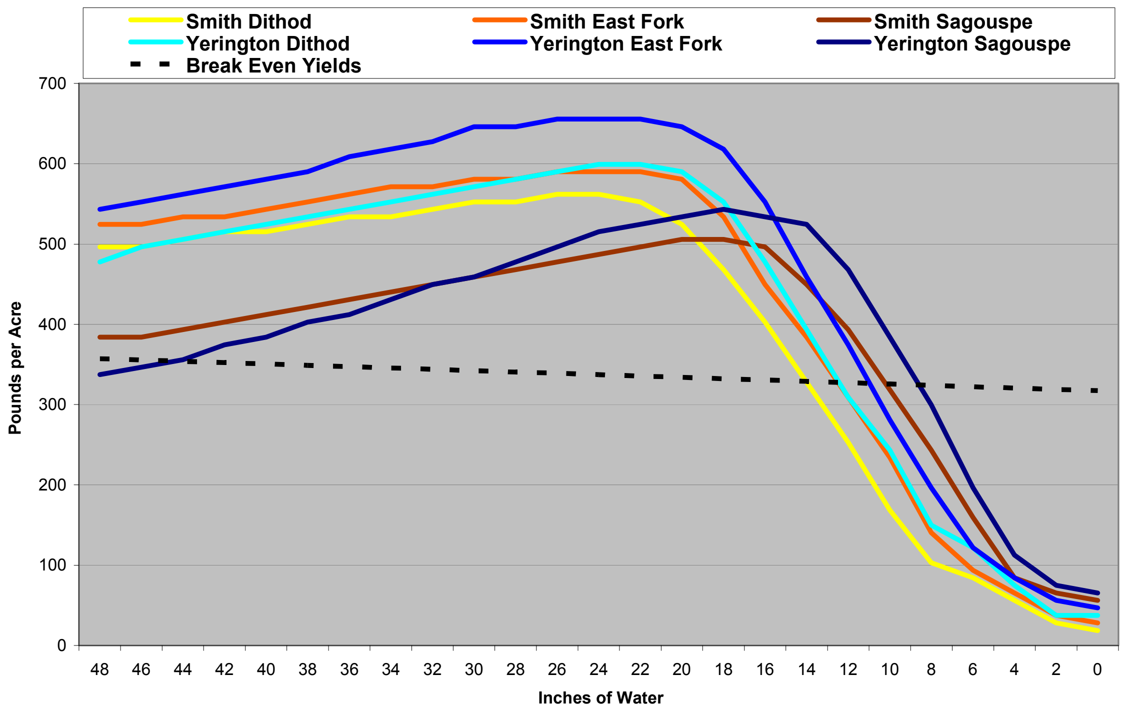

Figure 4. Great Basin wildrye seed yields for all soil types and both locations under all irrigation regimes.

At a price of $2.50 per pound for seed, break-even yield was 327.3 pounds of seed produced per acre. Prices and yields are reported in pounds and pounds/acre for this crop because that is the usual marketing practice. Break-even prices were $2.57 in Smith Valley and $2.13 in Mason Valley (Table 1). 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 (Table 2).

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 (Figure 4, Table 2). A thorough review of the literature revealed no studies with Great Basin wildrye at any level of irrigation above 12". Brent L. Cornforth, the farm manager for the USDA Natural Resource Conservation Service Plant Materials Center at Aberdeen, Idaho, stated he believed “600 pounds per acre yields are possible” under certain conditions, but had no firsthand knowledge of anyone increasing irrigation levels beyond current standards. Further extensive production studies need to be conducted with this native crop to determine if larger yields are possible with additional irrigation because of its many uses: it is useful for winter grazing, provides habitat for numerous species of wildlife, and is a prime choice for reseeding after disturbances, useful for restoration following fire and for reclamation of mining lands. 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 (Table 3). 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 (Figure 5).

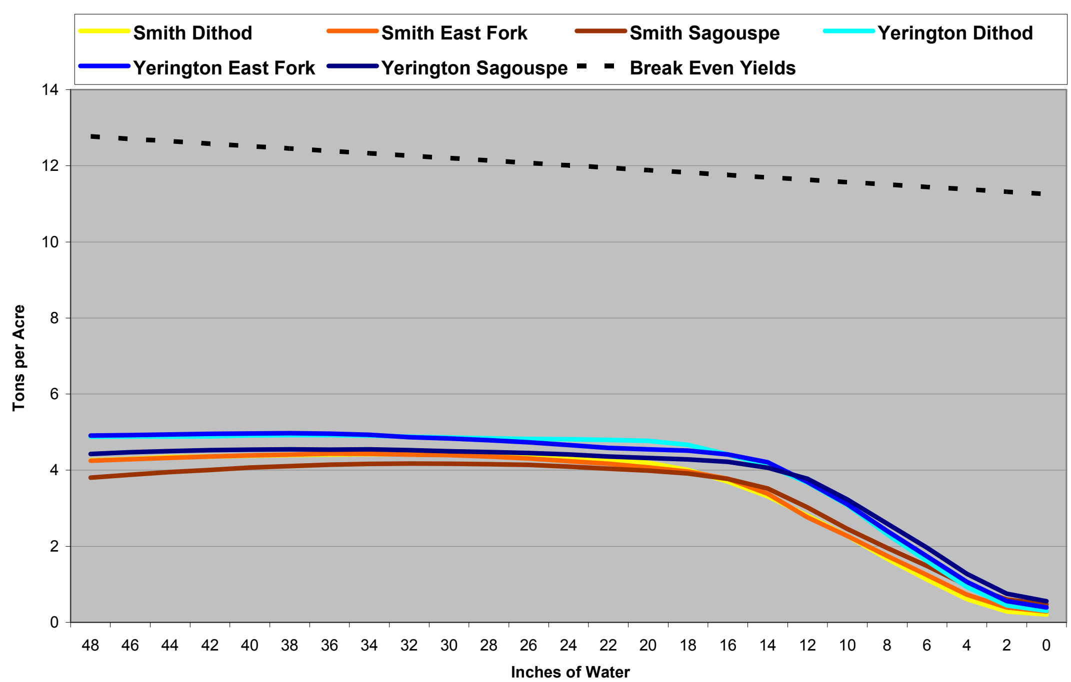

Figure 5. Switchgrass yields for all soil types and both locations under all irrigation regimes

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 (Table 1). 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 (Figure 6).

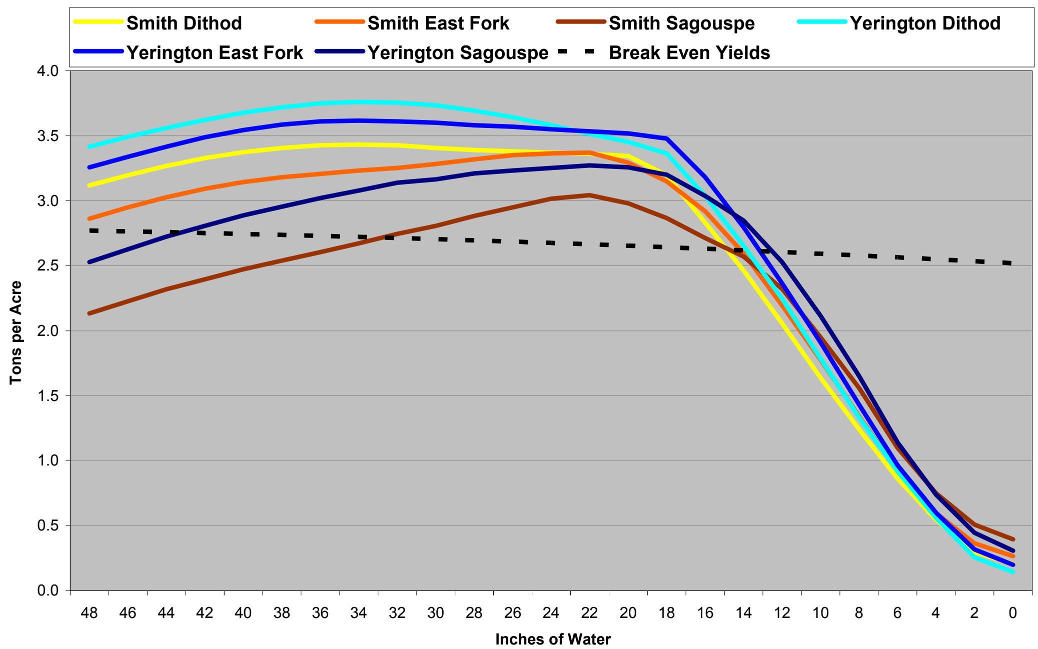

Figure 6. Two-row malt barley yields for all soil types and both locations under all irrigation regimes.

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 (Table 1). 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 (Figure 7).

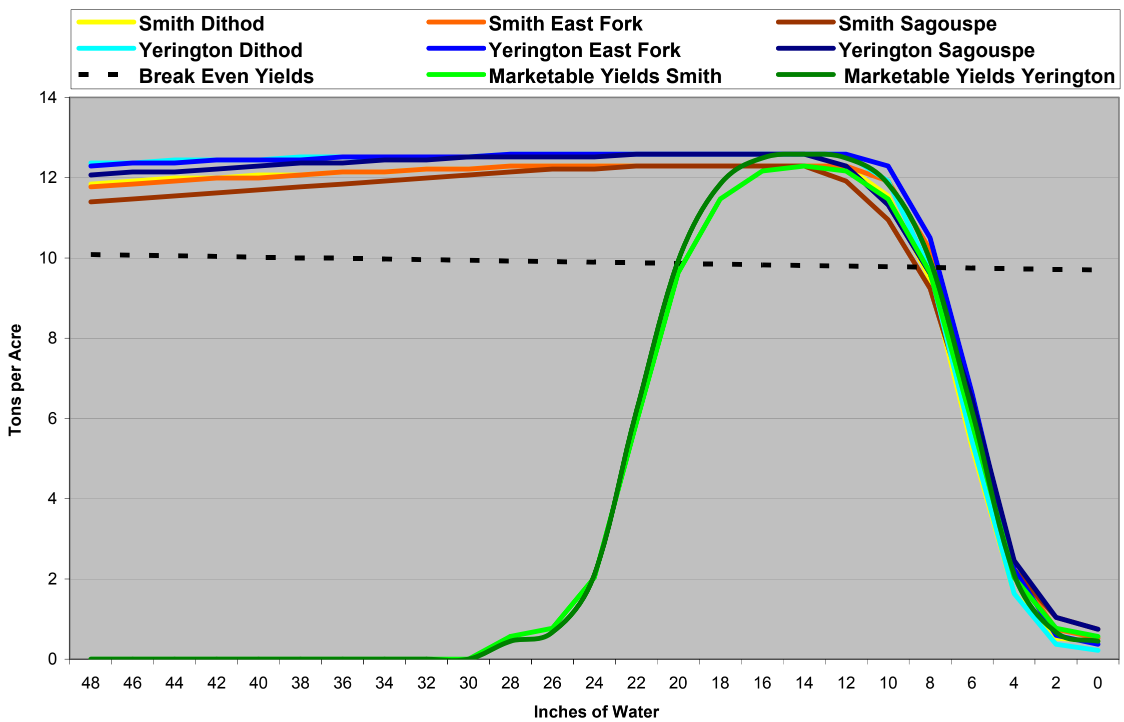

Figure 7. Leaf lettuce yields for all soil types and both locations under all irrigation regimes.

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 (Table 1). 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). When the Mason Valley received unexpected rain early this summer, one of the producers growing leaf lettuce was forced to plow the crop under. Leaf lettuce is a high return crop, yet also requires a large capital investment; an upside to this necessary large capital investment is that the equipment needed for lettuce is much of the same equipment used for onions: both use set spot sprinklers, drip irrigation, and refrigeration equipment in addition to large amounts of labor. Both crops are planted on approximately April 15, lettuce is harvested on June 15 when it would need refrigeration until shipping; onions would not require refrigeration until they are harvested in late August or early September. 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 for potential sale or lease. 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 (Figure 8).

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 (Table 1). 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 quantity alone is not the goal of producers; grapes, like onions and lettuce, differ between yield and marketable yields. The higher yields predicted by the WinEPIC model at higher levels of irrigation are not the main consideration; 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 that occur from reducing irrigation, while an undesirable trait in onion production, is a premium 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 (Table 3). 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.

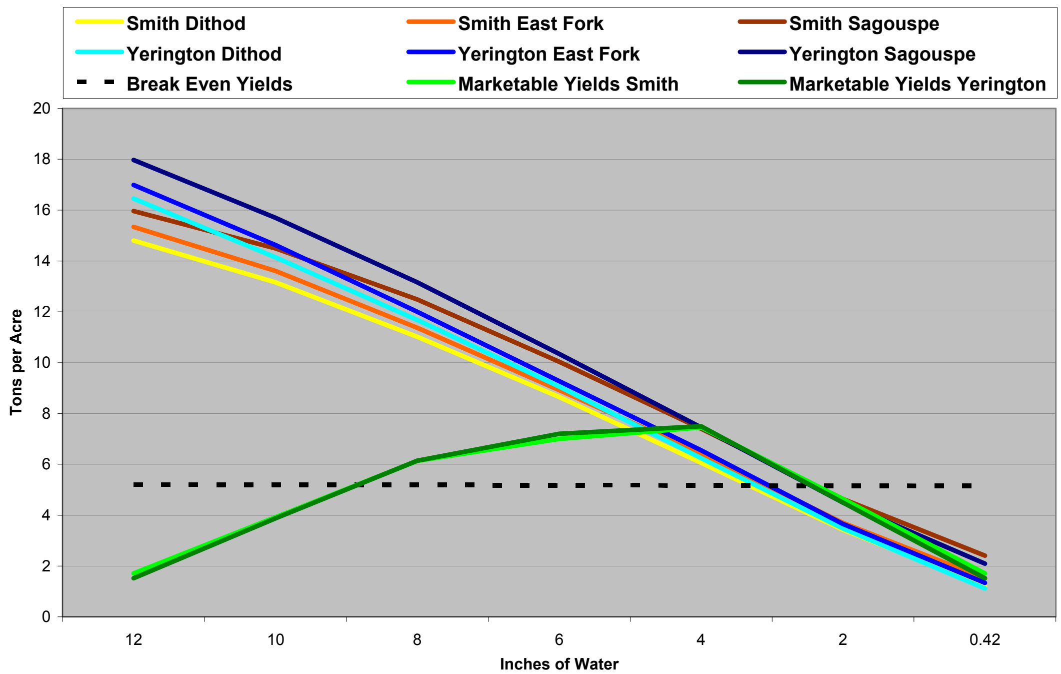

Figure 8. Wine grape yields for all soil types and both locations under all irrigation regimes

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 price that have recently occurred. For this reason a triangular pricing distribution was chosen with $144 per ton as the minimum (Curtis et al. various 2008), $177/ton as the midpoint, and current local reported pricing of $200/ton as the maximum (USDA-AMS July 2007b). 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 as there were only 10 years of available data and not the 20 required. The average of the last 10 years, or $288 per ton was used as the minimum; $320 per ton (Curtis et al. various 2008) 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 (Curtis et al. various 2008). 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. 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 (Curtis et al. various 2008), a mid-point price of $5.00/pound, and the 2007 retail at $7.50 (Utah Seed 2007). 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 (Curtis et al. various 2008), 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 (Idaho Barley Commission 2008) 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 the enterprise budgets was used as the maximum price (Curtis et al. various 2008). 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 (Curtis et al. various 2008), 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 (Curtis et al. various 2008), and the high of $954.00/ton (USDA-NASS 2007b). 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 (Figure 9).

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 (Table 4).

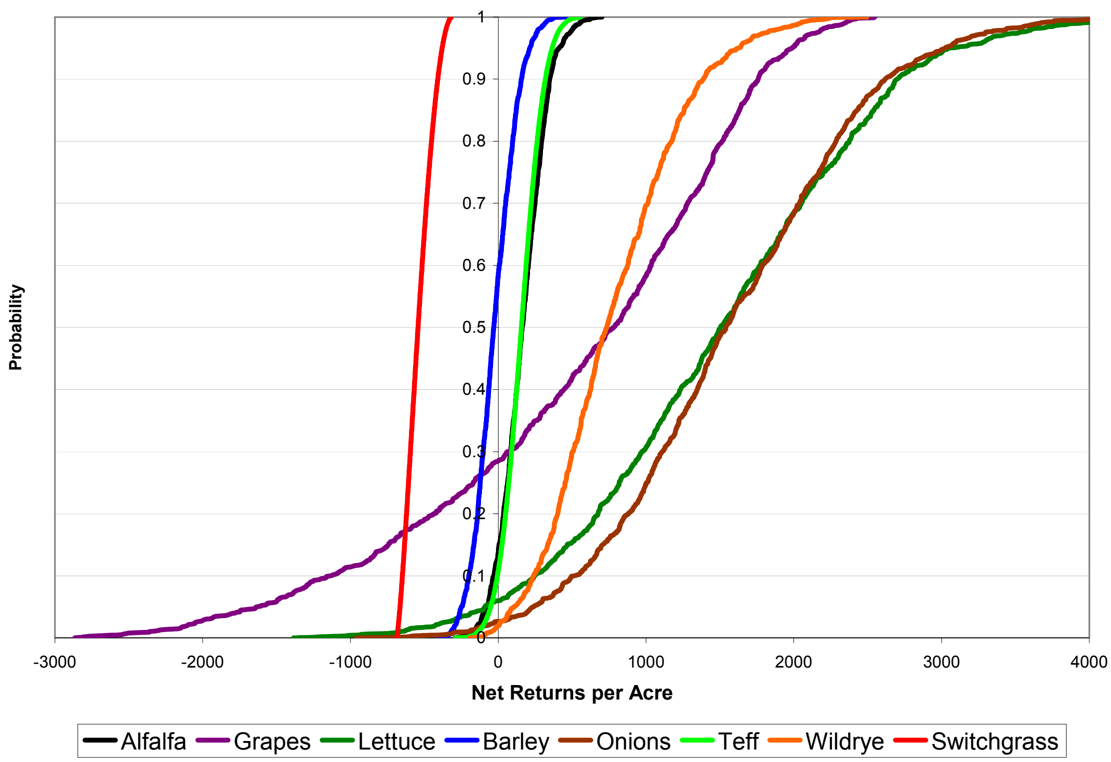

Figure 9. Combined comparative cumulative density function of net returns for all crops.

Table 4. 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 Lower RAC	**0**		Efficient Set Based on SDRF at 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

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, when applied to SIMETAR results (Figure 10).

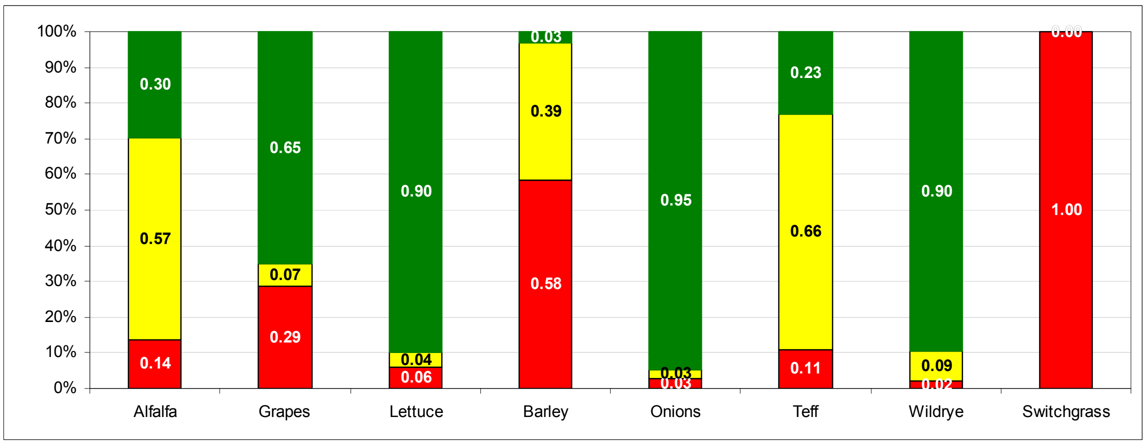

Figure 10. Probability of a favorable, cautious, or unfavorable result for returns greater than $250.00, but no less than $0.00

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.

SIMETAR allows 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 (Table 4).

SIMETAR also graphs the level at which risk adverse decision makers choose or switch between crops. As shown, alfalfa became preferred to lettuce and preferred to onions at very small levels of risk aversion (Figure 11).

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.

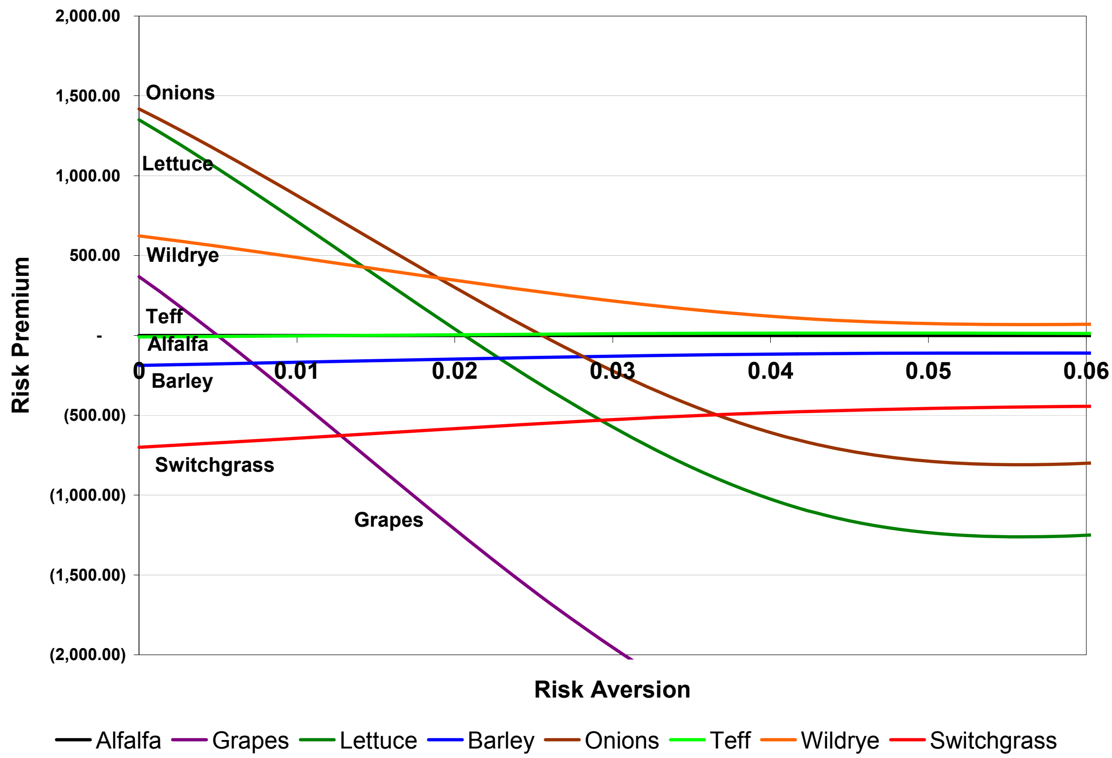

Figure 11. Risk aversion coefficient comparison between crops or SERF (Stochastic Efficiency with Respect to a Function) using a negative exponential weighted risk premium relative to alfalfa

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 who are not averse to variations in returns. 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 potentially sell or lease some of their water 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 are possible at higher irrigation levels than those of normal production practices.

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 at higher levels of irrigation were unverifiable, and adequate historical pricing was not available for teff, switchgrass, Great Basin wildrye, two-row malt barley or wine grapes.

An immense limitation exists in regard to the application of the results of this study by producers: current Nevada water law. Nevada's current water law does not easily permit the sale of a portion of water rights; all the water rights for a given parcel are normally sold. Nevada law also hampers leasing water rights for an agreed amount of time; 'use it or lose it' is the law rule in Nevada. Both of these concepts are a large impediment to reducing agricultural water use in Northwestern Nevada. Compensation levels would need to be extraordinarily high to convince producers who are by nature risk adverse, to give up a steady source of almost guaranteed income from alfalfa production, for both them and for their descendants for generations to come.

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