Dryland Wheat variety selection in the Texas High Plain

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Abstract: Selecting the best wheat varieties affects producers' profit and financial risk. This study identifies the optimal wheat variety selection using the portfolio approach at various risk aversion levels. Results showed that the optimal wheat variety selection was significantly affected by changes in levels of risk aversion of decision makers.

The most important wheat characteristics identified by wheat producers in the Texas High Plains and Rolling Plains regions include yield, drought tolerance, disease resistance, and test weight according to the annual Texas April Wheat Survey. For many years, wheat breeding programs in several locations in Texas have been supported by wheat producers group to develop new varieties with higher yield, better quality, and improved disease resistance. Some new varieties showed better performances compared to old varieties. For example, TAM 111 and TAM 112 have replaced TAM 105 and TAM 110, respectively.

The Uniform Wheat Variety Trial (UWVT) was coordinated and implemented by numerous Texas AgriLife Extension and Research faculty and staff, and Syngenta researchers. During the 2010-2011 wheat production season Texas producers planted 5.6 million acres of wheat according to the National Agricultural Statistics Service (NASS). Projected Texas wheat production is estimated at 52 million bushels with an average yield of 26 bu/ac. The production and yield was down significantly from 2010 due to the exceptional drought that the most of the states experienced during the growing season.

U.S. acreage of TAMU wheat varieties presented in Table 1 shows that 32 percent of 5,600,000 acres in Texas were planted with TAM varieties in 2010, and 16.7% of the 8,800,000 acres in Kansas are TAM varieties in 2011. It is predicted that the acreage of TAM varieties likely increased in 2011 in Texas. As such, 15 percent of the Great Plains hard red winter wheat acreage is being planted to TAM varieties. Among TAM varieties, more than half of the TAM acreage is TAM 111 and approximately 25 % is TAM 112.

Selecting the best wheat varieties could make an impact on crop yield, quality characteristics, and management practices, eventually resulting not only in producers' profit, but also in financial risk. Wheat producers in Texas make usually a decision of adopting new wheat varieties based on various sources including variety trial data, adoption by their neighbors, and recommendations by extension specialists. Stable yield performance over multiple years and multiple locations is the most desired varietal trait. However, previous research has primarily focused on agronomic aspects and a simple cost benefit analysis of each new wheat variety. There is little research that analyzes both profitability and risk involved in adopting new wheat varieties. Moreover, variety diversification has been strongly recommended to prevent economic losses from pests and adverse weather. However, there is no well-established diversification strategy of wheat varieties.

Literature review

The wheat yield variability observed in the UWVT indicates that risk is an important factor of varietal decision-making, i.e. when making a selection among the alternative wheat varieties. The practical implication of risk for producers is that they would take on greater variability to obtain higher yields and higher economic returns. Many economic studies (Markowitz, 1952; Sandmo, 1971; Batra and Ullah, 1974; Just and Pope, 1979; Pope, Chavas, and Just 1983) argued that decision makers should consider both the mean and variance of economic returns by discounting variability. In more useful words, an acceptable trade off between mean and variance of economic returns will require producers to choose alternatives that have a lower mean economic return in order to reduce variability and minimize exposure to risk (Robinson et al.,1984).

Within agricultural risk management, it is important to note that each decision maker will have different risk trade-offs according to their level of risk aversion since individuals express varying degrees of risk aversion (Pratt, 1964). In other words, each individual has a unique willingness to give up average income to lower income variability as a risk management tool. Therefore, optimal decision making should be made based on the statistical distribution of net economic returns (Richardson, 2003).

Previous studies on farm management have found that including risk made a significant difference in determining optimal cropping systems for producers (Anderson, 2000; DeVuyst and Halvorson, 2004; Dahl, Wilson, and Nganje, 2004). These studies demonstrate how incorporating risk can provide more efficient recommendations since risky alternatives can be eliminated. Since ignoring risk can lead to naïve and less realistic solutions, and since yield data has large variability, a risk model was developed for this study.

Several studies used stochastic dominance criteria, as a generic choice rule, in the risk management at the agricultural field level since it takes the entire probability distribution with a general condition of a farmer's risk preference. Stochastic dominance also imposes no restriction on the personal utility function. For instance, some recent papers addressed the economy and risk of farming strategies using a stochastic dominance criteria, such as the different cropping and tillage systems (DeVuyst and Halvorson , 2004; Ribera et al.,2004), the soil conservation program on crop production in Ethiopia (Kassie et al.2008), and the potential risk of adoption and selection of wheat variety (Al-Hamoudi et al., 1997 and Dahl, et al. 2004). However, the application of stochastic dominance criteria is limited when a portfolio approach should be accounted for in the diversification of land use due to the significant correlation between strategies (McCarl et al. 1987).

Portfolio is a concept of diversification in investing, with a goal of determining a combination of assets that has collectively lower variability than any individual assets. Portfolio theory was initially developed by Markowitz (1959) and Tobin (1958) as a solution to a broad class of problems in investment, finance, and resource allocation. More recently, it has been applied in various risk management strategies in agriculture, specifically farming decisions in Kenyan agriculture (Nyikal and Kosura, 2005), timber asset investment (Redmond and Cubbage, 1988), biodiversity (Figge, 2004), fishery management (Sanchirico, Smith, Lipton, 2005), and variety selection (Nalley et al., 2009, Nalley and Barkley, 2010).

Recently, there are studies on application of portfolio theory to variety decision. Barkely et al (2010) used portfolio theory to find the optimal, yield-maximizing and risk minimizing combination of wheat verities in Kansas. Also using the portfolio approach, Nalley and Barkey (2010) found that the optimal collection of wheat varieties could have lowered yield variance by 22 % to 33% in Northwest Mexico. Finally, Nalley et al. (2009) showed that combining rice varieties would be a benefit to producers because profit increased by 3 to 26 % by adopting a portfolio of rice varieties. However, these studies mainly focused on maximizing yield and profit at given variability (or minimizing variability at a given yield and profit) and failed to address various risk preferences.

Material Methods

Data and budget

The Uniform Wheat Variety Trial (UWVT) was conducted at 10 locations in Texas (Bushland, Canadian, Claude, Clovis, Etter, Hereford, Perryton, Sherman, Spearman, and Swisher) for three years from 2007 to 2009. This included 22 wheat varieties (Bullet, Deliver, Doans, Dumas, Duster, Endurance, Fannin, fuller, Hatcher, Jackpot, Jagalene, Jagger, Overley, Santa Fe, Shocker, T81, TAM111, TAM112, TAM 203, TAM304, TAM 401, and TAM W-101).

Table 2 shows summary statistics of yields for each of the 22 wheat varieties with their mean, standard deviation, coefficient of variation (CV), minimum, median, and maximum of yield (bushels per acre). The mean yield is the average of all the plots within a trial. The CV value, expressed at a percentage, indicates the level of unexplained variability present within the trial. A high CV value indicates a lot of variability existed within the trial not related to normal variations that might be expected between the varieties in the test. High CV values indicate a great deal of variation due to factors other than the genetic variation between varieties. The highest average yield for dryland wheat production was found in Hatcher, followed by TAM 112 and TAM 111 while the lowest average yield was in Fannin, followed by Shocker. The highest variation, as measured by the standard deviation, was found in Hatcher followed by TAM 304 and TAM111 while the lowest variation was found in TAM W-101 followed by Shocker and T81.

A production budget for dryland wheat production system is presented in Table 3. Estimated costs consist of direct expenses and fixed expenses. Direct expenses include seed, fertilizer, custom hire, crop insurance, operator labor, hand labor, diesel fuel, gasoline, repair and maintenance, and interest. Fixed expenses include implement, tractors and self-propelled equipment. Direct and fixed expenses were estimated to be $ 116.58 and $12.80 per acre, respectively, with a total expense of $129.38 per acre.

Methodology

Simulation

The distributions of the net economic returns from various wheat varieties were constructed through the multivariate empirical (MVE) distribution simulation from SIMETAR. The simulation model defined economic returns π_i as:

$$(1)\ \pi_i = P \times \tilde{Y}_i - PC_i$$

where $\tilde{Y}_i$ is the stochastic yield for wheat variety I, P is price for wheat, PC_i is operating costs including seeds, machinery operation, annual operating capital and rental. A stochastic variable in the model, $\tilde{Y}_i$, was used to construct the distribution of net returns for alternative grain production systems. The multivariate empirical (MVE) distribution was used in this study for two reasons. One is that wheat grain yields were found to be highly correlated with each other. The other is that simulated values for prices and yields are truncated variables (always greater than or equal to zero), conditions which the MVE is able to include in its formulation. Parameters for the MVE distribution were determined using historical yield data from the field trials.

A risk model was developed using the production data gathered from Uniform Wheat Variety Trial (UWVT) in Texas. A multivariate simulation was conducted using SIMETAR software to empirically construct the probability distribution of the grain yields for each wheat variety in the experiment. The probability distribution is the primary risk component of the simulation since it quantifies how yields are dispersed about the mean. Based on the observed data, the SIMETAR simulation used standard normal probability distributions for modeling the yields of each variety type. The SIMETAR simulation was successfully validated by comparing simulation output to the field experimental results using t-tests ($P<0.05$) on the mean values of the observed yields and their variance (Table 2 and Table 4). The probability distributions were used, along with the cost data from Table 3, to calculate the distribution of economic returns faced by producers. From that distribution, the mean economic return and its variance were calculated for each variety.

A negative exponential utility function is assumed:

(2) $U(w) = -\exp(-r_a w)$

where *w* is random wealth variables, and r_a is the Pratt-Arrow measure of the absolute risk aversion defined as $r_a = -U''(w)/U'(w)$. The unique characteristic of constant absolute risk aversion (CARA) is that the preferred land-use is not affected by changes (addition and subtraction) to total wealth or income (Grové, 2006). The lower and upper boundary of absolute risk aversion (r_a) is calculated based on the relation between absolute risk aversion and relative risk aversion (r_r) mentioned in Hardaker et al. (2004). The average wealth per acre for wheat production series ranges from $-115.98 to $493.34 with an overall average of around $52.91. Then, the calculated values of lower (hardly risk averse) and upper (very risk averse) boundaries for absolute risk aversion (r_a) with the initial wealth of $3,000 are 0.00016 and 0.0013 corresponding to 0.5 and 4 of relative risk aversion (r_r), respectively.

Direct expected maximization programming (DEMP)

In order to account for the possible portfolio issues, we used direct expected maximization programming (DEMP, Lambert and McCarl 1985) because all distributions of strategies do not follow normality and some strategies are correlated with each other. This nonlinear mathematical programming determines optimal portfolios of land use under the effect of the level of decision maker's risk preferences and changes in price of wheat. A non-linear mathematical programming was used to determine the effect of the level of decision maker's risk preferences on the optimal mix of wheat varieties. The objective function is developed using the direct expected maximization programming (DEMP, Lambert and McCarl 1985) as;

$$(3)\ \max_{x_j} EU = \sum_{i=1}^{n} P_i \cdot U(\sum_{j=1}^{m} x_j c_{ji}) \approx \sum_{i=1}^{n} P_i \cdot (-e^{-r_a \sum_{j=1}^{m} x_j c_{ji}})$$

$$\text{s.t.} \quad \sum x_j = Land,$$

$$x_j \geq 0 \ \forall \ j$$

where x_j is acres of each wheat variety under the optimal land use schedule , c_{ji} is a per acre net farm income distribution of x_j when state of nature i happens, $Land$ is total available farm land. The above objective function is to maximize the expected utility using the negative exponential function subject to the total land availability. The model determines the stochastic efficient set of optimal land use combination over the other land use schedule given the range of risk aversion coefficients (RACs). This model makes it possible for the farmer to make decisions using the stochastically efficient distribution of outcomes under the resource constraint (i.e. land constraint).

Result

The distribution of simulated net return for each dryland wheat variety is shown in Figure 1. The Box Plot dialog box showed that the distribution of net return for all varieties is skewed to the left because the top line segment is longer than the bottom line segment and that most distribution is not symmetrical since the median and mean show up as two lines. Fifty percent of the observe values fall within the box. As expected, the highest expected net return is found in the Hatcher, followed by TAM112.

Optimal portfolios of land use with the direct expected mathematical programming

Optimal portfolios of land use which maximize the expected utility with various levels of decision maker's risk aversion were determined using the direct expected mathematical programming. In addition, risk absolute coefficients (RAC) used for various risk levels (risk neutral, modestly risk averse, highly risk averse). Optimal portfolios of land use for various risk aversion levels are described in Figure 2. Since a risk neutral farmer would maximize expected profits without accounting for risk levels of strategies, optimal portfolio of land for a risk neutral farmer is to choose only one variety, Hatcher. However, as the risk aversion level increases (i.e. modestly and highly risk averse), two varieties (Hatcher and TAM112) begin to compose the optimal portfolio of land use.

When the level of risk aversion is light, only one variety, Hatcher, was included in optimal portfolio of land use as dominant choices. Major strategies in optimal portfolios of land use in the modest level of risk aversion were composition of two varieties, Hatcher and TAM112. This may indicate that more strategies (asset) with less risk are included in optimal portfolios of land use by replacing strategies with higher returns and risk as a farmer is getting more risk averse. The same composition of the portfolio was found in the high level of risk aversion but, more land with TAM112 was found.

Conclusion and Discussion

The simulation and mathematical programming were used to obtain optimal wheat variety selection using the portfolio approach at various risk aversion levels. Results showed that land management practices were significantly affected by changes in levels of risk aversion of decision makers. Including risk preferences in the economic analysis provides additional information that is particular useful with wheat variety selection. In the risk neutral case, there is only one variety in the optimal land management. When risk aversion is included in the analysis, two varieties become the preferred alternatives for optimal land use.

Future research will be required to explore different types of wheat varieties to identify a wider range of production options for producers. This should include investigating other wheat traits (test weight, protein contents) and stochastic components such as rainfall. This could also provide solutions to wheat producers from a wide range of farming systems beyond the Texas Panhandle.

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Table 1. U.S. Acreage of TAMU Wheat Varieties

	Total Planted	TAM111	TAM112	TAM304	TAM105	TAM110	TAM401	Other TAM	Total	%
Texas	5,600,000	840,000	392,000	28,000	224,000	168,000	-	140,000	1,792,000	32
Oklahoma	5,400,000	156,600	43,200	-	-	10,800	10,800	-	221,400	4.1
Colorado	2,500,000	237,500	42,500	-	-	-	-	22,500	302,500	12.1
Kansas	8,800,000	1,020,800	334,400	8,800	-	44,000	61,600	-	1,469,600	16.7
Nebraska	1,550,000	125,550	18,600	-	-	-	-	-	144,150	9.3

Note(s): Texas used 2010 survey data. Survey data for other states was from 2011.

Table 2. Summary Statistics of Yield for Each Variety, 2006-2010, Texas Panhandle

Variety	Bullet	Deliver	Doans	Dumas	Duster	Endurance	Fannin	Fuller	Hatcher	Jackpot	Jagalene
Mean	32.69	30.46	30.56	32.48	34.98	33.79	28.49	34.63	38.43	32.00	32.50
StDev	24.04	22.96	23.47	25.71	24.04	24.24	22.79	25.46	25.95	22.74	24.12
CV	73.54	75.36	76.80	79.16	68.71	71.72	80.02	73.52	67.53	71.04	74.21
Min	4.16	1.82	3.19	0.00	3.41	1.80	1.60	3.29	5.10	2.31	0.00
Median	19.69	23.03	19.29	21.79	25.13	24.30	19.38	21.77	28.71	20.49	23.40
Max	81.67	79.29	87.31	82.37	79.40	74.95	77.66	88.31	92.22	73.40	81.74

Variety	Jagger	Overley	Santa Fe	Shocker	T81	TAM 111	TAM 112	TAM 203	TAM 304	TAM 401	TAM W-101
Mean	31.93	30.80	32.94	28.81	33.74	35.55	36.80	31.59	32.86	29.85	30.90
StDev	23.09	21.56	24.96	21.58	22.47	25.77	23.31	24.70	25.85	23.08	20.80
CV	72.31	69.98	75.80	74.92	66.59	72.48	63.35	78.17	78.67	77.33	67.31
Min	2.60	4.11	3.40	3.60	6.54	0.40	2.35	3.97	1.80	1.24	1.16
Median	20.53	22.91	19.69	17.65	25.18	25.50	27.28	17.21	18.73	19.03	27.27
Max	79.58	71.02	90.87	74.61	75.80	89.46	82.13	79.96	89.40	74.86	67.74

Table 3. Estimated Costs of Dryland Wheat Production

Direct expenses			Unit		
Seed			bu		
	Seed-Wheat	$12.3		1	12.30
Fertilizer			lb		
	ANh3	$0.28		30	8.40
Custom					
	Fertilizer App	$11	acre	1	11.00
	Custom	$20	acre	1	20.00
	Custom Haul	$0.23	lb	75.30	17.32
Crop Insurance					
	Wheat-Dry		acre		15.00
Operator Labor			Hrs		
	Implements	$10.8		0.2764	2.99
	Tractors	$10.8		0.4425	4.78
Hand Labor					
	Implements	$10.8		0.2121	2.29
Disel Fuel			gal		
	Tractors	$2.05		2.2211	4.55
Gasoline					
	Self-propelled	$2.36		2.01	4.74
Repair & maintenance					
	Implements	$3.8	acre	1	3.80
	Tractors	$4.46	acre	1	4.46
	Self-propelled	$0.16	acre	1	0.16
Interest of Op. Cap		$4.79	acre	1	4.79
Total Direct expense					$116.58
Fixed expense					
	Implements	$6.18	acre	1	6.18
	Tractors	$6.38	acre	1	6.38
	Self-propelled	$0.24	acre	1	0.24
Total fixed expense					12.80
Total Expenses					$129.38

Table 4. Validation of the Simulated Yield Multivariate Distribution

Variety	Bullet	Deliver	Doans	Dumas	Duster	Endurance	Fannin	Fuller	Hatcher	Jackpot	Jagalene
	t test of simulated means vs. historical means										
P values	0.967	0.952	0.937	0.993	0.924	0.855	0.955	0.871	0.992	0.941	0.933
Fail/reject H_0[a]	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail
	F test of simulated variances vs. historical variances										
P values	0.415	0.470	0.373	0.457	0.387	0.465	0.441	0.440	0.387	0.427	0.447
Fail/reject H_0[a]	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

Variety	Jagger	Overley	Santa Fe	Shocker	T81	TAM 111	TAM 112	TAM 203	TAM 304	TAM 401	TAM W-101
	t test of simulated means vs. historical means										
P values	0.909	0.959	0.937	0.927	0.941	0.907	0.927	0.953	0.995	0.882	0.867
Fail/reject H_0[a]	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail
	F test of simulated variances vs. historical variances										
P values	0.425	0.434	0.393	0.386	0.395	0.491	0.452	0.379	0.394	0.449	0.400
Fail/reject H_0[a]	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

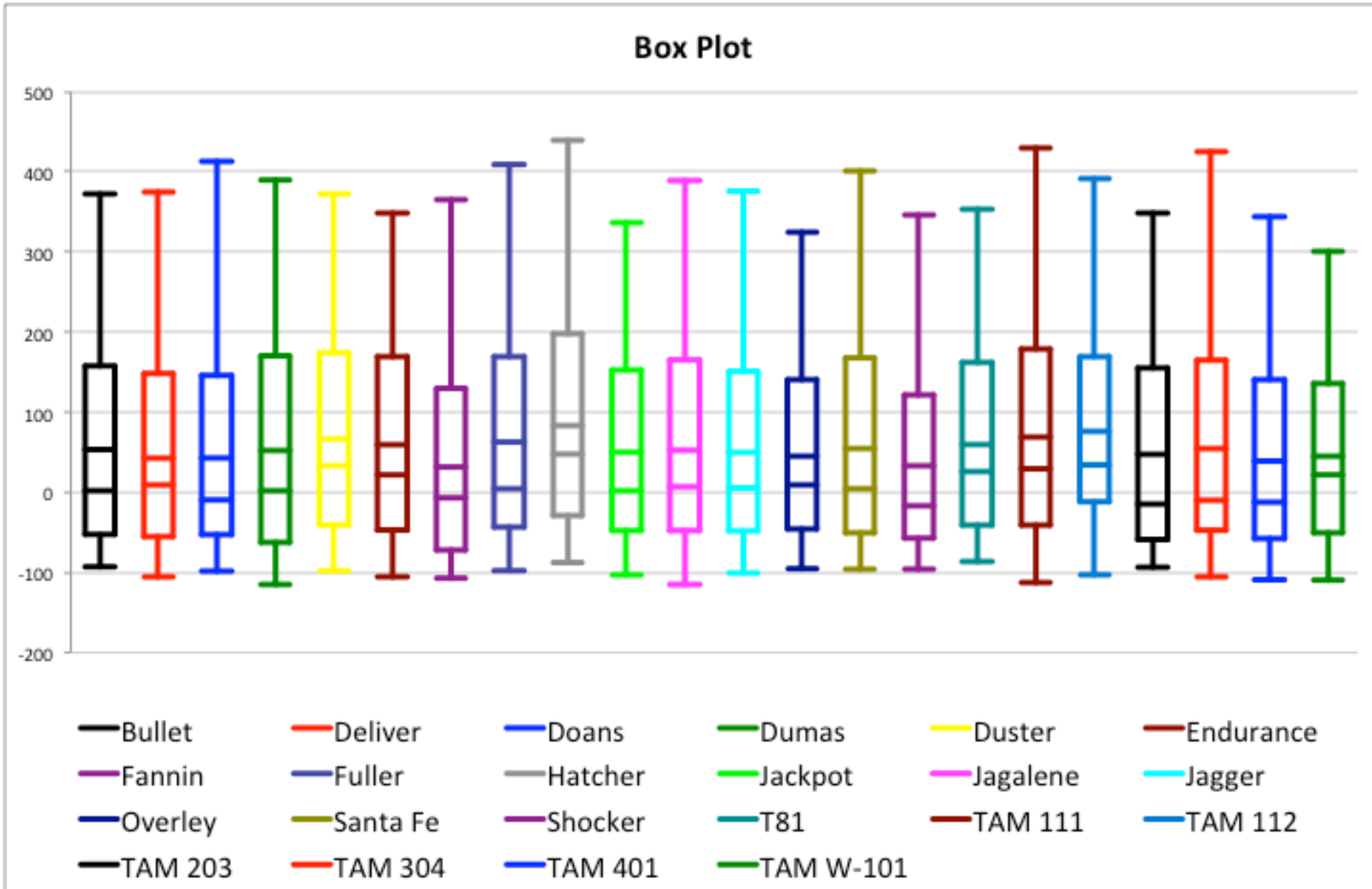

Figure 1. Box Plot of Net Returns of 22 Wheat Varieties

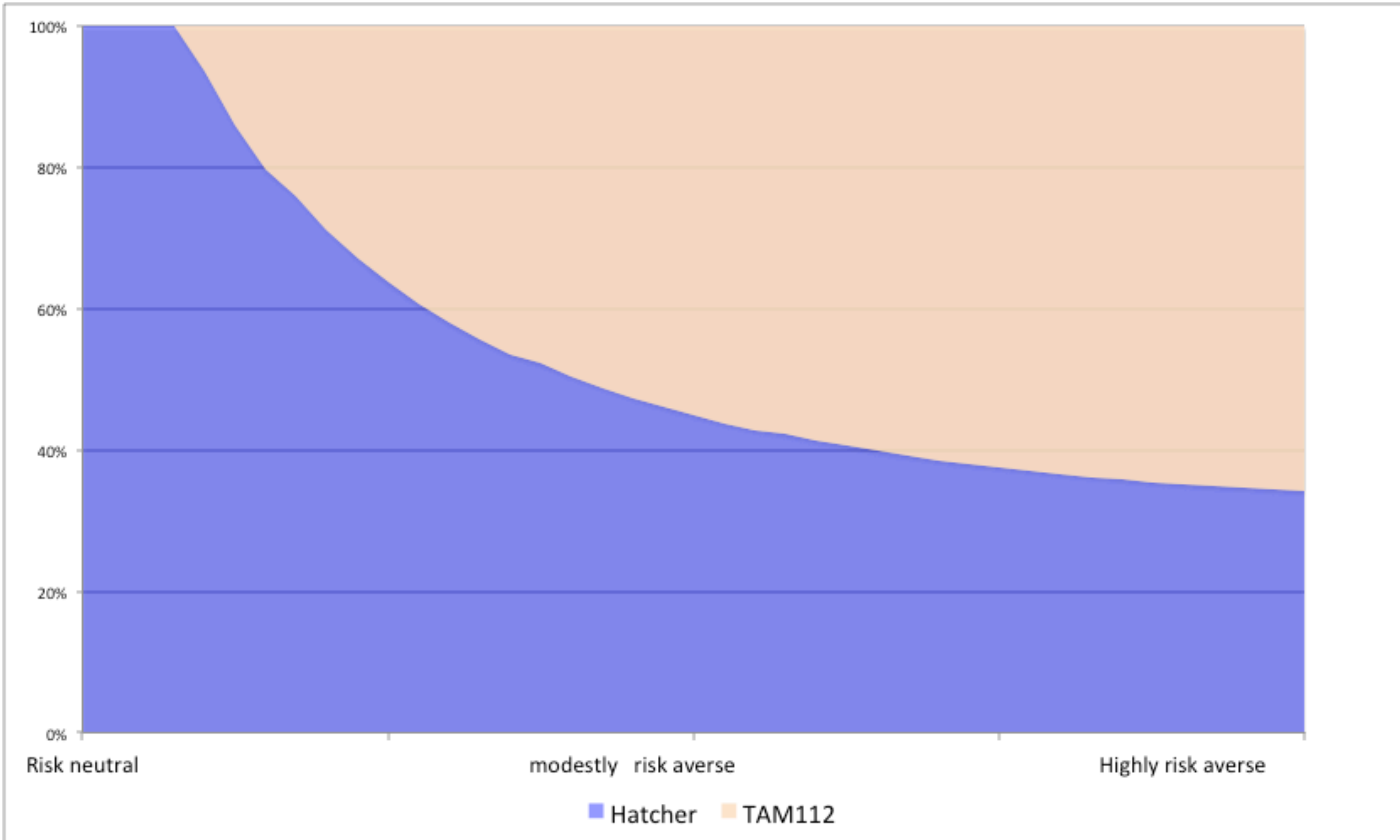

Figure 2. Optimal Portfolio of Land Use for Variety Selection