AgEcon Search Appendix I to: "Crop Insurance Savings Accounts: A Viable Alternative to Crop Insurance?" to appear in

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This appendix is comprised of two sections. The first section entitled "Yield Variability and Premium Estimation Error" establishes a range of plausible levels of crop insurance premium estimation error corresponding to typical corn production scenarios in the Midwestern US. The second section entitled "Distribution of Crop Insurance Subsidies" assesses the potential impact of such levels of premium estimation error on the distribution of the Crop Insurance subsidies across participating corn producers.

Yield Variability and Premium Estimation Error

The yield simulation scenarios are designed to resemble the case of corn production in the Midwestern US. Specifically, prototypical farms yields with a mean of 180 bushels/acre and standard deviations ranging from 30 to 50 bushels/acre are simulated. In the first part of the analysis (Scenario A), yields are assumed to be normally distributed. At the lowest standard deviation of 30 bushels/acre the probability of a yield value under 130 bushels/acre or over 230 bushels/acre is only 10% (5% under and 5% over). This would have to be a superior farmer with limited downside and substantial upside yield potential. At the highest standard deviation of 50 bushels/acre the 5% probability bounds are 97.5 and 262.5 bushels/acre. This could be farmer with a fair downside but an unrealistically high upside yield potential.

In the second part of the analysis (Scenario B), yields are assumed to follow a substantially left skewed SU distribution (Ramirez, Carpio and Rejesus 2011). At the lowest standard deviation of 30 bushels/acre and skewness and kurtosis values of -3.25 and 23.5, the 5%

probability boundaries are 125 and 207 bushels/acre (Figure 1). These expand to 88.5 and 225 bushels/acre at the highest standard deviation of 50 bushels/acre (Figure 2). In other words, the upside yield potential from the mean of 180 bushels/acre less than half as much as the downside potential. It is believed that these distributions are more consistent with the likely behavior of farm-level corn yields in the Midwestern US.

The actuarially fair premiums (AFP) corresponding to each of the above yield distributions for the Actual Production History (APH) farm-level yield insurance program under a price guarantee of $5/bushel and 60, 65, 70, 75 and 80% coverage levels are then computed using standard simulation methods. Specifically, 10 million random yield observations (Y_i) are simulated from the appropriate distribution (normal or SU) given the assumed parameter values (for a description of the procedure to simulate draws from an SU distribution see Ramirez, Misra and Field 2003). Each of those values is compared with CL times the known mean of the distribution (M=180), where CL is the coverage level (0.60, 0.65, 0.70, 0.75 or 0.80). If the simulated yield value is lower than CL*x*M the difference (CL*x*M-Y_i) is multiplied by the assumed price guarantee ($5/bushel), otherwise the observation is discarded. The sum of all the non-discarded values divided by 10 million is thus the expected indemnity associated with that specific yield distribution and, therefore, the actuarially fair premium that needs to be charged.

In the case of the normal distributions (Table 1), at the most common 65% coverage level, the AFP range from $0.97/acre when the standard deviation is 30 bushels/acre to $12.37/acre when the standard deviation is 50 bushels/acre. At the mid-point of 40 bushels/acre the AFP is $4.93/acre. This begins to illustrate the problem faced by the RMA. If the correct standard deviation of a farmer's yield distribution was 40 bushels/acre but the insurer estimated it at 45 bushels/acre, the premium estimate for 65% coverage would be $8.26/acre instead of

$4.93/acre. Unfortunately, as shown later because the limited amount of data available for rating, an estimation error of that magnitude might not be uncommon. Alternatively, the insurer could choose to charge all farmers the average premium for the most likely standard deviation value (e.g. 40 bushels/acre). In this case, however, farmers with only slightly lower or higher than average levels of yield variability (e.g. 35 or 45 bushels/acre) would pay quite more ($4.93 versus $2.50/acre) or less ($4.93 versus $8.26/acre) than what they actually should.

The situation is not much different when the yield distribution is assumed to be left-skewed (Table 1). Under this distributional assumption, at the 65% coverage level a producer who is able to maintain a 5% lower bound of 125 bushels/acre (Figure 1) should only pay a $7.14/acre premium. In contrast, a farmer whose 5% lower-bound is 88.5 bushels/acre (Figure 2) should be charged $21.17/acre. Unfortunately again, because of the limited amount of yield data available for participating producers, it is impossible to reliably estimate the correct location of the far left tail of the yield distribution and, as shown in the next section, errors of this magnitude might not be uncommon.

The distribution of the estimated premiums under any given yield distribution can be obtained by simulation methods as well. Specifically, 10,000 small samples of size n=20 are drawn from the underlying distribution and the distributional parameters are estimated based on each sample. In the case of a normal, the usual estimates for the mean and standard deviation are utilized. In the case of an SU, Maximum Likelihood methods are used to estimate the four distributional parameters (Ramirez, Misra and Field 2003). Once the parameter estimates corresponding to each of the 10,000 samples are available, the same procedure utilized to compute the actuarially fair premiums (AFP) is applied to obtain premium estimates. Those

10,000 premium estimates represent (i.e. are draws from) the statistical distribution of the estimated premiums associated with that particular yield distribution.

Key summary statistics describing the distribution of the premium estimates corresponding to each the 10 assumed yield distributions are presented in Tables 1 and 2. In the case of an underlying normal with a mean of 180 and a standard deviation of 40 bushels/acre, the average of the 10,000 premium estimates (labeled as APE in Table 1) at 65% coverage is $5.71/acre versus the AFP of $4.93/acre. In other words, the premium estimates exhibit a 16% upward bias in this particular instance. In addition, the average of the absolute differences between the estimated premiums and the AFP (labeled as MAD in Table 1) is $3.08/acre. This means that premium estimates that are several dollars apart from the AFP of $4.93/acre are fairly common, with a strong tendency for the estimates to be higher rather than lower than the AFP.

When the underlying yield distribution is an SU with the same mean (180 bushels/acre) and standard deviation (40 bushels/acre), the APE is $14.70/acre versus the AFP of $13.70/acre, and the MAD stands at $8.02/acre. This means that premium estimates that are more than 50% lower or higher than the AFP are fairly common. The column labeled PMAD (percentage MAD) in Table 1 is obtained by multiplying the MAD by 100 and dividing by the AFP, which expresses it as a percentage of the AFP. Note that, in all cases, the PMAD decreases with the coverage level and when the yield distribution has a higher standard deviation. Generally on a relative basis the MAD is lower at higher AFP. At the most common 65% coverage level, the PMAD ranges from 98.5 to 48.1 percent for the normal and 78.1 to 46.9 percent for the SU distributions.

While the yield distributions underlying the previously discussed bias and PMAD statistics are hypothetical in nature, they are by no means unrealistic representations of possible corn production scenarios in the Midwest. Nevertheless, more conservative (25 to 50 percent) PMAD values are assumed for the following analyses.

Distribution of Crop Insurance Subsidies

While it is not claimed that the previously discussed PMAD and bias magnitudes are characteristic of the RMA premium estimates for corn production in the Midwestern US, in this section they will be used to explore the potential impacts of such levels of premium estimation inaccuracy on the distribution of crop insurance subsidies across farmers who produce the same crop and (unknown to the insurer) exhibit identical yield risk profiles. Specifically, it is assumed that both the farmer and the insurer do not know what the AFP is and thus have to estimate it with various degrees of error (PMAD and bias). The producer and insurer premium estimates are denoted by PPE and IPE, respectively, and producers may be willing to pay a risk-protection premium (RPP) in excess of their PPE. A farmer's decision rule for participating in the program, thus, is $PPE+RPP \geq IPE$, i.e. that his/her own premium estimate plus any risk protection premium he/she is willing to pay is greater than the insurer's quote.

For each scenario in the analysis, it is assumed that 10,000 identical producers are eligible to participate in the program. Alternatively, this could be interpreted as conducting repeated outcome draws for a single producer. Each outcome (i) is characterized by a set of two premium estimates, one by the producer (PPE_i) and one by the insurer (IPE_i), which are randomly drawn as follows:

1) $PPE_i=AFP+PPB+U_{iP}$
2) $IPE_i=AFP+IPB+U_{iI}$

where AFP=10 in all cases, PPB and IPB are the biases in the producer and insurer premium estimates, respectively, and U_{iP} and U_{iI} are draws from uncorrelated uniform distributions with zero mean and whatever range is necessary to achieve the desired PMAD for PPE and IPE.

In the first scenario (S1a) presented in Table 2 it is assumed that IPB, PPB and RPP are all zero and that both the PPE and the IPE exhibit a relatively low PMAD of 30%. Thus, both U_{iP} and U_{iI} are set range between -6 and 6 which means that the premium estimates will range from 4 to 16 in both cases. Since the estimated premiums are not subsidized (Government Subsidy Rate=GSR=0 in Table 2) in this scenario, as expected, $PPE_i \geq IPE_i$ in just about 50% of the 10,000 simulated outcomes, which means that only half of the eligible producers would voluntarily participate (Producer Participation Rate= PPR=0.50). A more interesting question, however, is: what is the distribution of the premiums paid by the participating producers relative to the AFP, i.e. to what they should in fact be paying?

This question can be answered by comparing their IPE_i (i.e. what they ended up paying) with the AFP. As detailed in Table 2, in this scenario, over 25% of participating producers end up paying more than the AFP (i.e. what they should pay) while 16% pays less than half of the AFP. In addition, because only farmers for whom $PPE_i \geq IPE_i$ participate in the program and there is no RPP or any positive bias on the producer's premium estimate, the sum of their IPE_i (i.e. what they actually pay) is only 80.0% of the sum of their AFP, which means that this particular scheme could not operate without a substantial external subsidy. Thus, PPG (the Percentage Paid by Government) equals 0.20 in Table 2.

In practice, the RMA provides subsidized premiums to promote higher levels of participation. Mathematically, this alters the participation rule to $PPE_i \geq (1\text{-}GSR) \text{x} IPE_i$ where GSR is the government subsidy rate. For instance, if GSR=0.50 (50 percent), the insurer's quote would be 0.50x IPE_i. The second scenario (S1b) presented in Table 2 maintains the baseline assumptions of S1a (IPB=0, PPB=0, RPP=0, and PMAD=30%) but assumes a GSR of 52% which is roughly in line with what has been observed in recent years. In this case $PPE_i \geq 0.50xIPE_i$ in 9,020 of the 10,000 cases, i.e. the producer participation rate (PPR) is 90.2 percent. The sum of $0.50xIPE_i$ for the participating producers is only 46.2% of the sum of their AFP, which means that 53.8% of the total indemnity payments would have to be externally subsidized. Thus, PPG=0.538 in Table 2.

In addition note that, because of the high overall subsidy level, all participating producers now pay less than 80% of what is actuarially fair. However, while over 20% are charged 30% or less, on the other extreme, nearly 25% pay 60% or more of the AFP. That is, just by chance, two producers with identical yield risk profiles would often end up paying very different crop insurance premiums and thus receiving vastly disproportionate shares of the intended government subsidy. Table 2 presents several other scenarios involving various plausible combinations of premium estimate biases, PMADs and risk protection premiums, as well as the possibility of a substantial correlation (CORR) between the insurance and producer premium estimates. At least some degree of correlation should be expected since the RMA considers the farm's recent yield history on its rating protocol and the farmer could give some weight to the insurer's quote when determining what he/she thinks the actuarially fair premium might be. The scenarios are designed to approximately resemble the current program outcomes, specifically a 90% producer participation rate (PPR) given a 50% external premium subsidy (PPG).

Note that, in all the 90% participation (i.e. "b") scenarios, the 25% of the producers paying the highest premiums pay at least twice as much as the 25% paying the lowest premiums. In S6b, for example, 26.1% pay less than 30% of the AFP while 24.5% pay more than 70% of the AFP. In other words, just by chance, 26.1% of the farmers end up receiving a subsidy of at least 70% while 24.5% get a rate subsidy of 30% or less. Further, 14.8% receive a subsidy of at least 80% while 11.0% get 20% or less.

Numerous other scenarios are explored involving exhaustive combinations of producer and insurer PMADs, bias, RRP and CC. From these scenarios it is concluded that while some such combinations result in a high percentage of producers participating at relatively low levels of external subsidy (GSR and PPG), as long as a non-negligible PMAD (≥2.0) is assumed to be associated with the insurer's estimate for the AFP, the dispersion of the premiums to be paid by "identical" farmers remains high. It can thus be argued that this is an unavoidable disadvantage of crop insurance. While, through substantial external subsidies, it is possible to avoid a situation where too many farmers end up paying more than the AFP, it appears that the distribution of those subsidies across participating farmers will always be highly and randomly uneven. Just by chance, some producers will receive a large share of the subsidy while others get very little or possibly even none at all.

In order to facilitate comparisons, the previous analysis focus on the case of a set producers with identical risk profiles. However, a logical extrapolation of the above results is that an individual with a low-risk operation (i.e. whose AFP is relatively low) could very well end up paying a similar or even larger premium than another high-risk farmer. An alternative, of course, would be for the insurer to charge the same "average" premium to all producers whose operations appear to face about the same yield risk. The problem with this is that, because of the previously illustrated difficulties with accurately assessing farm-level risk (i.e. estimating the AFP), producers with substantially different risk exposure (i.e. AFP) could end up paying the same "average" premium.

References

Ramirez, O.A., C.E. Carpio, and R.M. Rejesus (2011). “Can Crop Insurance Premiums be Reliably Estimated?” *Agricultural and Resource Economics Review* 40(1): 81-94.

Ramirez, O.A., S.K. Misra, and J.E. Field (2003). Crop yield distributions revisited. *American Journal of Agricultural Economics* 85(1)(February 2003):108-120.

Table 1: Actuarially Fair Premium (AFP), Average of Premium Estimates (APE), Mean Absolute Deviation of the Premium Estimates from the AFP (MAD), Percentage Bias (PBIAS) and Percentage MAD (PMAD) for two alternative underlying corn yield distributions with 5 different standard deviations (STD).

	Normal Distribution - Mean = 180					**Non-Normal Distribution - Mean = 180**				
STD	**AFP**	**APE**	**MAD**	**PBIAS**	**PMAD**	**AFP**	**APE**	**MAD**	**PBIAS**	**PMAD**
30.00	0.97	1.38	0.96	41.58	98.46	7.14	8.73	5.57	22.36	78.07
35.00	2.50	3.12	1.89	24.96	75.70	10.20	11.67	6.82	14.38	66.86
40.00	4.93	5.71	3.08	15.80	62.39	13.70	14.70	8.02	7.27	58.55
45.00	8.26	9.26	4.47	12.18	54.13	17.29	17.84	9.20	3.19	53.22
50.00	12.37	13.52	5.95	9.30	48.06	21.17	21.20	9.92	0.17	46.87

Table 2: Distribution of the premiums paid by participating producers under various combinations of insurer premium bias (IPB), producer risk protection premiums (RPP), insurer and producer PMADs (IPMAD and PPMAD), and correlations between the insurer and the producer premium estimates (CORR).

IPB	0.00		0.00		0.00		0.00		-15%		15%	
RPP	0.00		0.00		10%		15%		15%		15%	
IPMAD	30%		40%		50%		50%		50%		50%	
PPMAD	30%		40%		50%		50%		50%		50%	
CORR	0.00		0.00		0.60		0.60		0.60		0.60	
Scenario	**S1a**	**S1b**	**S2a**	**S2b**	**S3a**	**S3b**	**S4a**	**S4b**	**S5a**	**S5b**	**S6a**	**S6b**
GSR	0.000	0.520	0.000	0.650	0.000	0.570	0.000	0.520	0.000	0.440	0.000	0.590
PPR	0.500	0.902	0.499	0.897	0.560	0.898	0.589	0.900	0.679	0.902	0.499	0.901
PPG	0.200	0.538	0.266	0.665	0.129	0.551	0.123	0.503	0.257	0.515	0.005	0.509
PAFP												
20%	1.000	0.985	1.000	0.742	0.866	0.792	0.866	0.809	0.779	0.756	0.964	0.852
25%	1.000	0.889	0.938	0.644	0.834	0.737	0.834	0.760	0.749	0.712	0.929	0.795
30%	1.000	0.793	0.878	0.550	0.802	0.682	0.803	0.710	0.719	0.669	0.894	0.739
35%	1.000	0.696	0.821	0.457	0.770	0.625	0.772	0.659	0.690	0.624	0.860	0.681
40%	1.000	0.601	0.765	0.369	0.739	0.569	0.741	0.609	0.661	0.580	0.827	0.622
45%	0.919	0.507	0.712	0.283	0.708	0.511	0.711	0.558	0.633	0.535	0.795	0.562
50%	0.840	0.416	0.660	0.200	0.677	0.451	0.681	0.507	0.605	0.491	0.762	0.501
55%	0.765	0.329	0.611	0.120	0.648	0.391	0.651	0.454	0.577	0.446	0.730	0.439
60%	0.694	0.248	0.563	0.045	0.619	0.330	0.623	0.400	0.549	0.401	0.699	0.375
65%	0.626	0.168	0.518	0.000	0.590	0.269	0.594	0.347	0.522	0.356	0.668	0.311
70%	0.562	0.095	0.473	0.000	0.562	0.207	0.566	0.292	0.496	0.311	0.638	0.245
75%	0.501	0.025	0.432	0.000	0.534	0.143	0.538	0.237	0.470	0.266	0.608	0.178
80%	0.444	0.000	0.391	0.000	0.507	0.078	0.511	0.182	0.444	0.220	0.580	0.110
85%	0.391	0.000	0.354	0.000	0.480	0.013	0.485	0.126	0.419	0.174	0.551	0.042
90%	0.341	0.000	0.317	0.000	0.455	0.000	0.460	0.069	0.394	0.127	0.523	0.000
95%	0.295	0.000	0.283	0.000	0.429	0.000	0.434	0.012	0.370	0.080	0.496	0.000
100%	0.252	0.000	0.251	0.000	0.403	0.000	0.409	0.000	0.346	0.033	0.470	0.000

Notes: GSR, PPR, PPG, stand for the Government Subsidy Rate to each individually estimated premium, the Producer Participation Rate in the program, and the Percentage (of the total program indemnities) Paid by the Government. The percentages on the first column under PAFP are the percentages of the AFP. The numbers in the columns next to them are to be interpreted as follows: on the second column, for example, there is a 100% probability that the producer will end up paying more than 40% of the AFP, a 91.9% probability that he/she will pay more than 45% of the AFP, an 84.0% probability that he/she will pay more than 50% of the AFP, and so on.

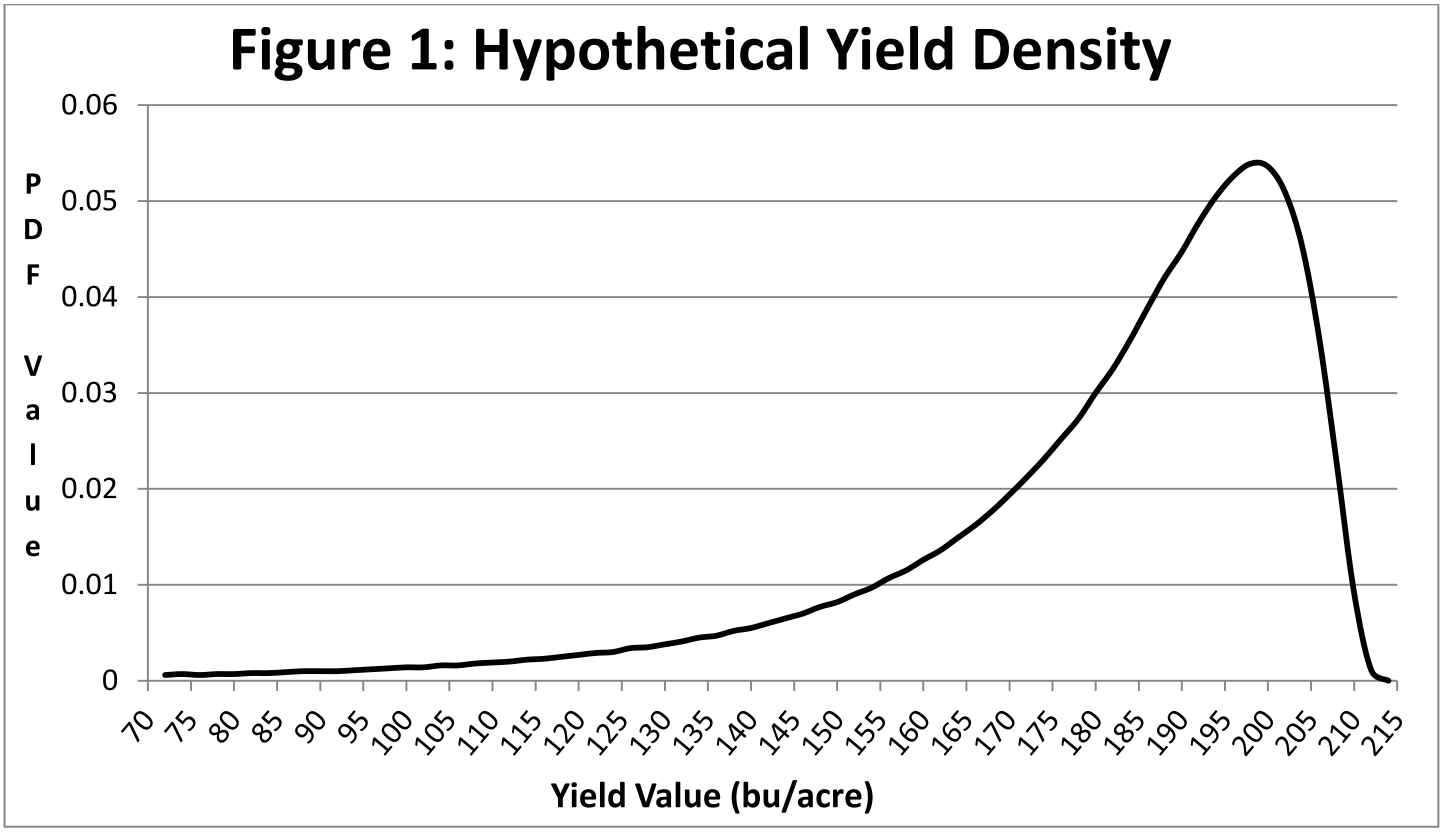
Figure 1: Hypothetical Yield Density
PDF Value
0.06
0.05
0.04
0.03
0.02
0.01
0
70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215
Yield Value (bu/acre)

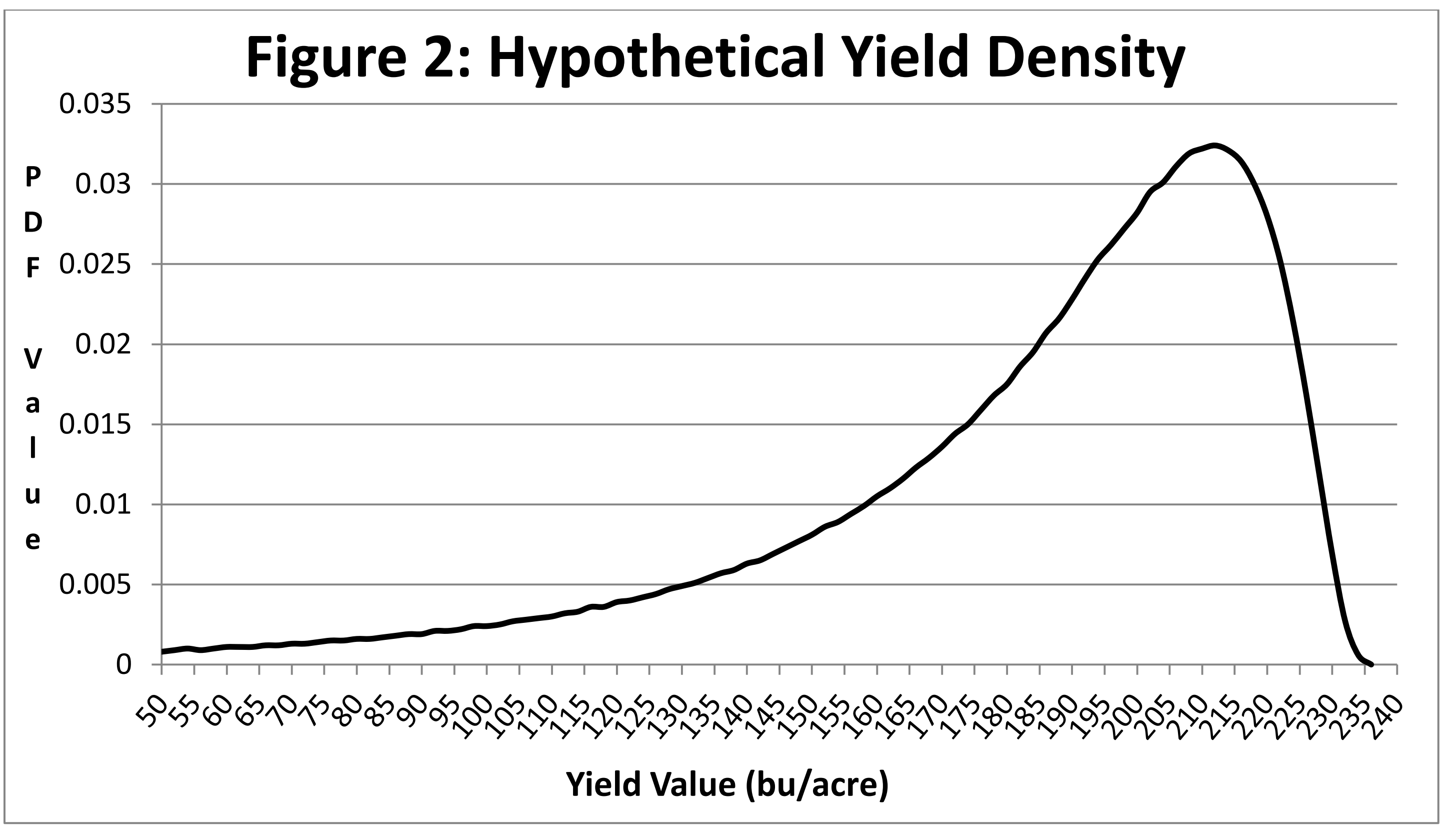
Figure 2: Hypothetical Yield Density
PDF Value
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240
Yield Value (bu/acre)