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Equity Considerations for Wetland Retention Programs: Using a Stochastic Frontier Approach to Investigate Policy Alternatives

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Abstract. This analysis presents a stylized depiction of a government program such as the wetland reserve, where a social planner determines which types of wetlands are brought into production and which are left idle. If the planner is concerned with the dispersion or variance of benefits across producers as well as the mean, his decision problem is algebraically equivalent to a mean-variance portfolio model for a risk-averse individual. The model also identifies an efficient frontier of policies under various "inequality tolerance" levels. Based on available survey data, I apply this method to determine the effects of wetland dispersion on producers' income.

1. Introduction

Wetlands provide a number of benefits to society, although these are typically non-market benefits, and thus difficult to quantify. In particular, wetlands filter and purify water, provide essential habitat for flora and fauna, buffer the effects of storms, provide watershed protection, and allow for biodiversity (Kahn). Because these beneficial services provided by wetlands do not have marketable rights, there is an incentive to convert wetlands to agricultural uses.

Despite the fact that wetlands are vital to ecosystems, they are disappearing rapidly. Approximately 215 million acres of wetlands existed in the United States at the time of European settlement. However, by the middle 1970s less than half of these wetlands remained (Blackwell 1995).

In protecting wetlands, it is necessary to narrow the gap between what is best for the private landowner and what is best for society, whether this involves changing old policies or creating new ones. The policy tools used to address the problem of loss of wetlands include: changes in the way federal flood control and drainage projects are planned, authorized, and financed;

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federal acquisition, easement, and oversight programs; provisions for preferential property tax assessments; tax credits; conversion penalties in the form of taxes; and cross compliance legislation linked to the receipt of federal commodity program payments (Blackwell 1995). In general, the goal of these policies is to provide incentives for firms to internalize the costs of externalities.

Seasonal wetlands are of particular importance to Kansas agricultural policy. Seasonal wetlands, which are areas that are hydrated only part of the year, are abundant on virtually all Kansas farms. Although the definition and determination of seasonal wetlands are variable, they are generally characterized as areas which are hydrated for at least seven days of the growing season, have hydric soils, and display vegetation typical of wetlands (McEowen and Harl 1998).

This paper uses a novel approach to highlight the importance of wetlands programs on the distribution of economic gains across farmers. The analysis is a stylized depiction of a government program such as the wetland reserve, where a social planner determines which types of wetlands are brought into production and which are left idle. Each producer has some willingness to pay (WTP) to farm each type of wetland. The planner has information on the WTP distribution and makes his land allocation decision accordingly. If the planner is concerned with the dispersion or variance of benefits across producers as well as the mean, his decision problem is algebraically equivalent to a mean-variance portfolio model for a risk-averse individual.[2] This model will identify an efficient frontier of policies under various "inequality tolerance" levels.

I apply this method to determine the effects of wetland dispersion on producers' income in Kansas, based on survey data from members of the Kansas Farm Management Association. As one would expect, a high social tolerance for inequality across farmers would imply that wetlands with the highest WTP are brought into production first, even though the variance of gains is also the highest. If less inequality is preferred, then a mixture of wetland types should be farmed. I proceed by discussing the background and reviewing related literature in Section 2, followed by discussion of the model and the results in Sections 3 and 4, respectively. The paper concludes with policy implications of my findings.

2. Background and Literature Review

Wetlands typically include areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (McEowen and Harl 1998).

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[2] Benefit accruing to an individual producer from farming a particular type of wetland is assumed to be equal to the producer's willingness to pay for that type of wetland.

1998). Wetlands generally include swamps, marshes, bogs, and similar areas. This description includes wetland habitats that are covered by water or have waterlogged soils for long periods during the growing season. However, also included are areas that are neither readily observable nor easily defined. These areas are seasonal wetlands; i.e., they are dry during most of the year.

The 1972 Clean Water Act (CWA) was the first policy instrument to adopt an aggressive stance at the federal level towards the problem of water pollution. Earlier federal laws had concentrated on water quality standards, leaving their implementation up to the individual states. The primary goal of the 1972 CWA was to eliminate the discharge of pollution into lakes and rivers, as well as to improve the quality and safety of bodies of water for recreational purposes.

Importantly, Section 404 of the CWA regulated the discharge of "pollutants" into the navigable waters of the United States, where "navigable waters" means waters that were actually navigable by boats. However, in 1975 the Congress gave administrative agencies the regulatory authority to administer the CWA. The Core of Engineers (COE) subsequently broadened the definition of navigable waters to include agricultural wetlands, streams, lake playas, etc. The COE again expanded the definition of such areas in 1977 as "areas that are inundated by surface groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in soil saturated areas." Wetlands generally include swamps, marshes, and similar areas (McEowen and Harl 1998).

The "Swampbuster" provisions of the 1985 Farm Bill further reinforced wetland restrictions. The law denied federal farm program benefits to persons planting agricultural commodities for harvest on converted wetlands. The provision was only concerned with conversion after the date of the enacted legislation, and it did not specifically include seasonal wetlands and playa lakes. However, in 1987 the provision was expanded to include such seasonal wetlands and playa lakes. The final rules described agricultural wetlands as playas, potholes, and other seasonal wetlands that were converted before December 23, 1985, but that still maintained wetland characteristics. Producers are allowed to maintain the draining of these areas that were converted prior to the date, as well as to cultivate such areas that were filled prior to Swampbuster; that is, if a given producer had been draining wetlands prior December 23, 1985, the individual is permitted to continue draining the area.

Finally, the 1996 Farm Bill allows producers to drain and redistribute wetlands. That is, if a farmer finds it profitable to drain a wetland and redistribute the water in another area, they are permitted to do so.

Recent studies have summarized some of the problems associated with economic impacts of wetland legislation. Heimlich (1994) estimated the costs associated with a federal program to protect the current federal target of one million acres of wetlands. With the assumption that protection would require permanent easement payments to prevent agricultural landowners from farming certain areas, he found the minimum cost of an agricultural wetland reserve of one million acres to be in the range of $105 to $197 million dollars per year. Of this cost, approximately two-thirds are easement costs, and the remainders are costs of wetland restoration.

Stavons and Jaffe (1990) explored the impact of federal programs that make agriculture more attractive through facilitating or discouraging conversion of wetlands to agricultural purposes. They used a dynamic model that showed the conditions for conversion of forested wetland into agricultural production. Using data from 36 counties in Arkansas, Louisiana, and Mississippi, their model predicted what would happen to wetland acreage if federal policies changed. Their model took into account the possibility that a marginal acre of wetland today was different from a marginal acre in the future. Several interesting findings emerged. First, landowners responded to economic incentives in land use decisions. Second, federal flood control and drainage projects caused a higher rate of wetland conversion. Third, federal projects made agriculture more feasible in areas that had previously been infeasible. Fourth, adjustment of land-use decisions due to incentives was gradual. The fifth and most substantial finding of this study, was the estimate that the absence of a federal flood policy subsequent to 1934 resulted in 1.15 million fewer acres of wetland being converted for agricultural use.

Norris, Ahern, and Koontz (1994) estimated the effect of wetland regulation on agricultural land prices as an unforeseen consequence of legislation on agricultural and natural resources. The model used in their study was a conventional present value model using a hedonic approach. The model was applied to determine the costs of wetland regulation to farmers in the study area, and the effects of wetland regulation exposure to farmers on land prices. Interestingly, the results indicated that increased exposure to wetland regulation had little effect on land prices.

Kramer and Shabman (1993) estimated the effects of agricultural and tax policy changes on the economic returns to wetland drainage in the Mississippi Delta region. Two major policy changes were made in the 1980s to reduce federal incentives to drain and clear wetland areas: the refusal of farm program benefits to landowners who cleared wetlands (the "Swampbuster" provision of the Food Security Act) and the removal of income tax deductions for drainage costs. The study quantified the effects of tax and agricultural policy changes on landowner returns and risks to wetland conversion using the Net Present Value (NPV) method. The results generally showed that economic returns to wetland conversion were no longer favorable, and that policy changes had effectively reduced the incentive to drain wetland.

Shabman and Bertelson (1979) examined development value estimates for coastal wetland permit decisions. Coastal wetlands provide non-market benefits such as wildlife habitat and biodiversity. Using hedonic procedures, the authors found that the increase in the value of the waterfront property was related to size of the land parcel and the year of sale. The year of the sale influenced the consumer's value estimates of the property. Other qualitative variables were also used to explain the value of a waterfront property such as the level of the waterfront amenity and an index representing neighborhood quality. The hedonic analysis included a variable to measure the level of the waterfront amenity derived from the filled coastal wetland, which was used to make predictions on the value derived from an additional acre of coastal wetland for residential development (Shabman and Bertelson 1979).

Barbier (1994) explored the theoretical underpinnings of how tropical wetlands played an economic role in development, investigating trade-offs between conserving or converting tropical wetlands, while assuming that high opportunity costs of wetland conversion lead to respectively lower levels of conversion. The paper also described extensions and limitations to cost-benefit analysis in determining non-market wetland values.

Gelso (2000) estimated the cost of permanent and seasonal wetlands to Kansas agricultural producers. The analysis was based on survey data collected from Kansas Farm Management Association members. Regression analysis indicated that wetlands are costly to agricultural producers. Permanent wetlands were found to be slightly more costly than seasonal wetlands. Importantly, the results suggested dispersed wetlands are more costly to Kansas farms compared to contiguous wetlands. This study provides information that could be useful in determining farm policy. A subsidy to aggregate wetland acres was expected to reduce costs to producers, while also benefiting society from increased biodiversity.

Together, these studies have the following implications. First, regulatory incentives impact producer decisions. Second, there is some indication from prior work that permanent wetlands impose costs on producers. Third, federal programs affect land values. However, studies have not addressed the effect of wetland policies on the distribution of economic gains across farmers. Hence, the current study is important and unique because it attempts to broaden our understanding of the value of seasonal and permanent wetlands to Kansas agricultural producers. In addition, the paper provides useful information for policymakers in developing fair and equitable wetland reserve programs.

3. Methods

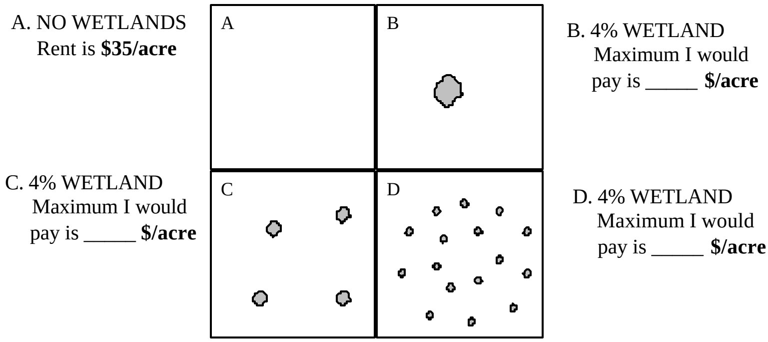
The first step in the analysis was to empirically estimate the value of agricultural wetlands to Kansas' landowners. Gelso (2000) utilized the Contingent Valuation Method (CVM) in a prior study to assess wetland value. The approach has been used in numerous studies to elicit preferences for non-market goods. The CVM approach attempts to establish value for public goods by asking individuals various questions regarding preferences.

The survey instrument was sent to agricultural planners in the Kansas Farm Management Association (KMFA) in June, 2000. The KFMA is comprised of six associations covering the entire state. The Association included 2311 farms, and provided detailed farm business and financial records, which lent well to analysis by researchers. Due to the availability and quality of the data, many prior studies have utilized the database.

The survey estimated the value of alternative distributions, levels, and frequencies of wetlands to agricultural producers, including questions on the maximum rental rate respondents would pay for land containing alternative distributions of either permanent or seasonal wetlands. In particular, in this vein the values of wetlands are indicated by WTP values given by respondents. The alternative versions accommodated different percentages of land covered by wetlands (1%, 2%, 3%, or 4%) and different frequencies of seasonal wetland being wet (1, 2, 3, or 4 years out of 5). For example, WTP results for 1 wetland section were greater than results for 4 and 16 wetlands. Hence, quarter sections of land with less dispersed wetlands are more valuable to agricultural planners. Figure 1 shows the pictorial depiction of the wetland dispersion as was presented in the survey instruments. For more information on the survey instruments and the WTP results obtained from the survey see Gelso (2000).

Interestingly, Gelso (2000) found that 1) wetlands restrictions are costly to agricultural land owners, 2) permanent wetlands are more costly than seasonal wetlands, 3) increased dispersion, total acres affected, and frequency of hydration reduce the perceived value of wetlands, and 4) demographic variables are correlated with planners' attitudes toward wetland value. The increased dispersion of wetlands (from 1 area to 4 areas) contributes as much to loss of value as would an 8% increase in the area of wetland.

This prior study (Gelso 2000) is important because it identified the value of wetlands with alternative land characteristics for agricultural uses, although the assessment of wetland value is based purely on the mean WTP for these lands by producers. Hence, the determination of value does not take into account the second moment of the WTP distribution. The current study is unique because it takes into account both the mean and variance of the distribution of WTP. For example, if the WTP for a certain land section was high, the prior study indicated the land section was more valuable than land sections with lower WTP. However, if the variance of the WTP for that land section is also high, the land section may not be optimal with high risk-aversion levels or low tolerance for inequality. Hence, this study chooses land sections optimally by maximizing the mean of WTP, while minimizing the variance of WTP, over a range of alternative inequality tolerance levels, for a sample of Kansas producers.



Survey Versions

Version	% Wet	Prob Wet
1.1	1%	20%
1.2	1%	40%
1.3	1%	60%
1.4	1%	80%
2.1	2%	20%
2.2	2%	40%
2.3	2%	60%
2.4	2%	80%
3.1	3%	20%
3.2	3%	40%
3.3	3%	60%
3.4	3%	80%
4.1	4%	20%
4.2	4%	40%
4.3	4%	60%
4.4	4%	80%

Figure 1: Pictorial Representation of Alternative Wetland Distribution and Survey Versions

Note: Respondents were instructed to reply with the maximum rental rate they would pay for crop-land that contains some wetland areas that may be too wet to farm, when tracts of similar quality land with no wetlands rent for $35 per acre. In order to determine the costs of wetlands, The cost of having wetlands was calculated as the difference between the maximum amount a respondent was willing-to-pay (WTP) for land containing wetlands and the given rental rate for land with no wetlands ($35/acre). Thus, as shown above, if a respondent to Version 4.2 of the survey indicated a maximum WTP of $30 per acre on question 7c, then the cost of having 4 seasonally wet areas on 160 acres that cover 4% of the land area and are wet an average of 2 years out of 5 is $5/acre ($35-$30). The right-hand-side illustrates the sixteen survey alternative versions which accommodated different percentages of land covered by wetlands (1%, 2%, 3%, or 4%) and different frequencies of seasonal wetland being wet (1, 2, 3, or 4 years out of 5).

For a given class of wetlands corresponding to one version of the survey (e.g., 4% permanent wetland area), suppose that each farm is made up of three types of land parcels: tracts that contain 1, 4, and 16 wetlands. On each farm, a fixed amount of acreage will be farmed and the rest will be left idle. The social planner wishes to determine the optimal percentage of each land type in the total acreage farmed. This planning problem is a simplified description of wetland policies that select parcels with certain characteristics. Note that the planner's problem is the mirror image of the implicit objective in many of these policies, in the sense that they optimally *remove* farmed acreage from production.

In the model, the social planner is assumed to maximize the certainty equivalency of his portfolio by choosing the optimal combination of wetland types to be farmed. This is an adaptation of the conventional Mean-Variance portfolio model (Markowitz) under risk aversion. Conceptually the maximization problem for the social planner is:

$$CE = \underset{(x)}{Max} \sum_{i=1}^{3} w_i x_i - \Theta \sum_{i=1}^{3} \sum_{j=1}^{3} x_i V_{ij} x_j \tag{1}$$

subject to

$$\sum_{i=1}^{3} x_i = 1$$

$$\Theta, x_i \geq 0 \, \forall \, i$$

where,

CE = certainty equivalency of optimal portfolio
w_1 = mean WTP for farmed acreage with 1 wetland parcel
w_2 = mean WTP for farmed acreage with 4 wetland parcels
w_3 = mean WTP for farmed acreage with 16 wetland parcels
x_1 = share of farmed acreage with1 wetland parcel
x_2 = share of farmed acreage with 4 wetland parcels
x_3 = share of farmed acreage with16 wetland parcels
Θ = inequality tolerance coefficient
V_{ii} = variance of WTP for type of wetland whose share is represented by x_i
V_{ij} = covariance of WTP for types of wetlands whose shares are represented by x_i and x_j.

The inequality tolerance coefficient in this model is directly proportional to the Arrow-Pratt absolute risk aversion coefficient (a) and is defined by the following relationship: $\Theta = \frac{a}{2}$. A large value for Θ corresponds to high aversion to risk and low tolerance for inequality. In the limiting case of $\Theta \to \infty$, the planner desires that the WTP of all producers equal to the same amount.

Two empirical models, one each for permanent and seasonal wetland, respectively, were specified. For each model, four sub-models representing

1%, 2%, 3%, and 4% wetland were estimated. The Θ coefficient was set to zero for the initial iteration and the optimal results generated. The Θ coefficient was then parameterized within a range of values from 0 to 0.5 in order to generate alternative results. This procedure was repeated for the remaining seven sub-models. For each Θ value under each sub-model, a value for the mean WTP, the standard deviation of the WTP, the CE of the optimal portfolio, as well as the optimal shares of the wetland types were recorded.

4. Results

The purpose of the mean-variance models was to identify optimal shares of each type of wetland in production for given inequality tolerance levels. The results for the permanent wetland sub-models are presented in Table 1. As the results show, the planner values the land section with the highest WTP if the value of the inequality coefficient is small but the planner chooses to diversify as inequality is penalized. Although the mean WTP with one wetland type may have the greatest value, the inequality can be reduced by investing in two or more land types. This inequality reduction strategy is illustrated in Table 1 where the planner diversifies land investments at or above an inequality tolerance parameter of 0.25.

Table 2 summarizes the results for the seasonal wetland sub-models. The results are identical to those for the permanent wetland, except that the optimal portfolios are more diversified across land types for the seasonal wetland. This is indicated by the reduction in the critical value of the inequality tolerance parameter at which the planner begins to diversify from 0.25 for the permanent wetland to 0.05 for the seasonal wetland.

The inequality-efficient frontier for the permanent wetland is presented in Figure 2. The Figure shows that 3 and 4% permanent wetland types are clearly dominated by the 2% permanent wetland type. The 1% permanent wetland type has only one unique point on the efficient frontier and dominates all other wetland types for that mean-standard deviation combination. In essence, the inequality-efficient frontier for the permanent wetland, represented by the dashed lines, exists along the 2% curve and extends to the 1% point. Therefore, any optimal selection of portfolios of land types by the social planner must fall on this curve. The relative proportions of 1, 4, and 16 wetland types in the optimal choice along the efficient frontier are presented in Figure 3. As the social planner becomes less tolerant to inequality in the WTP for wetland among producers (i.e., as the inequality tolerance coefficient increases), the proportion of 1 wetland type in the optimal portfolio decreases while the proportions of 4 and 16 wetland types increase.

Table 1: Permanent Wetland Portfolio Results

1% Permanent Wetland

Equity Tolerance	C.E.	m	s	Portfolio Levels: 1 Wetland	4 Wetlands	16 Wetlands
0.00	32.766	32.766	5.604	1.00	0	0
0.0045	32.625	32.766	5.604	1.00	0	0
0.025	31.981	32.766	5.604	1.00	0	0
0.05	31.196	32.766	5.604	1.00	0	0
0.125	28.840	32.766	5.604	1.00	0	0
0.25	25.161	32.766	5.604	0.848	0.152	0
0.375	21.750	32.766	5.604	0.781	0.219	0
0.5	18.411	32.766	5.604	0.748	0.252	0

2% Permanent Wetland

Equity Tolerance	C.E.	m	s	Portfolio Levels: 1 Wetland	4 Wetlands	16 Wetlands
0.00	32.166	32.166	4.959	1.00	0	0
0.0045	32.055	32.166	4.959	1.00	0	0
0.025	31.551	32.166	4.959	1.00	0	0
0.05	30.937	32.166	4.959	1.00	0	0
0.125	29.092	32.166	4.959	1.00	0	0
0.25	26.053	31.920	4.844	0.942	0.058	0
0.375	23.193	31.629	4.743	0.873	0.127	0
0.5	20.405	31.484	4.707	0.839	0.161	0
1.25	4.061	30.893	4.633	0.760	0.207	0.033

3% Permanent Wetland

Equity Tolerance	C.E.	m	s	Portfolio Levels: 1 Wetland	4 Wetlands	16 Wetlands
0.00	31.644	31.644	5.568	1.00	0	0
0.0045	31.504	31.644	5.568	1.00	0	0
0.025	30.869	31.644	5.568	1.00	0	0
0.05	30.094	31.644	5.568	1.00	0	0
0.125	27.769	31.644	5.568	1.00	0	0
0.25	24.254	30.898	5.155	0.818	0.182	0
0.375	20.996	30.640	5.071	0.756	0.244	0
0.5	17.802	30.512	5.042	0.724	0.276	0

4% Permanent Wetland

Equity Tolerance	C.E.	m	s	Portfolio Levels: 1 Wetland	4 Wetlands	16 Wetlands
0.00	30.949	30.949	5.643	1.00	0	0
0.0045	30.806	30.949	5.643	1.00	0	0
0.025	30.153	30.949	5.643	1.00	0	0
0.05	29.357	30.949	5.643	1.00	0	0
0.125	26.969	30.949	5.643	1.00	0	0
0.25	23.154	30.310	5.350	0.862	0.138	0
0.375	19.679	29.899	5.221	0.774	0.226	0
0.5	16.328	29.458	5.124	0.712	0.258	0.030

Table 2: Seasonal Wetland Portfolio Results

1% Seasonal Wetland

Equity Tolerance	C.E.	m	s	Portfolio Levels: 1 Wetland	4 Wetlands	16 Wetlands
0.00	33.421	33.421	6.842	1.00	0	0
0.0045	33.210	33.421	6.842	1.00	0	0
0.025	32.251	33.421	6.842	1.00	0	0
0.05	31.080	33.421	6.842	1.00	0	0
0.125	27.569	33.421	6.842	1.00	0	0
0.25	22.097	32.185	6.352	0.794	0.175	0.031
0.375	17.297	31.211	6.091	0.682	0.227	0.091
0.5	12.740	30.724	5.997	0.627	0.252	0.121

2% Seasonal Wetland

Equity Tolerance	C.E.	m	s	Portfolio Levels: 1 Wetland	4 Wetlands	16 Wetlands
0.00	33.826	33.826	7.742	1.00	0	0
0.0045	33.556	33.826	7.742	1.00	0	0
0.025	32.328	33.826	7.742	1.00	0	0
0.05	30.858	33.512	7.286	0.913	0.087	0
0.125	27.646	32.487	6.224	0.630	0.370	0
0.25	22.996	31.861	5.955	0.523	0.450	0.027
0.375	18.752	31.108	5.740	0.464	0.448	0.088
0.5	14.696	30.731	5.663	0.435	0.446	0.119

3% Seasonal Wetland

Equity Tolerance	C.E.	m	s	Portfolio Levels: 1 Wetland	4 Wetlands	16 Wetlands
0.00	31.816	31.816	7.318	1.00	0	0
0.0045	31.575	31.816	7.318	1.00	0	0
0.025	30.477	31.816	7.318	1.00	0	0
0.05	29.138	31.816	7.318	1.00	0	0
0.125	25.122	31.816	7.318	1.00	0	0
0.25	18.464	31.185	7.220	0.909	0.091	0
0.375	12.063	31.036	7.113	0.778	0.222	0
0.5	5.826	30.465	7.020	0.724	0.232	0.044

4% Seasonal Wetland

Equity Tolerance	C.E.	m	s	Portfolio Levels: 1 Wetland	4 Wetlands	16 Wetlands
0.00	30.528	30.528	8.200	1.00	0	0
0.0045	30.225	30.528	8.200	1.00	0	0
0.025	28.847	30.528	8.200	1.00	0	0
0.05	27.166	30.528	8.200	1.00	0	0
0.125	22.123	30.528	8.200	1.00	0	0
0.25	13.718	30.528	8.200	0.794	0.175	0.031
0.375	5.314	30.448	8.187	0.993	0	0.007

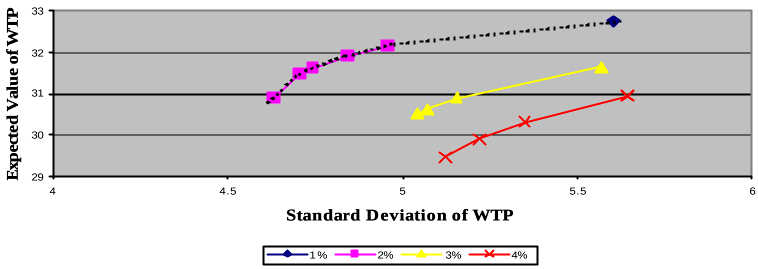


Figure 2: Inequality-Efficient Frontier for Permanent Wetland in Kansas

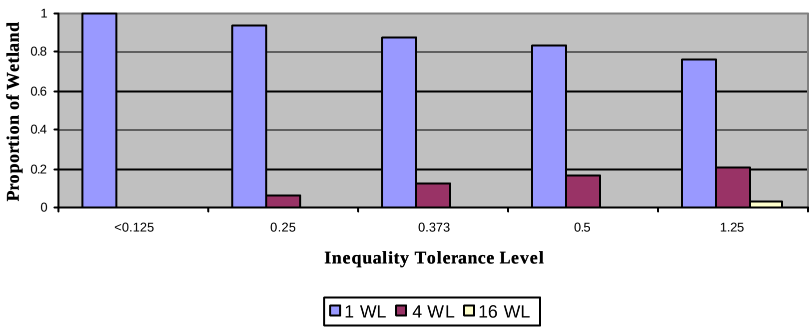


Figure 3: Optimal Proportion of Permanent Wetland (WL) Parcel

The inequality-efficient frontier for the seasonal wetland is presented in Figure 4. The results for the seasonal wetland are similar to those for the permanent wetland; however, there are significant changes in the proportion of wetland types in the optimal portfolio compared to the permanent wetland case. Both the 3 and 4% wetland types are dominated by the 1 and 2% wetland types. The inequality-efficient frontier, represented by the dashed lines, again falls on the 2% curve, except for a point on the 1% curve. The relative proportions of 1, 4, and 16 wetland types in the optimal choice along the efficient frontier are presented in Figure 5. It is interesting to note that while the optimal portfolio consists solely of 1 wetland type at an inequality tolerance level of 0.025 or below, the optimal portfolio is made up of about 52% of 1 wetland type, 45% of 4 wetland type, and 3% of 16 wetland types at an inequality tolerance level of 0.25.

In making policy decisions about wetland retention, the inequality-efficient frontiers generated for permanent and seasonal wetlands will serve useful purposes for the social planner. The social planner is aware that any optimal portfolio will have to fall on the frontier. The regulator may choose a particular mean-standard deviation combination on the frontier based on other knowledge or information exogenous to the model. The corresponding portfolio of wetland types for that particular mean-standard deviation combination will then be determined from Table 1 in the case of the permanent wetland and from Table 2 in the case of the seasonal wetland. Alternatively, the social planner may choose a "desirable" inequality tolerance level based on information exterior to the model. The optimal portfolio corresponding to the chosen level could be determined from Figure 3 or 5, as applicable, and the corresponding mean-standard deviation combination determined from Table 1 or 2, as the case may be.

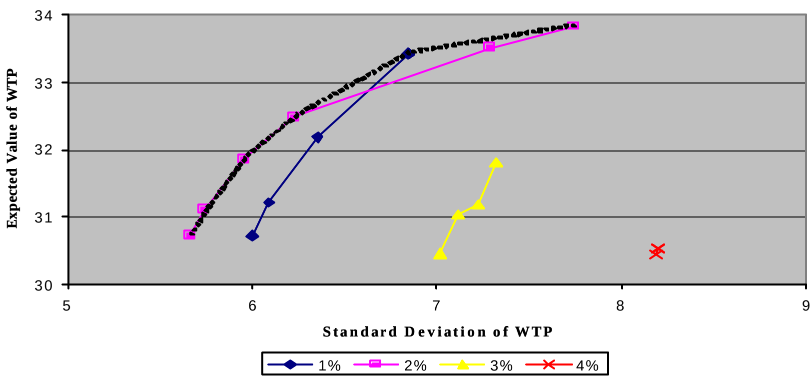


Figure 4: Inequality-Efficient Frontier for Seasonal Wetland in Kansas

5. Policy Implications and Conclusions

This paper has identified inequality-efficient frontiers for permanent and seasonal wetlands in Kansas. The optimal combinations of wetland types along these frontiers have also been generated to aid policymakers in setting policies for wetland retention programs in the state. Findings indicated that only 1% and 2% permanent and seasonal wetlands should be converted for agricultural uses. Within these land types, it is only optimal to farm the land parcels containing one wetland if minimal or no consideration is given to inequalities in the willingness to pay for the wetland. However, various combinations of land parcels containing 1, 4, or 16 wetlands will be farmed as increasing considerations are given to inequalities in the willingness to pay for these land wetlands.

Important economic considerations can be drawn from a model that quantifies the distribution of benefits to agricultural producers from wetlands that are taken out of production. The results of this analysis provide a snapshot of how wetland reserve programs might affect the distribution of land benefits across farmers. If inequality is an issue for the policymaker, the dispersion of wetlands in such programs is important. For example, if the social planner desires equality in the benefits accruing to producers, some models indicated contiguous wetland might be undesirable.

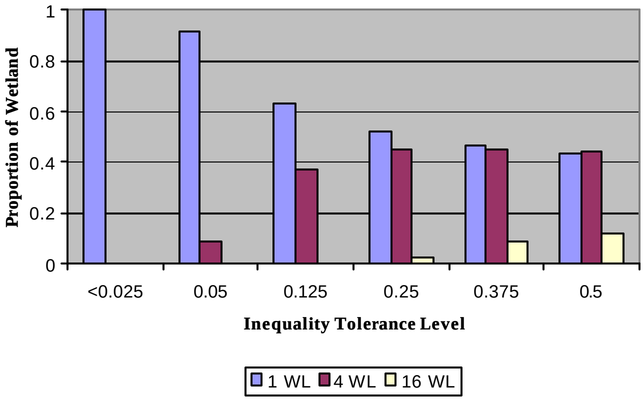


Figure 5: Optimal Proportion of Seasonal Wetlalnd (WL) Parcel

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