PORTFOLIO DIVERSIFICATION USING FARMLAND INVESTMENTS

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ABSTRACT

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This study examines the impact of farmland investments on the risk-efficiency of mixed asset portfolios. Traditional asset classes considered available for investment include various equity market indices, commercial REITs, corporate bonds of investment- and sub investment grade, government bonds and treasury bills, corporate bonds, ex-U.S. equity indices, short term interest rate indexes, and commodity investments. Unlevered farmland returns were constructed at the state level as the sum of cash rent and capital gains less property taxes as a fraction of asset values. In addition, a unique, high quality data set comprised of the returns to all managed farmland properties in the NCREIF Farmland Index was also considered. A traditional optimal E-V frontier is first identified considering optimal financial-asset only portfolios in the absence of the farmland asset class. Results show that, relative to financial-asset only portfolios, the inclusion of farmland significantly improves the risk-efficiency of the optimal E-V frontier. To address potential aggregation and smoothing biases, farmland returns are systematically penalized through reduced returns and increased variability. While the mix and shares of farmland investments under these restrictions are reduced, the fundamental result remains that farmland investments significantly improve the risk-efficiency of mixed-asset portfolios.

Key words: portfolio diversification, farmland investments, farm returns

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Introduction

Portfolio diversification has always been a major concern for private investors, financial planners and institutional investors who seek to maximize overall return for a given level of risk, as well as to reduce risk itself. Investors and financial planers traditionally have allocated reasonably constant shares of their positions to general asset categories such as equities, or fixed income securities, and then have selected individual investments within class with some attention to within-class diversification. However, these types of investment strategies have generally ignored real asset classes, and have the potential to be result in significantly risk-inefficient portfolios. These concerns, along with the recent performance of real estate investments have increasingly led investors and fund managers to reconsider investment portfolio construction heuristics, and to increasingly consider formal portfolio balancing tactics including real estate, and to lesser degree, farmland in the set of available investment classes.

In response to these concerns, this study examines the impact of the inclusion of different types of farmland investments to improve a mixed asset portfolio's efficiency. To do so, the study: i) examines whether geographic diversification contribute to improving the performance of a traditional investment portfolio's risk-return profile, ii) assess whether farmland investments should be considered as a separate asset class for a mixed asset portfolio under condition of uncertainty, and if so in what proportion to meet investors' preferences for risk and returns, and iii) assess the sensitivity of the results to different risk and return scenarios for the farmland components as well as for selected scenarios.

This paper extends and generalizes the analysis of farmland investments in institutional portfolio presented in Lins and Sherrick (1992) by expanding the time period, extending the asset classes examined, and by examining cropland investments separately, rather than concentrating only on farmland aggregate investments. An important contribution of the this paper is the inclusion of the NCREIF Farm Indices which allowed to have real scenario that an investor could analyze in terms of farmland investments, since they represent the acquisition and management of existing properties only, wholly-owned, and joint venture investments.

Background

Farmland is by far the dominant asset in the US Agricultural Sector's balance sheet, accounting for approximately three-fourth of the value of all farm assets (Sherrick and Barry, 2003). Farm real estate values are an indicator of the general economic health of the agricultural sector and changes in their values directly affect the equity position of farmers. Questions related to the determinants of farmland values have appeared many times in the literature. A large number of authors have identified a diverse range of factors as important determinants in farmland values. Beginning in 1910, real farm sector asset values increased, reaching a peak in 1915 which was followed by a decline until 1932 when they began to increase again (Featherstone and Baker, 1987). During the 1970's the price of land experienced an explosive appreciation, and during the 1980's a rapid depreciation. Recovery in nominal U.S average real estate values begun in 1987. This variation in U.S. farmland has stirred a great interest to explain price fluctuation following the 50 years of relatively stable farmland prices. Several studies present different explanations that include factors such as returns to farming (Alston and Burt, 1986), capital gain considerations (Mehchar, 1979), credit market constraints and imperfections (Reinsel, Shalit, and Schimitz, 1982), change in expectations (Castle and Hoch, 1982), change in risk (Barry, 1980), non-farmland returns to land (Robison and Lins, 1985), portfolio impact of change in non-farmland investment opportunities (Feldstein,1980), government payments, interest rates (Featherstone, 1987) and urbanization pressure among others (Barnard, 2003).

The desirability of including farmland in an investment portfolio in order to reduce risk has been discussed since at least the early 1980's. Barry (1980) shows that investment in farm real estate at a national or regional level has low risk relative to other assets. Kaplan (1985), Hartzell et al. (1986), and Ziobrowski and Ziobrowski (1997) show that farmland is an attractive asset, and therefore it is expected that optimal mixed asset portfolios include a large proportion of real estate assets with strong diversification among them. They indicate that farmland investments can provide diversification benefits within the portfolio by lowering the risk and by increasing potential returns. Farmland investment gives investors the opportunity to diversify their portfolios into an alternative asset class that behaves differently from the traditional stock indices and bond markets. Most studies show that these results are robust to increases in the estimated variance of returns on farm assets (e.g. Webb and Rubens (1988)).

A large debate has taken place around whether stocks or land provides a better investment profile. In attempting to answer this question, Duffy (2001) compares 50 years of returns to both types of assets using Iowa land returns obtained from Iowa State University and the Dow Jones index. Duffy shows that the conclusion of whether the stock market or land is the best investment depends largely on the period that is being analyzed; it is the stock market the one that appears to have higher returns in most of the 50 years analyzed but there are also some time periods where land investments give the higher returns. Nevertheless the percentage of land purchasers that are classified as investments has increased from 12 percent in 1989 to 27 percent in 2001. One of the main reasons is that land has been used increasingly for non agricultural purposes such as summer houses, hunting camps and recreational purposes. Duffy also points out that investors buy land to diversify their portfolios, and highlights two main points to explain what will happen to the value of farmland in the following years. The first point is the future of government farm programs. He states that the 2002 farm bill might have a strong impact on land values, since most of the net farm income has come from government payments in the past years. The second point is the performance of the stock market; positive effects from investors looking for a "safe" investments as well as negative effects from increased interest rates could take place and the final effect on land values is impossible to predict.

Another concern in the literature has been the identification of the differences between optimizing the farmland portion of a portfolio separately or together with other assets. Using data from 1967 through 1988, Lins and Sherrick showed that farmland returns are negatively correlated with returns to stocks and bonds and positively correlated with inflation, and therefore may be used by investors to reduce as a purchasing power hedge. They find that the minimum variance portfolio in the case where only farmland is included consists of investments in four states, (Vermont, New Jersey, South Dakota and Texas) and will allow the investor to generate an average annual return of 11.8%, with a standard deviation of 4.5%. On the other hand, for the case where a mixed asset portfolio is considered, it was found that only five states enter the optimal portfolios. When farmland only investments are considered such that no more than 10 percent of farmland is allowed to come from one state, then 15 states appear on the frontier of optimal portfolios, although 11 at most enter at a time. Nevertheless, farmland remains as the dominant asset in the portfolios under this scenario. Geographic restrictions on investments led to very similar results. These findings support the inclusion of farmland in a portfolio to reduce the risk and increase return, although no formal

test of the increase in risk efficiency was provided. Hardin and Cheng (2003) showed that the mean-variance portfolio efficiency was improved when using cropland and pastureland class assets. Nevertheless, their sensitivity analysis shows that it is not necessary for cropland to have a positive weight in a mixed-asset portfolio for the creation of equally efficient mixed asset portfolios

In general, the literature concludes that farmland has a number of attractive characteristics that fit the needs of long-term investors in terms of risk/return features, diversification benefits, and inflation hedging potential, thereby providing portfolio managers with the ability to construct portfolios that meet various investment objectives. By investing in various regions, in different crops, and by varying the management style and size of properties, a farmland portfolio may be constructed with significant in-class diversification taking into account that funds are typically allocated to particular classes (e.g. 30% equity, 60% bonds and 10% real state) which are in turn administered by different managers. Farmland investments historically have also shown negative correlation with returns of stocks and bonds. This characteristic potentially makes farmland an attractive diversification tool to balance a portfolio and provide protection from financial and commercial real estate market volatility.

It is also important to recognize that real estate investments have several characteristics that creates difficulty in comparing to or combining with traditional assets such as stocks and bonds. Among these characteristics are low liquidity relative to stocks and bonds, and inability to be standardized. Secondly, transactions cost are much higher for real estate investments, and finally farmland returns are often measured based on estimates of appraisal values of the land in contrast to the market based returns typically employed for bonds and stocks. Still on balance, most recent asset allocation studies have concluded that real estate is underrepresented in the typical investment portfolio. According to the National Council of Real Estate Investment Fiduciaries (NCREIF), pension fund managers typically allocate between 5% and 7% to real estate assets in contrast to evidence that suggests that 10% to 20% allocation for real estate would be more nearly optimal. The results of this study add further to that evidence, and provide general guidance for improving existing portfolios that are currently absent real asset positions.

Methodology and Model Specification

A traditional expected return-risk (E-V) efficiency model is used to obtain the allocations of assets that define portfolios on the risk-efficient frontiers, among which investors then choose a risk-efficient portfolio. The efficient frontier describes the set of portfolios that minimize the level of risk for a given rate of return. The approach is to allocate investment so that the variance of the portfolio is minimized subject to the constraint that the expected return of the portfolio equals a given value, and then parametrically vary this constraint to trace out the frontier. To solve this problem it is necessary to know the variance and covariance structure of the assets being considered. Formally this problem can be stated as follows for the case of two assets.

Let R_1 and R_2 be the return to two different assets and let *"a"* be the fraction of wealth in asset 1. The respective expected values and variances on assets 1 and 2 are represented by $E(R_1)$, $var(R_1)$ and $E(R_2)$ and, $var(R_2)$. Then the problem is to choose *"a"* to minimize the portfolio variance, subject to the constraint that $E(Rp) = m$ where m is some target set, say for example 15 percent. For two assets, the expected return and variance of the return for the portfolio can be defined as:

(1.) $$E(R_p) = \alpha * E(R_1) + (1-\alpha) * E(R_2) = m$$

and

(2.) $$\text{var}(R_p) = \alpha^2 * \text{var}(R_1)^2 + (1-\alpha)^2 * \text{var}(R_2)^2 + 2 * \alpha * (1-\alpha) * \text{cov}(R_1, R_2)$$

In other words, the problem stated above is equivalent to solving:

(3.) $$\underset{\alpha}{Min}\left\{\text{var}(R_p) = \alpha^2 * \text{var}(R_1)^2 + (1-\alpha)^2 * \text{var}(R_2)^2 + 2 * \alpha * (1-\alpha) * \text{cov}(R_1, R_2)\right\}$$

subject to the constraint

(4.) $$\alpha * E(R_1) + (1-\alpha) * E(R_2) = m$$

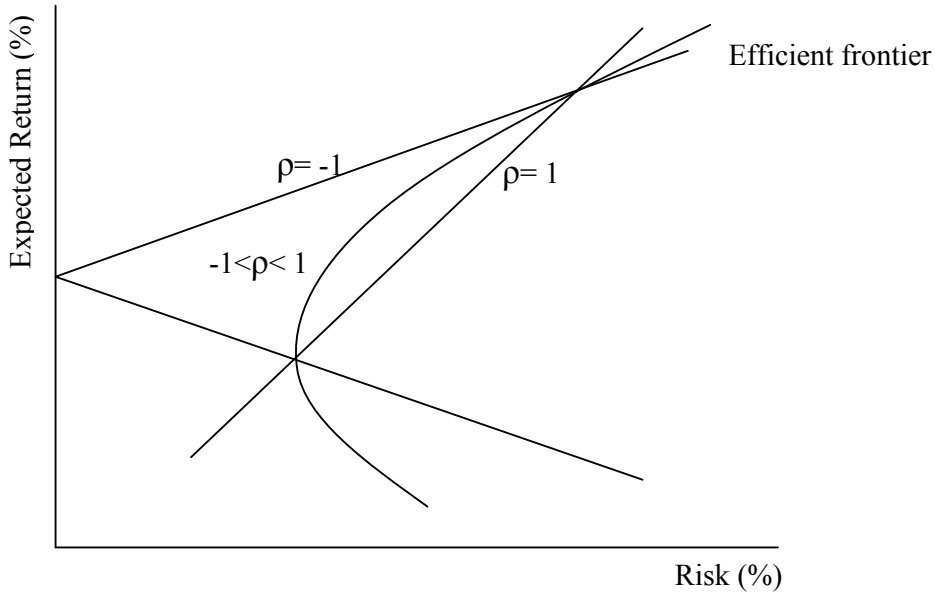
This problem can be generalized for the case of many assets using matrix notation as follows:

(5.)

$$\underset{\omega}{Min}\left\{\text{var}(R_p) = \omega' \sum \omega \right\}$$
$$st. \quad \omega' * E(R_p) = m$$

Where ω represents a vector of the fractions of wealth assigned to each asset, or the vector of weights; and Σ is the variance-covariance matrix of the portfolio. By parametrically varying *m*, the efficient portfolio frontier can be identified and mapped. The location of the portfolio frontier in the mean-standard deviation space depends on the correlation among assets; if assets are perfectly positively correlated (ρ=1) then the portfolio frontier will be an upward sloping straight line. On the other hand, for assets that are perfectly negatively correlated (ρ=-1), the portfolio frontier will be a downward sloping straight line. If the correlation among assets is in absolute terms lower than one (-1<ρ<1), the portfolio frontier will be a hyperbola that will lie between the straight lines described above as shown by Figure 1.

Figure 1: Efficient Portfolio Frontier



Importantly, it has been repeatedly noted that this approach holds only under either one of two possible assumptions with the first being that the returns are elliptically distributed, which means that all linear combinations of possible returns are completely characterized by the first two moments of the distribution; if returns have an elliptical

distribution; all its moments are fully characterized by the mean and variance of the returns[1]. The normal distribution is a particular example of an elliptical distribution and the most commonly assumed in the literature. The second condition under which E-V analysis is considered a valid approach to defining investors' optimal portfolios is that investors have quadratic utility functions, in which case even if the distribution of returns is characterized by higher moments, investors do not care about them. This second assumption has been considered in the literature more unrealistic than the first, since it implies among other things that the amount of money allocated to risky assets decreases as wealth increases. On the other hand the assumption of elliptically symmetric errors has been widely used in the literature; nevertheless it is still important to understand the implications of this assumption. The main consequence this assumption brings to the model is the fact that an investor will be indifferent between two different distributions that have the same mean and variance, regardless of differences in the higher moments. Another important assumption of this model is that investors are price takers; this assumption may not hold if we want to draw conclusions for large investors. Regardless, it is believed that the approach provides useful and valid implications, even if there are violations of strict interpretations of the background assumptions.

Once a particular investment portfolio is constructed or identified, it is necessary to evaluate the relative risk-efficiency of an alternative portfolio to see if, for example, the inclusion of an additional asset class permits a statistically significant improvement in risk efficiency. As gains in risk efficiency can come from either reductions in risk at a given level of return, or increases in returns at a given level of risk, a method is needed that considers both aspects simultaneously. Sharpe's ratio provides such a measure of portfolio risk and return measure, defined as the ratio of the difference between portfolio return and the risk-free asset return to the standard deviation of the portfolio's return. Based on this ratio, Gibbons et al. (1989) build an F-distributed test statistic to evaluate differences between two portfolios mean-variance efficiencies using portfolio dependent Sharpe ratios. The F-test defined by Gibbons et al. (1989) has the following form:

[1] Balvers, R. "Foundations of Asset Pricing", Chapter II

(6.)
$$F = \frac{T\left(T-n-1\right)}{n\left(T-2\right)}W$$

where

(7.)
$$W = \left[\frac{\sqrt{1+S_i^2}}{\sqrt{1+S_j^2}}\right]^2 - 1$$

and T is the number of observations, Sj is the Sharpe ratio for portfolio j , and n refers to the number of investment opportunities available. The null hypothesis that the optimal portfolio is not more efficient than the alternative portfolio under a mean-variance criterion. Following Hardin and Cheng (2003), it is also useful to compare various points along the entire E-V frontier to the naïve portfolio to assess overall improvements in risk efficiency from the optimization rules employed.

Data

The data used in this study consist of returns for different asset classes and various individual returns series within each asset class. Included classes (specific data series) are government bonds and treasury bills (*TBCM1y, TBsm3m, T-10y, SLbond*), common stocks (*Dow Jones, S&P500 and NYS*E), corporate bonds (*Baa, Aaa, CP3M and CD3M*), *MSCI* equity indices *(EAFE, EUROPE, PACIFIC, North America*), interest rates (*BBALibor and ED3M*); real estate investment trusts (*Equity , Mortgage and Hybrid REITs*), commodity indices (*Reuters, CRB Spot and CRB Futures*), cash rents for cropland, and NCREIF farmland indices. The historic data cover the period from 1972 through 2003 with the exception of the NCRIEF indices which cover the period of 1991 to 2003. Although in most of the cases, the original observation periods of the data are monthly, the returns are in all cases transformed to an annual geometric basis. Table 1 describes the average annual returns, standard deviation and the minimum and maximum values for the traditional assets. When examining this table, *North America* equity index, *Equity REITS* and *NASDAQ* show the highest mean returns while *BBALibor* and *SLBond* have the lowest standard deviation for the period analyzed.

Table 1: Basic Statistics for Different Assets Types

Variable	Observations	Mean	Std. Dev.	Min	Max
SP500[1]	44	0.06808	0.15743	-0.3527	0.2935
DOWJONES[1]	44	0.06213	0.15469	-0.3227	0.32448
NASDAQ	19	0.11016	0.28727	-0.499	0.61834
NYSE[2]	37	0.07275	0.15833	-0.3607	0.31063
EAFE[2]	34	0.0755	0.23221	-0.6054	0.53027
EUROPE[2]	34	0.07232	0.18855	-0.3127	0.54992
PACIFIC[2]	34	0.08248	0.2778	-0.4301	0.70467
NORTH AMERICA[2]	34	0.10713	0.16513	-0.3095	0.31534
ALLREITS[3]	32	0.09627	0.20474	-0.5487	0.3986
EQUITY REITS[3]	32	0.12143	0.15663	-0.2408	0.38926
MORTGAGE REITS[3]	32	0.07228	0.29047	-0.6038	0.57292
HYBRID REITS[3]	32	0.08274	0.27983	-0.7386	0.44592
BBALIBOR	18	0.05655	0.02011	0.01271	0.09294
ED3M[4]	33	0.07312	0.03455	0.01142	0.16995
TBCM1Y	44	0.06311	0.02818	0.01244	0.14778
TBSM3[4]	44	0.05714	0.02651	0.01011	0.14025
T10Y[4]	44	0.07133	0.0252	0.03879	0.13911
SLBOND[4]	44	0.06111	0.02051	0.03162	0.11659
CD3M[4]	39	0.06827	0.03021	0.01151	0.16122
BAA[4]	44	0.08943	0.02819	0.0483	0.16113
AAA[4]	44	0.07947	0.02476	0.04258	0.14171
CP3M	33	0.06867	0.03083	0.0111	0.1534
REUTERS[5]	43	0.02668	0.15086	-0.1719	0.602
CRBFI[5]	44	0.02126	0.11672	-0.1909	0.38939
CRBSPO[5]	44	0.02375	0.11179	-0.1446	0.44811
CPI[1]	44	0.04195	0.029	0.00669	0.12482
PPI[1]	44	0.03382	0.04711	-0.0613	0.18968

[1] Source: Financial Forecast Center (www.forecasts.org)
[2] Source: Morgan Stanley Capital International Inc web site (www.msci.com)
[3] Source: National Association of Real Estate Investment Trusts
[4] Source: H.15 release of the Federal Reserve
[5] Commodity Research Bureau data base

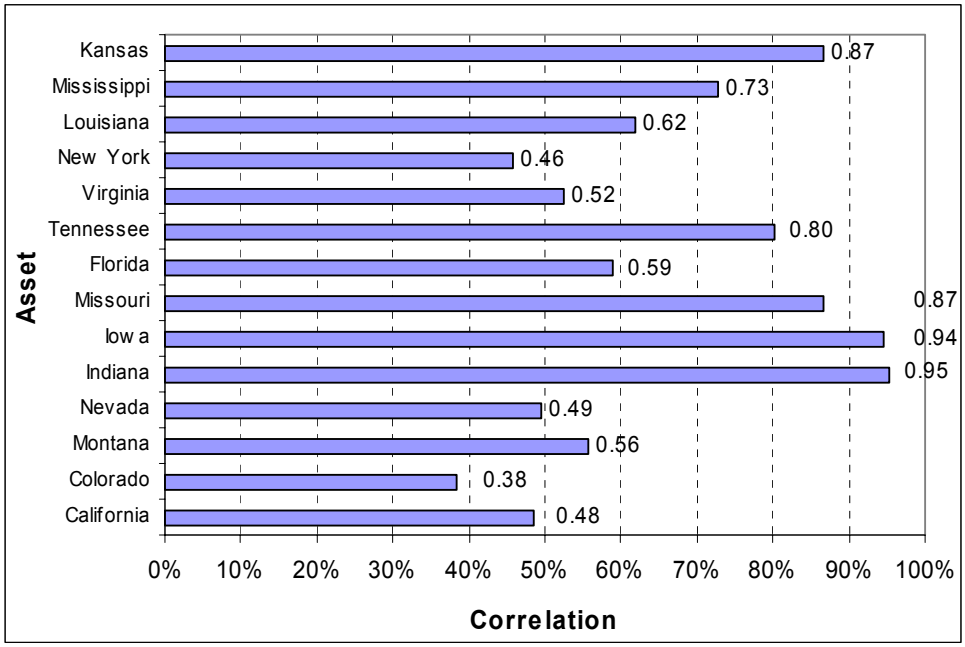
The land values data for the year 1969 to 2003 were obtained form the National Agricultural Statistics Service (NASS). Cash rent estimates were obtained from the USDA Economics and Statistics System for the same period.[2] To calculate the annual returns on the annual returns were calculated by adding cash rents and capital gains as a percentage of land value, and subtracting property taxes as a rate for farm real estate.[3] Note that since the only

[2] http://usda.mannlib.cornell.edu/
[3] The last five year of the tax time series were missing the average of the last three years available was used to estimate them and complete the series. The variation in previous year was insignificant.

farmland values where obtained, the assumption that the farmland and cropland land appreciation rates are similar, is required.

When examining the annual returns (Table 2), it is clearly that the cropland returns are quite similar between states. The majority of the states have on average relatively high returns on cropland and a moderate standard deviation; Colorado, Missouri, Montana, Washington have the highest returns of all which are above 12%. New York, Oregon and Tennessee show the lowest standard deviation with level below 6.5% . The correlation of Illinois's return with other states in the Corn Belt region as well as with the other regions is very high, as shown in Figure 2.[4] The correlations among the Lakes States are still high but lower than the correlation among the Corn Belt States but as strong as the members of the Northern Plains States. The Mountain Region has on average the lowest correlations among all the subgroup; on average Missouri and Tennessee present the highest correlations with the other states, Arizona and New Jersey show the lowest ones.[4]

Figure 2: Correlation Returns between Illinois and Other States



[4] The geographic areas used correspond to the USDA classification of different production regions

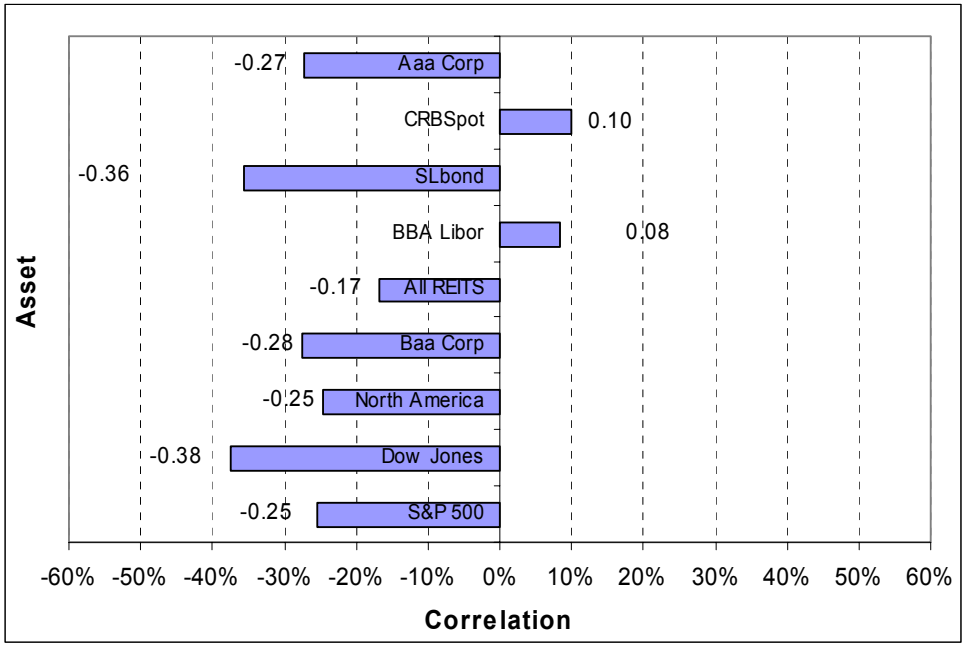
Table 2: Basic Statistics for Cropland Returns by State

Variable	Years	Mean	Std. Dev.	Min	Max
Alabama	35	0.1141	0.0739	-0.0233	0.2711
Arizona	35	0.1124	0.1694	-0.0792	0.9576
Arkansas	35	0.1123	0.0818	-0.0907	0.2880
California	35	0.0898	0.0767	-0.0799	0.2964
Colorado	35	0.1441	0.0871	-0.0317	0.3931
Delaware	35	0.0900	0.0734	-0.1052	0.2622
Florida	35	0.0829	0.0689	-0.0180	0.2841
Georgia	35	0.1115	0.0729	-0.0372	0.3022
Idaho	35	0.1143	0.0745	-0.0852	0.2620
Illinois	35	0.0957	0.1012	-0.2243	0.3573
Indiana	35	0.1077	0.1001	-0.1333	0.3453
Iowa	35	0.1088	0.1216	-0.2518	0.3623
Kansas	35	0.1038	0.0838	-0.1166	0.2744
Kentucky	35	0.1147	0.0680	-0.0291	0.2520
Louisiana	35	0.0918	0.0970	-0.2228	0.2696
Maine	35	0.1122	0.0667	-0.0083	0.2623
Maryland	35	0.0762	0.0745	-0.0894	0.2372
Michigan	35	0.0924	0.0763	-0.0878	0.2815
Minnesota	35	0.1183	0.1117	-0.1769	0.3033
Mississippi	35	0.1137	0.0898	-0.0805	0.2974
Missouri	35	0.1233	0.0862	-0.1561	0.3359
Montana	35	0.1394	0.0808	-0.0445	0.3176
Nebraska	35	0.1186	0.1027	-0.1951	0.3174
Nevada	35	0.1080	0.0938	-0.1141	0.3469
New Mexico	35	0.0886	0.0920	-0.1076	0.3043
New York	35	0.0905	0.0618	-0.0040	0.2730
North Carolina	35	0.0964	0.0688	-0.0539	0.2729
North Dakota	35	0.1192	0.0943	-0.1095	0.3758
Ohio	35	0.0975	0.0897	-0.1616	0.3020
Oklahoma	35	0.0890	0.0766	-0.1365	0.2223
Oregon	35	0.1180	0.0632	-0.0613	0.2316
Pennsylvania	35	0.0827	0.0780	-0.0948	0.2538
South Carolina	35	0.0902	0.0708	-0.0657	0.2596
South Dakota	35	0.1160	0.0824	-0.1526	0.3015
Tennessee	35	0.1160	0.0653	-0.0367	0.2498
Texas	35	0.0990	0.0767	-0.1074	0.2762
Utah	35	0.1020	0.1050	-0.0896	0.3614
Vermont	35	0.0969	0.0533	-0.0172	0.2013
Virginia	35	0.0962	0.0738	-0.0877	0.2847
Washington	35	0.1308	0.0697	-0.0336	0.2863
West Virginia	35	0.1077	0.0907	-0.0992	0.3169
Wisconsin	35	0.1151	0.0851	-0.1035	0.2381
Wyoming	35	0.1056	0.0756	-0.0739	0.2776

The negative correlation of farmland with the stocks indices, as well as the low correlation of farmland with *REITs* indices makes farmland investment attractive for portfolio

diversification or for volatility reduction. Figure 3 show the correlation between Illinois cropland returns and other financial assets. Illinois return are negatively correlated with the majority of the traditional assets with the exception of *CRBSpot* and *BBALibor*.

Figure 3: Correlation Returns between Illinois and Traditional Assets



The NCREIF farmland indices were obtained from the National Council of Real Estate Investment Fiduciaries. The NCREIF Index is an index of the quarterly total returns to the commercial farm real estate properties held for tax-exempt institutional investors by the members of NCREIF. Calculations are based on quarterly returns of individual properties before the deduction of funds or portfolio-level assets or investment management fees.[5] It includes separate reporting of the "total returns" and the two components which make up the total return; “income return” and “capital return”. The NCREIF Index is intended to convey information relevant to quantifying the quarterly investment performance of the population of properties held by NCREIF members for institutional investors such as pension funds. Sold properties are removed from the data base quarterly, thus only historical data remains. The value of each property is calculated by real estate appraisal methodology. The risk of the NCREIF indices is very low as evidenced by the relatively low standard deviation of all assets. The returns from the NCREIF indices are similar to the crop returns by state but with a

[5] All properties have been acquired at least in part, on behalf of tax-exempt institutions and held in a fiduciary environment

clearly lower risk; the average return is approximately 8 % with an average standard deviation of 3 %. The average correlation among NCREIF indices is positive it is very low. Cropland return as well as with the NCREIF indices are negatively correlated with PPI and the CPI used proxies for inflation; therefore farmland investment can be employed as a hedge mechanism against inflation.

Traditional Asset Only Optimal Investment Portfolios

The following section considers only investment on traditional assets such as stocks, bonds, and the more frequently used real estate indices. Table 3 shows the optimal portfolio allocation using only traditional assets. Note that 11 out of the 25 initial assets enter the frontier. The highest risk return is achieved when 100% is invested in Equity REITs with a value of 12.1% and a standard deviation of 15.4%. As the risk and return are reduced, NASDAQ and Baa enter the portfolio; subsequently CRBSpot, BBALibor and Mortgage REITs enter as well. The minimum standard deviation portfolio consists of investments in seven assets, and allows the investors to make a 5.6% average annual return with a risk of 1.3%. The NASDAQ Index and Baa bonds remain in the portfolio at all return levels except for the highest one. BBALibor dominates the portfolio for lower risk values up to 7% of risk return. SLBonds and CRBFut are present only for the low risk cases but in relative high proportions, contrary to the Baa bonds which dominate the portfolios from middle to high levels of risk-return. An ex-post test was conducted for the traditional asset to verify that the optimal portfolio is more efficient than the naïve portfolio, where all the assets enter the portfolio in the same proportion. The test shows that the increase of efficiency is evident when the portfolio is optimized for low and middle returns. Using an equally weighted portfolio reduces the risk efficiency for low as well as for middle values of standard deviation. As the risk of the portfolio increases, the benefits of the optimized portfolio over the naïve portfolio become.

Farmland Optimal Investment Portfolio Analysis

To estimate optimal farmland portfolios, several specific scenarios are defined. The first corresponds to the case where optimal portfolios are exclusively formed by farmland investments and the second scenario corresponds to the case where optimal portfolios include cropland investments or NCREIF Farm indices as part of a mixed farmland asset portfolio. The first scenario is intended to identify investments on croplands as a separate investment class to be managed independently within the portfolio. Once the meaningful groups are isolated, they can be included in conjunction with the traditional

financial assets to find the optimal mixed asset portfolios. Furthermore, to restrict the analysis to meaningful regions most likely to be considered by investors, the forty-four available individual state returns were ordered according to the value of the state's production of crops, vegetables, fruits and cotton. Only states in the upper 50th percentile are used in the subsequent analysis. This restriction is imposed to focus only in the areas where agriculture production is a central activity, and where it would be more likely that farmland would be available to an interested investor. The results are presented for the minimum variance portfolio, and then in intervals of 1/30 of the overall range of the expected return up to the highest available single return in the available investments. The optimal portfolio allocation of cropland formed from 25 states is provided inTable 3: Efficient Portfolio – Traditional Assets

	Portfolios													
E(Rp)	5.6*	5.9*	6.3*	6.6*	7.0*	7.3*	7.7*	8.3*	8.7*	9.0*	9.7*	10.1	10.4	11.1
St. Dev.	1.3	1.3	1.4	1.5	1.6	1.8	1.9	2.3	2.5	2.8	4.4	5.8	7.2	10.3
NASDAQ	1.2	1.4	1.5	1.6	1.6	1.5	1.4	1.4	1.5	1.6	4.0	5.3	6.5	9.1
Equity REITS	0.0	0.0	0.0	0.0	0.0	1.1	2.2	2.9	2.8	3.0	21.8	31.8	41.7	61.6
Mortgage REITs	2.9	2.9	2.8	2.5	2.2	1.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HybridREITs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BBALibor	66.7	67.6	65.6	56.9	48.3	40.8	33.4	16.5	7.5	0.0	0.0	0.0	0.0	0.0
SLBond	21.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CD3M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baa	0.0	11.1	22.5	32.3	42.0	50.2	58.2	76.4	86.1	94.9	74.2	63.0	51.7	29.3
Reuters	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRB Fut	1.9	1.3	1.1	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRBSpot	6.2	6.5	6.4	6.0	5.5	5.1	4.3	2.7	2.0	0.6	0.0	0.0	0.0	0.0

* Statistically significant improvement in portfolio efficiency over the naïve portfolio (95% confidence level)

Table 4

Table 4. Overall, 25 states were considered but only seven entered in the optimal portfolio. Even though three states from the Mountain Region entered the portfolio, there is not a clear geographic dominance in the result as the optimal frontier includes investments in four different geographic areas. The highest expected return is obtained when 100% of the portfolio is invested in Colorado where the production value is concentrated in grains,

oilseeds, dry beans, and dry peas. The annual return is 14.4% with a standard deviation of 8.6%; return that is dominated by the capital gain component. As the expected return and risk were lowered Montana and Tennessee entered in the portfolio, and then Nevada, Virginia and New York and finally California. The last three states differ from the Mountain States in terms of geographic location as well as the agricultural production, which is concentrated in nursery, greenhouse, floriculture, sod, fruits, tree nuts, and berries. The minimum expected return as well as the lowest standard deviation is obtained when investing in those seven states with a resulting average returns of 11.2% with a 4.9% of standard deviation. A comparison between the optimal portfolio and a naïve diversification strategy was also conducted. The geographic diversification showed no statically significant improvement in portfolio efficiency over the naïve portfolio, a result that is similar to Hardin et al. (2002). The lack of statistically difference between optimized and naïve portfolio allows the use of an equal weighted index to analyze a mixed asset portfolio.

NCREIF Farmland Indices are next examined for their role in constructing risk-efficient portfolios. NCREIF Farmland Indices are available both for income generating farms and for all farms; for this paper only NCREIF indices for all farm are considered.

Table 3: Efficient Portfolio – Traditional Assets

	Portfolios																	Naïve
E(Rp)	5.6*	5.9*	6.3*	6.6*	7.0*	7.3*	7.7*	8.3*	8.7*	9.0*	9.7*	10.1	10.4	11.1	11.4	11.8	12.1	6.7
St. Dev.	1.3	1.3	1.4	1.5	1.6	1.8	1.9	2.3	2.5	2.8	4.4	5.8	7.2	10.3	11.8	13.4	15.4	6.3
NASDAQ	1.2	1.4	1.5	1.6	1.6	1.5	1.4	1.4	1.5	1.6	4.0	5.3	6.5	9.1	10.4	11.7	0.0	9.1
Equity REITS	0.0	0.0	0.0	0.0	0.0	1.1	2.2	2.9	2.8	3.0	21.8	31.8	41.7	61.6	71.6	81.5	100.0	9.1
Mortgage REITs	2.9	2.9	2.8	2.5	2.2	1.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1
HybridREITs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1
BBALibor	66.7	67.6	65.6	56.9	48.3	40.8	33.4	16.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1
SLBond	21.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1
CD3M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1
Baa	0.0	11.1	22.5	32.3	42.0	50.2	58.2	76.4	86.1	94.9	74.2	63.0	51.7	29.3	18.0	6.8	0.0	9.1
Reuters	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1
CRB Fut	1.9	1.3	1.1	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1
CRBSpot	6.2	6.5	6.4	6.0	5.5	5.1	4.3	2.7	2.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1

* Statistically significant improvement in portfolio efficiency over the naïve portfolio (95% confidence level)

Table 4: Efficient Portfolio when Assets Classes are Restricted to Cropland – 50% Upper Quintile of Production Values

	Portfolios																	Naïve
E(Rp)	11.2	11.4	11.6	11.8	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.2	14.4	11.2
St. Dev.	4.9	5.0	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.8	6.0	6.2	6.5	6.8	7.1	7.6	8.6	5.1
California	10.1	7.8	5.5	3.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Colorado	18.7	20.3	22.0	23.7	25.3	27.2	29.3	31.4	33.0	34.2	36.1	40.7	45.4	50.0	54.6	67.6	100.0	14.3
Montana	15.0	15.8	16.5	17.2	18.0	18.6	19.1	19.6	20.9	23.2	25.9	29.3	32.8	36.2	39.7	32.4	0.0	14.3
Nevada	4.6	4.9	5.3	5.6	5.9	5.7	4.9	4.1	2.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Tennessee	7.7	10.7	13.4	16.3	19.3	22.5	26.0	29.5	33.2	37.0	38.0	29.9	21.9	13.8	5.7	0.0	0.0	14.3
Virginia	17.4	17.0	17.0	16.8	16.5	15.7	14.4	13.2	9.9	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3
New York	26.5	23.5	20.3	17.2	14.2	10.4	6.3	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3

The geographic areas correspond to the USDA geographic area definitions; this classification allows to maintain contiguous states and to group similar types of agriculture, soil types and climatic conditions that affect inherent risk associated with agricultural production. Table 5 shows the optimal portfolio when all properties farm indices are considered. Note that four of the six regions enter in the E-V frontier. The Delta region dominates the portfolio for the low levels of risk-return while the Corn Belt region for the higher levels of risk-return. The highest risk-return occurs when 99.96% of the portfolio is invested in the Corn Belt region and only 0.4% in Delta region. The annual return is 9.12% with a standard deviation of 4.39%. Corn Belt and Delta regions compete to each other alternating the dominant position all along the frontier. Moving down on the risk- return level more regions enter in the optimal portfolios increasing the diversification in terms of geographic location. It is clear that the maximum geographic diversification is achieved at the lowest level of risk-return; even though the Delta region dominates the portfolio, the other participant states have similar weight on optimal portfolio. The minimum expected return is 7.32% with standard deviation of 0.59%. These results show the advantages of using NCREIF indices instead of cropland returns when diversifying cropland portfolios alone, since the risk associated with the former assets is considerably lower than the risk associated with cropland investment. The comparison of Sharpe ratios between the optimal portfolio and the naïve portfolio indicates that portfolio efficiency is improved relative to a naïve portfolio only for low and upper risk-return regions of the frontier.

Table 5: Efficient Portfolio when Assets Classes are Restricted to NCREIF Farmland Index - All Properties without Restrictions

	Portfolios									Naïve
E(Rp)	7.32*	7.54*	7.77*	7.99*	8.22	8.44	8.67	8.89	9.12*	6.89
St. Dev.	0.59	0.61	0.66	0.73	0.89	1.50	2.41	3.39	4.39	1.27
Corn Belt	5.45	5.51	5.57	5.63	13.65	33.74	55.81	77.89	99.96	25.00
Delta States	66.89	68.56	70.24	71.91	80.01	66.26	44.19	22.11	0.04	25.00
Southeast	14.43	10.21	5.99	1.77	0.00	0.00	0.00	0.00	0.00	25.00
Mountain	13.22	15.72	18.21	20.70	6.33	0.00	0.00	0.00	0.00	25.00

* Statistically significant improvement in portfolio efficiency over the naïve portfolio (95% confidence level)

Cropland Investment as Part of a Mixed Asset Portfolio

The previous section considered only cropland investment and traditional asset investment as separated groups. This section concentrates on the effect of land investment on a mixed asset portfolio using cropland returns. The analysis is divided in three parts. The first considers a mixed asset portfolio formed with traditional assets and cropland returns by states and regions. The second one considers cropland investment in a mixed portfolio under specific restrictions, and the third and final part of this analysis looks at the sensitivity of the results to changes in the expected return and risk of the portfolio.

Cropland has a low or negative correlation with other assets indicating a possible risk reduction when including cropland returns in a mixed asset portfolio. **Error! Reference source not found.**Table 6 shows the optimal portfolio when cropland returns are allowed to compete against traditional assets without any restriction in terms of individual participation or composition. The highest risk-return of 14.4% with a standard deviation of 8.6% was obtained when investing 100% in cropland, specifically in Colorado. As the return is decreased, Montana, Tennessee, North America equity index, and then Missouri, Virgina, Baa and Aaa corporate bonds, Equity REITs, SLBond, Dow Jones, BBALibor enter the portfolio; the minimum risk-return portfolio is obtained when investing 92.9% in traditional assets and only 7.4% on cropland; the portfolio is dominated by BBALibor and SLBond. Whenever cropland is included, it is always present in the frontier and dominates the portfolio for higher levels of risk-return. For low risk returns, the participation of cropland is reduced but still remains above the 7%. The introduction of cropland returns into the portfolio is expected to change the composition of the portfolio since the covariance matrix is altered compare to the covariance matrix of individual groups. However it is surprising to see that composition of the portfolio in terms of traditional assets remains very similar to the case where only traditional assets are considered. The results for the efficiency test over the naïve portfolio indicates that there is no statistically significant improvement in the portfolio efficiency over the naïve portfolio.

Investors usually do not allocate high proportions of their assets to cropland and/or real estate to avoid concentration problems and idiosyncratic risk. Thus individual upper bounds are imposed for each one of the considered assets. A cropland investment in a specific state can not exceed 25% of the entire portfolio, neither any single real estate investment such as REITs indices nor any traditional asset. However liquidity issues of the portfolio are

always a concern for the investors, thus an additional restriction is considered to account for this fear; no more than 25% of the total investment of cropland in the portfolio could come from any state. Even though REITs indices are more liquid than farmland investment, there are still considered real estate investments with lower liquidity than the traditional assets. Thus, a similar restriction of maximum 25% of the total investment is imposed on investment in REITs. The optimal portfolios representing the efficient frontier that takes into account these restrictions are presented in **Error! Reference source not found.**Table 7.

Even with a all this restriction for individual state investment in cropland and for overall cropland investment, farmland is always present in the portfolio; the same states that entered the portfolio when optimizing them separately enter in this case with the exception of California and Louisiana. The highest risk-return is obtained when 25% of the portfolio is invested in cropland and 75% in traditional assets. As the return is reduced the participation of cropland decreases but still always remains above 10% of the entire portfolio. In general, the risk of the portfolio increased and the expected return decreased compared to the lowest risk-return portfolio in the unrestricted case. The number and weights on the portfolios from participating states changes as the risk decreases, however the frontier always has an important participation of real estate, either from cropland or *REITs*. At the lowest risk, return is 7.3% with a standard deviation of 1.4%; with five states entering the portfolio. As the return is increased New York and Mississippi abandoned the frontier before the constraint of a maximum of 25% of the total portfolio invested in cropland becomes binding. The portfolio's composition in terms of traditional assets does not change significantly compared to the unrestricted case. *BBALibor*, *Aaa* bonds and *SLBond* Index still dominate the portfolio along the lower range of returns. The middle range of risk return is dominated again by *Baa* and *Aaa* bonds as well as *SLBond* while the higher risk returns are dominated by North America equity index, Equity *REITs* and *Baa* bonds.

To test the sensitivity of the results to changes in the levels of variance in the returns from the historic data, selected cases are analyzed after imposing penalties the variance and levels of returns of both farmland and real estate investments. First the levels of the expected return were decreased by 10%, second the variances of the returns were increased by 10%, and finally third both expected return and variance of the return were changed simultaneously. To be able to compare the results with the results without any change in the returns and their variances, the same portfolio restrictions are applied. In general for the

three cases, the results in terms of portfolio composition did not change dramatically compared to the results where no parametrically changes were imposed. Cropland is likely to remain a major component of the optimal portfolios even when the risk profile is significantly worsened. The result for the case where both variance and return were changed simultaneously are reported in Table 8. Cropland investment is always present in the portfolio; the same states that entered the portfolio before remained in the frontier after changes in the level of return and their variances were imposed. The participation of cropland is slightly reduced compared to the unrestricted case for low risk-return levels. In general the risk of the portfolio increases and the expected returns decrease compared to the unrestricted case. The composition and number of participating states as well the composition in terms of traditional assets change in decrement of farmland investments and in favor of the traditional assets. These results suggest that the inclusion of farmland in the optimal portfolio is consistent even after major parametrical changes are produced on returns and variance of portfolios.

NCREIF Farm Index Investment as Part of a Mixed Asset Portfolio

In this section NCREIF Farmland Indices are examined for their role in constructing risk efficient portfolios. NCREIF Farmland Indices are available both for income generating farms and for all farms; these two classifications are also available in a more disaggregated form, by geographic areas and property subtype. A first attempt to obtain optimal portfolios for NCREIF indices shows that the results in either case are very similar. Therefore only the geographically disaggregated set (NCREIF All Properties) was analyzed. This section first considers investment in NCREIF properties as a separate investment class to be managed independently within the portfolio. The second part of the analysis examines the effect of investment on mixed asset portfolio using NCREIF Indices. The third part of the analysis conducts a sensitivity analysis for the result of the mixed asset portfolio.

Table 9 shows the optimal portfolio when all properties geographic regions are considered. Note that four out of six regions enter in the E-V frontier. The Delta region dominates the portfolio for the low levels of risk-return while North America equity index for the higher levels of risk-return. The highest risk-return occurs when 99.96% of the portfolio is invested in North America equity index only 0.4% in Baa corporate bonds. The annual return is 10.7% with a standard deviation of 16.2%. Moving down on the risk- return level

more regions enter in the optimal portfolios increasing the diversification in terms of geographic location.

Table 6: Cropland Allocation in a Mixed Asset Portfolio without Restrictions

	Portfolios																			Naïve
E(rp)	6.5	6.9	7.3	7.7	8.1	8.5	8.9	9.3	9.7	10.1	10.5	10.9	11.6	12.0	12.4	12.8	13.2	13.6	14.0	14.4	9.5
St. Dev.	1.2	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.4	2.5	3.0	3.0	3.0	3.8	4.5	4.7	5.3	6.0	7.3	8.6	3.9
S&P500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Dow Jones	1.3	2.1	2.1	2.7	0.0	3.3	0.9	1.0	2.4	0.6	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	4.2
North America	0.0	0.0	0.1	0.0	2.7	3.2	4.6	5.5	5.0	5.8	4.5	9.9	7.5	1.7	15.9	12.3	13.9	13.0	0.0	0.0	4.2
All REITS	0.8	0.5	0.7	0.0	0.4	0.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	4.2
BBALibor	32.8	22.9	20.8	14.4	12.9	8.7	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
T-10y	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
SLbond	52.6	60.1	58.9	56.7	55.8	52.8	51.7	48.7	43.0	41.6	37.5	23.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Baa	0.0	0.0	0.2	3.7	4.0	3.6	6.1	10.4	9.1	8.8	7.9	11.6	43.3	29.4	9.3	12.3	2.0	0.0	0.0	0.0	4.2
Aaa	0.0	0.0	0.1	1.9	1.8	0.5	1.6	3.2	0.3	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	4.2
CRBSpot	5.1	4.4	3.0	2.4	1.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	4.2
California	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	4.2
Colorado	0.0	0.0	3.1	3.8	5.3	7.6	7.9	9.3	13.9	15.0	18.0	17.3	18.5	24.5	28.6	32.3	37.0	45.2	54.3	100.0	4.2
Montana	0.0	0.0	0.2	0.0	0.9	2.9	4.0	5.4	9.1	10.1	12.5	13.6	15.6	20.6	24.1	29.3	33.8	39.5	43.2	0.0	4.2
Nevada	0.3	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	4.2
Illinois	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	4.2
Indiana	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	4.2
Iowa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	4.2
Missouri	2.4	5.4	5.8	5.5	5.8	6.7	6.3	4.4	6.1	6.6	7.7	5.3	0.0	2.3	3.9	0.0	0.0	0.0	0.1	0.0	4.2
Florida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	4.2
Tennessee	0.0	4.1	4.7	7.4	7.8	8.4	9.3	10.2	11.1	11.4	11.9	12.8	15.0	16.7	18.0	13.8	13.4	2.2	0.5	0.0	4.2
Virginia	0.0	0.0	0.0	1.6	1.5	0.8	1.5	1.7	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	4.2
New York	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Louisiana	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Mississippi	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2

Table 7: Cropland Allocation in a Mixed Asset Portfolio with Restrictions

	Portfolios										
E(rp)	7.3	7.7	8.1	8.5	8.9	9.3	9.7	10.1	10.5	10.9	11.3
St. Dev.	1.4	1.4	1.4	1.6	1.7	1.9	2.0	2.1	2.7	4.0	7.9
DowJones	3.2	2.7	3.7	0.0	3.0	0.0	0.2	0.0	0.0	0.0	0.0
North America	0.0	0.0	0.0	2.8	1.5	3.7	5.6	5.9	10.6	22.4	25.0
All REITS	0.5	0.6	0.0	0.0	0.8	0.6	1.2	0.0	0.0	0.2	25.0
BBALibor	25.0	23.9	16.9	15.8	12.3	9.0	0.0	0.0	0.0	0.0	0.0
T-10y	0.0	0.0	0.0	0.0	0.0	1.5	3.2	17.2	14.4	2.4	0.0
SLbond	25.0	25.0	24.3	23.6	22.0	19.9	20.2	1.9	0.0	0.0	0.0
Baa	5.1	6.8	11.1	11.1	12.4	13.3	19.2	25.0	25.0	25.0	25.0
Aaa	25.0	25.0	25.0	24.8	25.0	24.8	25.0	25.0	25.0	25.0	0.0
CRBSpot	5.7	4.4	4.1	2.4	0.9	2.1	0.4	0.0	0.0	0.0	0.0
Colorado	0.0	0.9	2.0	3.3	5.7	11.2	9.0	6.8	14.5	23.2	25.0
Montana	0.0	0.0	0.0	1.1	1.7	1.9	3.2	7.1	10.5	1.8	0.0
Nevada	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Illinois	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Indiana	0.5	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Iowa	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Missouri	4.9	5.2	4.6	5.3	5.2	4.1	4.1	6.1	0.0	0.0	0.0
Florida	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Tennessee	0.9	5.1	7.8	8.3	9.0	7.2	6.3	4.9	0.0	0.0	0.0
Virginia	0.0	0.0	0.5	0.5	0.5	0.5	0.8	0.0	0.0	0.0	0.0
New York	2.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mississippi	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8: Cropland Allocation in a Mixed Asset Portfolio when the Levels of Return are Decreased by 10% and the Variance of Returns are Increased by 10%

	Portfolios										
E(rp)	7.26	7.62	7.97	8.33	8.69	9.05	9.40	9.76	10.12	10.48	10.83
St. Dev.	1.37	1.40	1.45	1.55	1.72	1.87	1.97	2.13	2.71	3.96	7.87
Dow Jones	3.11	2.77	3.58	3.36	0.00	0.00	0.11	0.00	0.00	0.00	0.00
North America	0.00	0.00	0.00	0.07	3.30	3.13	5.00	6.20	11.22	22.28	25.00
All REITS	0.54	0.46	0.00	0.39	0.46	0.70	0.89	0.00	0.00	0.00	25.00
BBALibor	25.00	21.94	15.76	13.98	12.74	8.80	0.00	0.00	0.00	0.00	0.00
T-10y	0.00	0.00	0.00	0.00	0.00	1.37	2.86	18.80	13.78	2.72	0.00
SLbond	25.00	25.00	23.78	22.87	22.21	19.85	19.30	0.00	0.00	0.00	0.00
Baa	5.24	9.07	13.48	14.21	14.71	16.14	21.53	25.00	25.00	25.00	25.00
Aaa	25.00	25.00	25.00	24.95	24.91	25.00	25.00	25.00	25.00	25.00	0.00
CRBSpot	5.61	4.36	3.66	1.70	0.44	0.00	0.29	0.00	0.00	0.00	0.00
Colorado	0.00	0.83	1.49	3.82	5.19	7.58	8.76	8.05	14.18	20.99	25.00
Montana	0.00	0.00	0.00	0.84	1.56	3.24	3.69	6.47	10.82	4.01	0.00
Nevada	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00
Illinois	0.06	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
Indiana	0.54	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
Iowa	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
Missouri	4.70	5.18	5.29	5.69	5.97	6.16	5.11	3.89	0.00	0.00	0.00
Florida	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00
Tennessee	1.22	5.39	7.68	8.13	8.44	8.02	6.03	6.59	0.00	0.00	0.00
Virginia	0.00	0.00	0.28	0.00	0.08	0.00	0.55	0.00	0.00	0.00	0.00
New York	2.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi	1.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Error! Reference source not found. It is clear that the maximum geographic diversification is achieved at the lowest level of risk-return; even though the Delta region dominates the portfolio, the other participant states compete to each other in the lower risk portfolios. A smaller proportion of the total portfolio consists of traditional assets opposed to what happened when cropland returns in a mixed portfolio were analyzed. The minimum standard deviation portfolio consists of investment in three NCREIF Indices and three traditional assets, allowing the investor to obtain a 7.1% annual return with a standard deviation of 0.5%. It is interesting to note that NCREIF indices are always over 35% for the eight lower risk-return portfolios. All *REITs*, *SLBond* and *CRBSpot* are only present for low risk-return portfolios. Despite the reduction in farmland's participation as the returns are increased, it is important to note that this type of investment remains an important component of the portfolio in most cases. The comparison of Sharpe ratios between the optimal portfolio and the naïve portfolio shows that only for higher risk-return portfolios there is no significant improvement, this indicates that the inclusion of cropland investments is only justified for lower to middle risk-return portfolios, in other words portfolio optimization pays off only for the low level of risk-returns. This provides statistical confirmation of prior research that used mean-variance optimized portfolio to imply increased portfolio.

In the following case, a restriction is imposed to a percentage of portfolios that is allowed to come from NCREIF indices. NCREIF All Properties investment in a specific geographic area are constrained to be no more than 25% of the entire portfolio; a similar restriction is impose on single real estate investment such as *REITs* indices. In addition, no more than 25% of the total portfolio may come from investments in NCREIF Indices. Similarly, *REITs* Indices were restricted to a maximum 25% of the total investment. The portfolios representing the efficient frontier taking into account these restrictions are shown in Table 10. **Error! Reference source not found.**As it can be seen five out of six NCREIF indices enter the portfolio. The minimum risk-return is 6.79% with a standard deviation of 1.07%. It is achieved by investing in four different NCREIF indices, Pacific Northwest, Delta States, Southeast and Mountain regions, as well as by investing in five traditional assets, where again *BBALibor* and *SLBond* dominate this portfolio. Southeast and Pacific Northwest regions appear only for the lowest risk-return portfolio whereas when the analysis was done without restriction, Southeast region entered the portfolio for five lowest range risk-return portfolios. NCREIF Indices investments are always present in the optimal portfolio and their participation is always 25%. The Corn Belt region appears for the middle range

risk-return portfolios. The Mountain region enters the frontier up to middle range risk-return portfolios as in the previous case without restriction. The highest risk-return is 9.87% which is 0.83 point lower than the unrestricted case. The standard deviation for this case is 8.69%, almost half than the standard deviation of the unrestricted case. These results suggest that imposing restrictions in the portfolio reduces the overall risk suggesting that NCREIF Index investments represent a good investment alternative for cropland investment, and help to diversify the portfolio.

The variance and returns of the NCREIF Indices and *REITs* were changed by increasing the variance by 10% and reducing the returns by 10% separately, and then both returns and their variances were changed simultaneously. The results are presented in Table 11. Comparing this table with **Error! Reference source not found.**the previous one, it is clear that the proportion of the portfolio of NCREIF indexes as well as traditional assets did not change significantly. The minimal risk-return decreases by 0.9% while the variance increases by 0.9%. The overall return of the portfolio also decreases and the risk of the portfolio increases, although these changes are minimal. These results for the modified portfolio confirm that NCREIF Indexes are likely to remain a major component even if the historical variance and returns have been understated.

Table 9: Efficient Portfolio –NCREIF All Farm Index Allocation in a Mixed Asset Portfolio without Restrictions

	Portfolios														Naïve
E(rp)	7.1*	7.3*	7.6*	7.9*	8.2*	8.5*	8.7*	9.0*	9.3*	9.6*	9.9*	10.1	10.4	10.7	7.5
St. Dev.	0.5	0.5	0.5	0.6	0.6	0.7	0.9	1.2	1.6	1.9	2.4	6.0	11.0	16.2	3.8
North America	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.4	34.5	67.0	99.6	11.1
All REITS	0.9	0.9	0.8	0.7	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1
SLbond	11.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1
Baa	0.0	6.7	10.5	13.4	16.3	23.0	34.5	48.2	63.7	79.1	97.1	65.5	33.0	0.4	11.1
CRBSpot	2.2	2.0	1.8	1.6	1.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1
Corn Belt	0.9	1.4	1.5	1.6	1.6	3.8	6.3	8.1	9.0	9.6	0.6	0.0	0.0	0.0	11.1
Delta States	60.3	62.3	62.2	61.5	60.9	57.9	52.4	43.6	27.3	11.2	0.0	0.0	0.0	0.0	11.1
Southeast	13.8	13.2	9.9	5.8	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1
Mountain	10.9	11.6	13.3	15.4	17.5	14.5	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1

* Statistically significant improvement in portfolio efficiency over the naïve portfolio (95% confidence level)

Table 10: Efficient Portfolio when NCREIF All Properties Farm Index are Used in a Mixed Asset Portfolio with Restrictions[6]

	Portfolios											
E(rp)	6.79	7.07	7.35	7.63	7.91	8.19	8.47	8.75	9.03	9.31	9.59	9.87
St. Dev.	1.07	1.08	1.12	1.18	1.23	1.34	1.50	1.76	2.38	3.42	4.76	8.69
North America	0.00	0.00	0.00	0.00	0.00	1.03	1.69	2.03	5.51	14.49	24.19	25.00
All REITS	1.26	1.25	1.27	1.27	1.13	0.37	0.00	0.00	0.00	0.00	0.00	25.00
BBALibor	25.00	25.00	25.00	25.00	22.30	7.17	0.00	0.00	0.00	0.00	0.00	0.00
T-10y	0.00	0.00	0.00	0.00	0.00	0.00	16.62	22.97	19.49	10.51	0.81	0.00
SLbond	25.00	24.27	13.34	4.09	0.00	12.42	2.94	0.00	0.00	0.00	0.00	0.00
Baa	0.00	0.00	5.90	15.06	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Aaa	18.70	20.03	25.00	25.00	22.05	25.00	25.00	25.00	25.00	25.00	25.00	0.00
CRBSpot	5.05	4.45	4.49	4.58	4.52	4.01	3.75	0.00	0.00	0.00	0.00	0.00
Pacific Northwest	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corn Belt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.38	22.97	25.00	25.00	25.00
Delta States	18.08	18.65	18.83	19.21	20.53	25.00	25.00	19.62	2.03	0.00	0.00	0.00
Southeast	1.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mountain	5.14	6.35	6.17	5.79	4.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[6] NCREIF Indexes and Real Estate are both restricted to a maximum level of 25% of the total portfolio. A maximum of 25% of the portfolio is allowed to be invested in each traditional asset. In addition, a constrained that no more than 25% of the total investment may come NCREIF Indexes or REIT's

Table 11: Efficient Portfolio when NCREIF All Properties Indices are Used in a Mixed Asset Portfolio and the Levels of Return are Decreased by 10% and the Variance of Returns is Increased by 10%

	Portfolios											
E(rp)	6.7	6.9	7.2	7.5	7.8	8.1	8.4	8.7	9.0	9.3	9.6	9.8
St. Dev.	1.1	1.1	1.1	1.2	1.3	1.4	1.6	2.1	3.0	4.3	6.3	8.2
North America	0.0	0.0	0.0	0.0	0.0	1.5	2.1	4.4	10.8	20.8	25.0	25.0
All REITS	1.3	1.3	1.3	1.3	1.2	0.0	0.0	0.0	0.0	0.0	11.9	25.0
BBALibor	25.0	25.0	25.0	25.0	19.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0
T-10y	0.0	0.0	0.0	0.0	0.0	4.3	21.0	20.6	14.2	4.2	0.0	0.0
SLbond	25.0	20.0	10.3	0.7	0.5	13.6	0.0	0.0	0.0	0.0	0.0	0.0
Baa	0.0	0.0	8.9	18.4	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Aaa	18.7	24.2	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
CRBSpot	5.0	4.4	4.5	4.6	4.2	3.9	2.0	0.0	0.0	0.0	0.0	0.0
Pacific Northwest	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn Belt	0.0	0.0	0.0	0.0	0.0	0.0	0.1	13.6	25.0	25.0	13.1	0.0
Delta States	18.1	18.3	18.8	19.2	21.8	25.0	24.9	11.4	0.0	0.0	0.0	0.0
Southeast	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mountain	5.2	6.7	6.2	5.8	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Summary and Conclusions

Previous studies have shown that portfolio diversification enhances the performance of the portfolio of institutional investors, but have left aside the perspective of other agents such as farmers. This paper extends previous studies by looking at the advantages from portfolio diversification from a more general perspective. It compares the benefits from investment in different type of farmland using the NCREIF farmland Indices. Farm real estate is an alternative for investors who are looking for more diversified portfolios. One of the main advantages of farmland is that it behaves differently from traditional stock indices and bond markets, providing a natural protection tool against market volatility. Furthermore, farmland returns are negatively correlated with stocks and bonds and positively correlated with inflation and therefore it may be used by investors to reduce risk in times of higher inflation. Farmland may also provide the investors with considerable in-class diversification, for example, by including investments from different geographical regions.

For the period 1969-2003, cropland shows a negative correlation with returns of stocks and bonds; other measures of farmland investments used in this study (NCREIF all properties), and had negative correlation with returns of stocks and bonds as well. Farmland investments, as measured by both cash returns and NCREIF indices, exhibit higher returns and lower standard deviation than most of stocks or bonds. Traditional assets show a mean return of 6.8% with a standard deviation of 12.1% on average. On the other hand, cropland returns have an average return of 11% with a standard deviation of 8.3%; NCREIF all properties mean return is 6.1% and their standard deviation in 4.2%; and finally. These numbers confirm that investments in cropland and through NCREIF indices provide a good tool for diversification and inflation hedging.

Earlier studies typically conclude that fund managers allocate between 5% and 7% to the real estate assets, while more recent studies suggest an allocation between 10% and 20% of optimal portfolio on real estate. This paper suggests that in most cases 10% to 25% of the optimal portfolio should allocate to real estate, and that in general, farmland improves the performance of a traditional investment portfolio's return of risk profile. As cropland is added to the mixed asset portfolio the returns of the optimal portfolio increase and the variance decreases. On the other hand when adding NCREIF indices to the mixed asset portfolio, a reduction in variance is seen for low levels of returns compared to the mixed asset portfolio

including cropland; the portfolio that includes NCREIF income generating shows lower variance compared to the mixed asset portfolio including NCREIF all properties farm indices. Furthermore, for lower returns the standard deviation of the optimal portfolio including NCREIF indices is lower than the standard deviation of the optimal portfolio using cropland. At higher levels of returns the standard deviation of the optimal portfolio is lower for the cropland case than when considering NCREIF indices into the mixed asset portfolio; for returns higher than 9.9% none of the NCREIF indices improve the performance of the mixed asset portfolio compared to cropland case.

To add realism to the analysis, it was necessary to include several restrictions to the estimation of the portfolio optimization. Participation constraints were added where an upper bound was defined a *priori* for investment by state or geographic region, as well as farmland's total participation in the mixed asset portfolio. When restricting the portfolio, the diversification benefits that farm real estate brings to a mixed asset portfolio are still present. Sensitivity analysis shows that these results are consistent even when parametrical changes are imposed on the returns and variance of cropland and NCREIF indices.

This study showed that the contribution of farmland to portfolio diversification is consistent across different portfolio restrictions and strongly indicates, using three alternative measures for farmland real estate assets, that farmland significantly improves portfolio performance.

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