Proposed Farm Bill Impact On The Optimal Hedge Ratios For Crops

Trang Tran

Keith H. Coble

Ardian Harri

Barry J. Barnett

John M. Riley

Department of Agricultural Economics

Mississippi State University

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Abstract

Revenue insurance with shallow loss protection for farmers has been introduced recently. A common attribute of most shallow loss proposals is that they would be area-revenue triggered. The impact on optimal hedge ratios of combining these shallow loss insurance proposals with deep loss farm-level insurance is examined. Since crop insurance, commodity programs and forward pricing are commonly used concurrently to manage crop revenue risk, the optimal combinations of these tools are explored. Numerical analysis in the presence of yield, basis and futures price variability is used to find the futures hedge ratio which maximizes the certainty equivalent of a risk averse producer. The results generally reveal a lower optimal hedge ratio with area-insurance than with individual insurance and show that STAX and ARC tend to slightly increase optimal hedge ratios.

Keyword: crop insurance, simulation, hedging

Introduction

Uncertainty in crop price and yield is a fundamental problem for agricultural producers. Risk management tools, which reduce crop price volatilities, are available from the public sector and private markets. Privately - provided risk reducing products such as futures contracts have been shown to be effective instruments that help farmers deal with price fluctuations. In the public sector, the government provides various risk reducing instruments. For example individual and area yield insurance products have been offered for decades. In 1996, individual revenue insurance was introduced which added price risk protection to the federally-subsidized insurance products. This created a controversy at that time about whether the new revenue insurance designs were a substitute for futures and options contracts.

Ag Risk Coverage (ARC) and Stacked Income Protection Plan (STAX) are two examples of aggregate revenue insurance designs that have been proposed in legislation passed by the U.S. Senate in 2012, but no adopted in law. These designs are both area revenue-triggered shallow loss programs. By "shallow loss" we mean that once triggered the indemnity function pays only for a thin layer of losses. These programs are designed to work in conjunction with individual coverage crop insurance that indemnifies deeper losses. Both ARC and STAX have many attributes of the Group Risk Plan (GRP) and Group Risk Income Protection (GRIP) insurance programs except that GRP and GRIP are assumed to stand alone and cover both deep and shallow losses. If farm yield and county yield are not perfectly correlated, farmers have to deal with the yield basis risk in these products (Deng et al., 2007). Thus, aggregate revenue insurance may have a different effect on the optimal hedge. To our knowledge the effect of area-based insurance such as the Group Risk Plan (GRP) and Group Risk Income Protection (GRIP) on optimal hedge ratios has not been addressed. This study examines those products and the effect of ARC and STAX on the optimal hedge ratios. Specifically, we evaluate the mutual interaction of crop insurance, commodity programs and futures.

To understand the impact of new commodity programs on farmers' welfare, a computation of return from each insurance program is required. Implementing this requires a detailed simulation of prices and yields as well as their correlation. From this simulation, outcomes of prices and yields are employed to evaluate the change of optimal hedging ratios from using only crop insurance and futures to those associated with new aggregate based revenue insurance programs supporting the shallow loss coverage (ARC and STAX).

This paper makes several contributions to the literature. The results show the difference in the effect on the optimal hedge of county yield insurance with that of individual yield insurance. Moreover, the findings of the shallow loss protection insurance combined with hedging can point out that this type of insurance is a complement to the futures market. As to the other contribution of this paper, the question of whether the participation of the U.S government in price risk protecting market supports or overlaps with the futures market can be answered from that assessment. Thus, the role of the U.S government in providing price risk protecting tools for farmers can be appraised more clearly.

Literature Review

Optimal Hedge Ratios

There have been several related works on how the optimal hedge ratios of farmers vary under the combined effect of futures, insurance and federal insurance program. McKinnon (1967) in his seminal paper found the "natural hedge" of yield variability. He showed the shield from "natural hedge" would lower the optimal hedge ratios of producers because farmers can forecast the higher price in a year of low yield.

The growing literature on optimal hedge ratios under price change, basis and yield risk with futures and insurance was addressed by Coble et al. (2000). They contributed an understanding to the investigation of the positive effect of yield insurance on optimal hedge ratios versus the negative effect of revenue insurance when these risk management tools are used with hedging. Their research found that yield insurance has a positive effect on the optimal hedge ratios given no yield basis risk. With the assumption of basis and price risk, Coble et al. found that Revenue Protection with harvest price exclusion has a negative effect on optimal hedge ratios lowering the ratios about 10%. The effect of area based insurance on the optimal hedge ratio has not been evaluated.

Price and yield distributions

Specification of particularly distributional form which is appropriate for price has been an attractive topic for various debates. Recent studies tend to prefer lognormal distribution as a proper functional form for crop prices. Goodwin et al. (2000) found that the price distribution can be a mixture of distributions having different variances, thus the normality distribution imposed on price in previous studies was not appropriate. They suggested the use of a lognormal distribution for crop prices.

The literature on yield distribution can be categorized into two groups: the parametric and the nonparametric models. Nonparametric models were proposed by Goodwin and Ker (1998). This approach employs Kernel density estimation methods to fit a distribution to a finite set of data. Nevertheless, this method also has some drawbacks. First, due to the use of “bandwidth”, the data outside the range are not fitted precisely so that the outlier effect would not be fully evaluated. Second, there is no density formula specified which hinders researchers in calculating some statistical indices. The parametric model can give a specific functional form and convenient calculation to researchers. Moreover, this method can give a specific density imposed on a range of data. Parametric models imposed on yield distributions include the Gamma distribution (Gallagher, 1987) and the conditional beta distribution (Nelson and Preckel, 1989). Harri et al. (2009) tested the normality assumption on a wide range of data collected across the U.S crops. Their result showed that in Corn Belt area, there is a rejection of the normality hypothesis. Outside this area, other counties' yields have distributions which are positively or negatively skewed. The normality testing for wheat yield in southern and central plains region failed to reject the hypothesis of a Gaussian distribution. For yield distribution, the Beta distribution can reasonably explain the data series because of its flexibility and measurability of statistical orders.

Trend estimation

Technology and weather change over time periods can have a strong influence on crop yields. Furthermore, technological trends may change over time. Hafner (2003) proposed the linear trend estimation in detrending crop yields. This method is straightforward in that it uses the ordinary least squares approach in calculating the residuals and thus, implicitly infers that technological alteration on crop yields is consistent over time periods. Harri et al. (2011) employed the more sophisticated models – the one and two knot spline models. The knots are freely defined so that the trend of crop yields would be more accurate. In other words, the yield data would itself "tell" the true trend. This technique is employed in this analysis to detrend historical yields.

Area based insurance

Deng et al. (2007) investigated that when farm yield is not perfectly correlated with county yield, yield basis risk occurs. Thus, farmers have to choose between a higher basis risk (area based product) and a higher cost (farm based product). This study adds two area based revenue insurance products to examine their result. One is ARC and the other is STAX. It is important to note that the previous papers addressing optimal hedging all assume the individual based insurance has no yield basis risk. Thus, the implication of hedging with area revenue products has not been examined in the literature.

Simulation

Revenue is the product of yield and price, thus its volatility depends on yield variability, price volatility and the interaction between price and yield. Simulation can be employed to solve for the join distribution. The common idea in every simulation depends on the Inversion method in which the special property of the cumulative density function (cdf) is used. For any given variables that follow the cdf, they have to be uniformly distributed. Simulation uses the advantage of uniform distribution in that it is invariant during the translation process. Thus, it preserves the nexus between variables needed to be simulated. The simulation procedure employed is Phoon, Quek and Huang (PQH) described by Anderson et al. (2009). This procedure permits users to simulate correlated random variables in joint distribution without restricting the basic form of marginal distributions. Hence, it is useful to simulate variables that are not normally distributed.

Conceptual Framework

von Neuman-Morganstern expected utility is employed as the theoretical construct of this research. Certainty equivalents are derived from a constant relative risk aversion (CRRA) utility function and used to calculate the optimal hedge ratios. The CRRA utility function for each farmer is given by the canonical formula following:

$$U = \frac{W^{1-r}}{1-r} \text{ if } r \neq 1 \text{ and } U = \ln W \text{ if } r = 1$$

where U is the utility of a farmer, W is stochastic end of season wealth of a farmer and r is the coefficient of this CRRA utility function. Once the expected utility is defined, the certainty equivalent can be calculated as follow:

$$CE = [E(U)(1-r)]^{\frac{1}{1-r}} \text{ if } r \neq 1 \text{and } CE = e^{E(U)} \text{if } r = 1$$

where CE is certainty equivalent and $E(U)$ is expected utility calculated from the CRRA utility function with a known probability. According to Hardaker et al. (1997), the certainty equivalent for a given outcome can be used to define which alternative outcome is preferred. Ending wealth is the sum of beginning wealth and net return from both the market and risk managing instruments. The modeling specification of crop insurance, commodity program and hedging used is similar to that of Coble et al. (2000). Stochastic ending wealth of farmers at the end of the crop year can be calculated as follow:

$$W_{jk} = W_0 + NI$$

where W_{jk} is the end of season wealth which j denotes insurance program/crop insurance and k represents futures, W_0 is the beginning of season wealth, NI are net returns obtaining from realized income of farmer from his crops and from alternative risk management tools used at the beginning of his planting. Net realized income from planting crops of a farmer is:

$$NI_c = p_1 y_1 - C$$

where p_1 is harvest time stochastic cash price, y_1 is harvest time stochastic yield, C is the planting time cost which is assumed to be known. Net return from crop insurance, NI_i, comes from Actual Production History (APH), Revenue Protection with harvest price exclusion (RPPE), Revenue Protection (RP) and Group Risk Plan (GRP). APH is an individual yield insurance with yield shortfalls indemnified based on harvest time futures prices at planting time. The formula for net return of APH can be computed as:

$$NI_{APH} = f_0 Max[CL * y_0 - y_1, 0] - R_{APH}$$

where CL is level percentage of yield coverage, y_0 is expected yield at the planting time which is assumed to be known, f_0 is the harvest time futures price at the beginning time period and R_{APH} is premium paid at sign up. RPPE is based on the Revenue Protection policy and is a simple revenue guarantee based on planting time price expectations. Thus, this insurance does not count the upside effect of price in case harvest time futures price is larger than the beginning futures price. The formula for net return of RPPE can be written as:

$$NI_{RPPE} = Max[CL * f_0 y_0 - f_1 y_1, 0] - R_{RPPE}$$

where f_1 is the harvest time futures price, R_{RPPE} is premium paid at sign up.

RP is a second revenue insurance product. The loss at harvest time will be valued at the higher of the harvest time futures price or the planting time futures price. The net return formula may be written as:

$$NI_{RP} = Max[CL * Max(f_0, f_1) y_0 - f_1 y_1, 0] - R_{RP}$$

where R_{RP} is premium paid at sign up, other variables are previously defined. Farmers receive indemnity from the futures contract when the harvest time futures price is less than planting time futures price at sign up. The net return from hedging by futures can be calculated as:

$$NI_F = h_f * y_0 (f_0 - f_1) - R_f$$

where h_f is hedging ratio computed as percentage of expected yield at sign up, R_f is the transaction cost. Interest is assumed to be zero. GRP is the only county yield insurance examined in this study. Thus, it has the yield basis risk. The formula for the insurance can be calculated as:

$$NI_{GRP} = f_0 Max[CL * y_{0c} - y_{1c}, 0] - R_{GRP}$$

where y_{0c} and y_{1c} is expected county yield at the planting and harvest, R_{GRP} is premium paid at sign up. This paper examines two area revenue insurance programs that support farmers in covering the shallow loss. ARC provides both farm yield level trigger and county yield level trigger. For both farm and county levels, the indemnity has to be less than 10% of the benchmark revenue. The revenue guarantee has a trigger of 89% of average benchmark revenue for both cases. This paper evaluates the county level ARC. The benchmark revenue at this level is calculated similar to that of farm level but it is based on the 5 year Olympic average of county yields.

$$REV_{Bc} = y_{OAc} Max(f_{MYA}, f_{loan})$$

where REV_{Bc} is the ARC benchmark revenue at county level, f_{MYA} is the 5 year Olympic average of the national marketing year average, and other variables are as previously defined.. The county level ARC revenue guarantee is counted for 89% of the benchmark revenue:

$$REV_{Gc} = 0.89 REV_{Bc}$$

where REV_{Gc} is the county level ARC revenue guarantee. The county level ARC would be triggered as the county revenue at harvest time is less than the county level ARC revenue guarantee. Net return from the county level ARC is calculated as:

$$NI_{ARCc} = \delta 0.75 Max(0.1 REV_{Bc}, REV_{Gc} - REV_c)$$

where δ is dummy variable which is 1 if county revenue is smaller than revenue guarantee and 0 otherwise, REV_c is the county revenue at harvest time which is the product of average county yield and the higher of marketing loan rate or the "midseason price". The county revenue can be calculated as:

$$REV_c = y_{1c} Max(f_{MYA5}, f_{loan})$$

where REV_c is the ending time county revenue and other variables are as previously defined. STAX is a modified program from the Risk Management Agency (RMA) crop insurance program GRIP (Group Risk Income Protection). STAX sets a reference price, which is the higher price between futures prices at sign up and harvest time, to calculate the STAX revenue benchmark. This price protection builds a shield for farmers in case the crop price increases during the planting time period. The STAX guarantee revenue can be written:

$$Guarantee_{STAX} = 0.90 * CY_{OA} * \max\left(f_0, f_1\right)$$

where CY_{OA} is Olympic Average realized county yield. The STAX income protection insurance trigger depends on county yield. STAX is triggered if realized county revenue is less than STAX guarantee revenue. The net return from STAX can be written as:

$$NI_{STAX} = \max\Big(0, \Big(\max\Big(0.20 * Guarantee_{STAX}, \big(Guarantee_{STAX} - CY * f_1\big)\Big)\Big)\Big) - R_{STAX}$$

where CY is realized county yield, R_{STAX} is premium paid at sign up time, other variables are previously defined.

The objective function maximizes expected utility by choosing the optimal hedge ratio.

$$\underset{h}{Max} \int_p \int_y U(W_0 + p_1 y_1 - C + h y_0 (f_0 - f_1) - R_f + NI_i + NI_{ARC} + NI_{STAX}) f(p, y) dp dy$$

where h is the optimal hedge ratio, NI_i is the net returns from the individual insurance programs.

Data and Modeling

Data used to compute futures price changes and basis together with yields were obtained from the U.S. Department of Agriculture's National Agricultural Statistical Service (NASS) and the Commodity Research Bureau (CRB) database. Three counties evaluated are: McLean County in Illinois with soybean and corn crops, Sheridan County in Kansas with corn and wheat crops, and Yazoo County in Mississippi with soybean and cotton crops. The PQH simulation is employed to generate variables of futures price changes, basis, marketing year average price and yields. One knot model (Harri et al., 2011) is used to detrend the county yields.

Table 1 reports the descriptive statistics of the simulated outcome for futures prices, farm yields and crop revenues. The coefficients of variation (CV) for futures prices across crops are almost the same and range from 0.17 to 0.21. Thus, there is not too much difference in the futures price variability among the counties. However, for farm yields, the highest CV is for the crops in Yazoo County so that it results in the higher yield variability in this area compared to other regions.

Table 2 reports the correlation matrices of the variables as the input of the PQH simulation. There exists a negative relationship between futures price change and yields. This result is also consistent across crops. The correlation between farm yield and county yield is highest in McLean County and lowest in Yazoo County. Therefore, farmers in Yazoo County have to deal with the highest risk compared to the others.

Results

The optimal hedge ratio for each crop in the presence of alternative crop insurance combining with shallow loss insurance is examined. Figures 1 through figures 8 show the results of optimal hedge ratios found when different types of insurance are used with hedging[1]. The solid line in every figure is the optimal hedge ratio change at different coverage level when only yield insurance used. Sheridan County with wheat has the earliest change in the optimal hedge ratio at 35% of insurance coverage. In most counties, the earliest change in the optimal hedge

[1] The range of coverage levels examined goes beyond those actually offered by the Risk Management Agency. However, other coverage levels are modeled to investigate the relationships of interest.

ratio starts from around 45% of coverage level. As the coverage level increases for each county, there exists the consistent relationship between the optimal hedge ratio and the coverage level. APH, which is the individual yield insurance, results in higher hedge ratios than RP, RPPE, or GRP for every county. McLean County with corn and Sheridan County with wheat have the highest hedging level as the coverage level increases from 40%. This can be explained in that APH is a typical farm yield based insurance so that it protects farmers from yield risk. Moreover, APH does not have yield basis risk, which incurs only for county yield based insurance. This result is consistent with the finding of Coble et al. in that individual yield insurance is a complement to hedging. For revenue insurance, the results are interesting. RPPE is always associated with the decrease in the optimal hedge ratio as the increase of crop insurance coverage for every county. This result clarifies the finding of Coble et al. in that the revenue insurance has the mixed effect on the optimal hedge. RPPE combined with hedging even decreases the optimal hedge ratio to zero in Yazoo County because this county has more yield variability compared to other counties. Although RP has upside price protection, it increases the optimal hedging in only McLean County corn. In other counties, this insurance decreases the optimal hedge ratio. These results of RP and RPPE can be explained in that as coverage levels increase, the revenue insurance substitutes for the price risk protection provided by hedging. As GRP coverage levels increase, optimal hedge ratios increase for every county. However, the optimal hedge ratio is below that of APH insurance at the same coverage level. Unlike APH, GRP insures county yields. Therefore, yield basis risk would have an effect on GRP. This explains why GRP has lower optimal hedge ratios than APH.

ARC and STAX results show that they are complements to hedging when they are combined with either yield insurance or revenue insurance. While ARC slightly increases the optimal hedge ratio at about 4% for every crop, STAX increases the optimal hedge ratio by approximately 10%. This result may reflect the fact that ARC covers a narrower layer of revenue risk than does STAX.

Conclusion

This study examines the effect of county based revenue insurance, which protects the shallow loss for farmers' revenue, on the optimal hedge ratio as producers use either yield insurance or revenue insurance in combination with the futures contract. Results show that ARC and STAX are moderate complements to hedging in that they increase the optimal hedge ratios as the insurance coverage increases. But, the effect is generally not more than ten percent. The paper also contributes a new finding in that, due to yield basis risk, the county based yield insurance, has a lower optimal hedge ratio than would occur with the equivalent coverage level individual yield insurance. Obviously, other counties should be examined in the future to test the findings of this paper.

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Table 1: Descriptive statistics of data from simulation

Parameter		McLean, IL Corn	McLean, IL Soybean	Yazoo, MS Cotton	Yazoo, MS Soybean	Sheridan,KS Wheat
		Counties				
Futures price	Std. Dev	1.375	2.69	0.148	2.68	1.42
	Mean	7.14	15.01	0.716	15.03	8.35
	CV	0.19	0.18	0.21	0.18	0.17
Farm yield	Std. Dev	44.08	13.43	419	21.92	14.4
	Mean	191.61	55	1060	51.96	42.6
	CV	0.23	0.24	0.40	0.42	0.34
Revenue	Std. Dev	322.42	207.33	807.45	296.01	269.35
	Mean	1411.7	818.38	1418.5	683.86	380.88
	CV	0.23	0.25	0.57	0.43	0.71

Table 2: Correlation matrix for Phoon-Quek-Huang simulation

Table 2.1: Correlation matrix for McLean,IL - Corn

	Futures price change	Basis	MYA	Farm yield	County yield
Futures price change	1	-0.366	0.546	-0.533	-0.611
Basis		1	0.259	0.371	-0.541
MYA			1	-0.288	-0.242
Farm yield				1	0.682
County yield					1

Table 2.2: Correlation matrix for McLean,IL - Soybean

	Futures price change	Basis	MYA	Farm yield	County yield
Futures price change	1	-0.284	0.488	-0.592	-0.593
Basis		1	0.102	0.325	-0.247
MYA			1	-0.123	-0.252
Farm yield				1	0.62
County yield					1

Table 2.3: Correlation matrix for Sheridan Wheat

	Futures price change	Basis	MYA	Farm yield	County yield
Futures price change	1	-0.181	0.402	-0.443	-0.524
Basis		1	0.14	0.07	-0.227
MYA			1	-0.167	-0.312
Farm yield				1	0.54
County yield					1

Table 2.4: Correlation matrix for Yazoo, MS-Cotton

	Futures price change	Basis	MYA	Farm yield	County yield
Futures price change	1	0.6092	0.498	-0.403	-0.453
Basis		1	0.142	0.1883	-0.261
MYA			1	-0.1415	-0.233
Farm yield				1	0.294
County yield					1

Table 2.5: Correlation matrix for Yazoo,MS-Soybean

	Futures price change	Basis	MYA	Farm yield	County yield
Futures price change	1	-0.49	0.465	-0.481	0.5114
Basis		1	-0.366	0.194	-0.353
MYA			1	-0.0733	-0.41
Farm yield				1	0.34
County yield					1

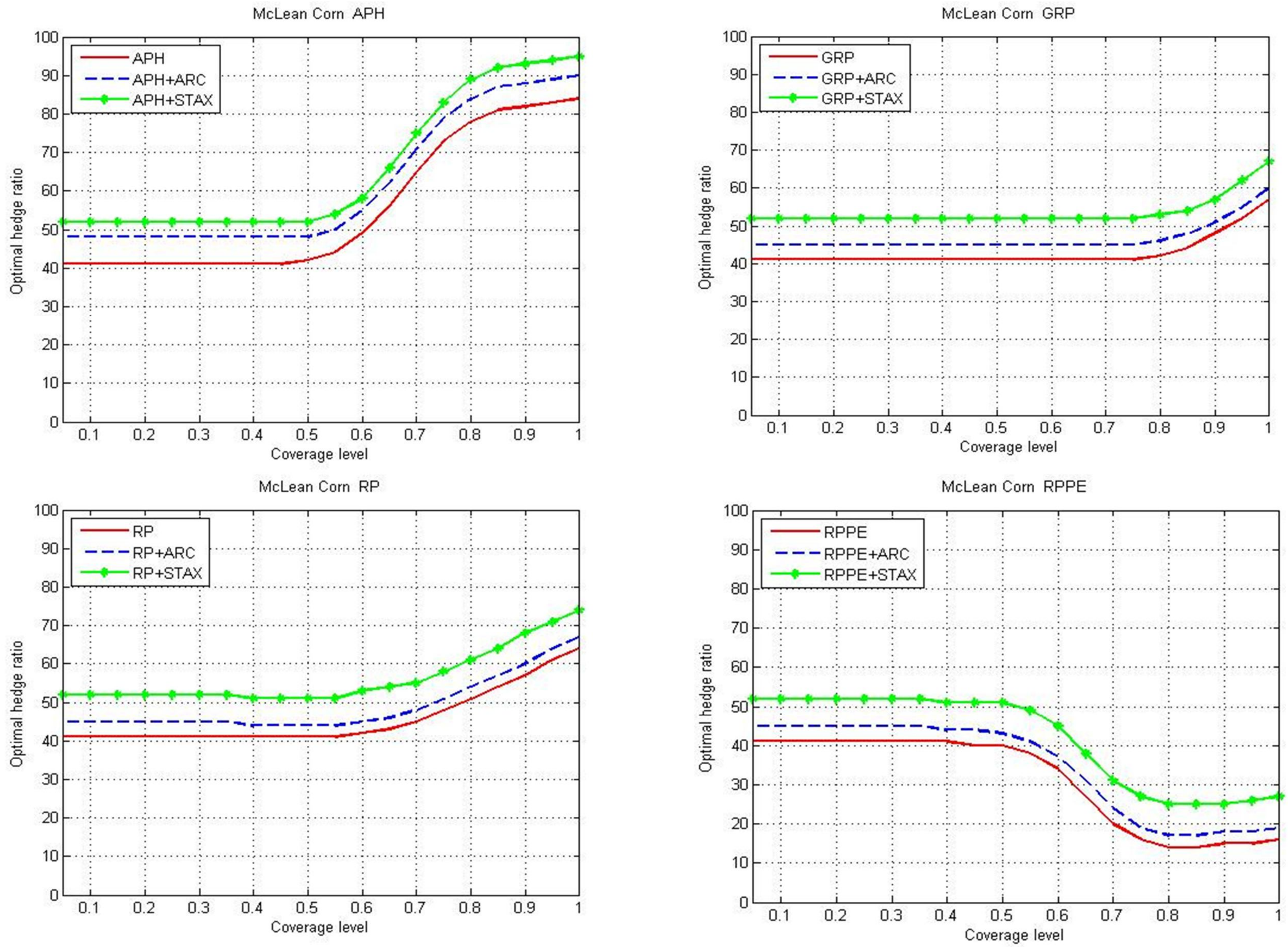

Figure 1: Optimal hedge ratios for Corn Crop in McLean County

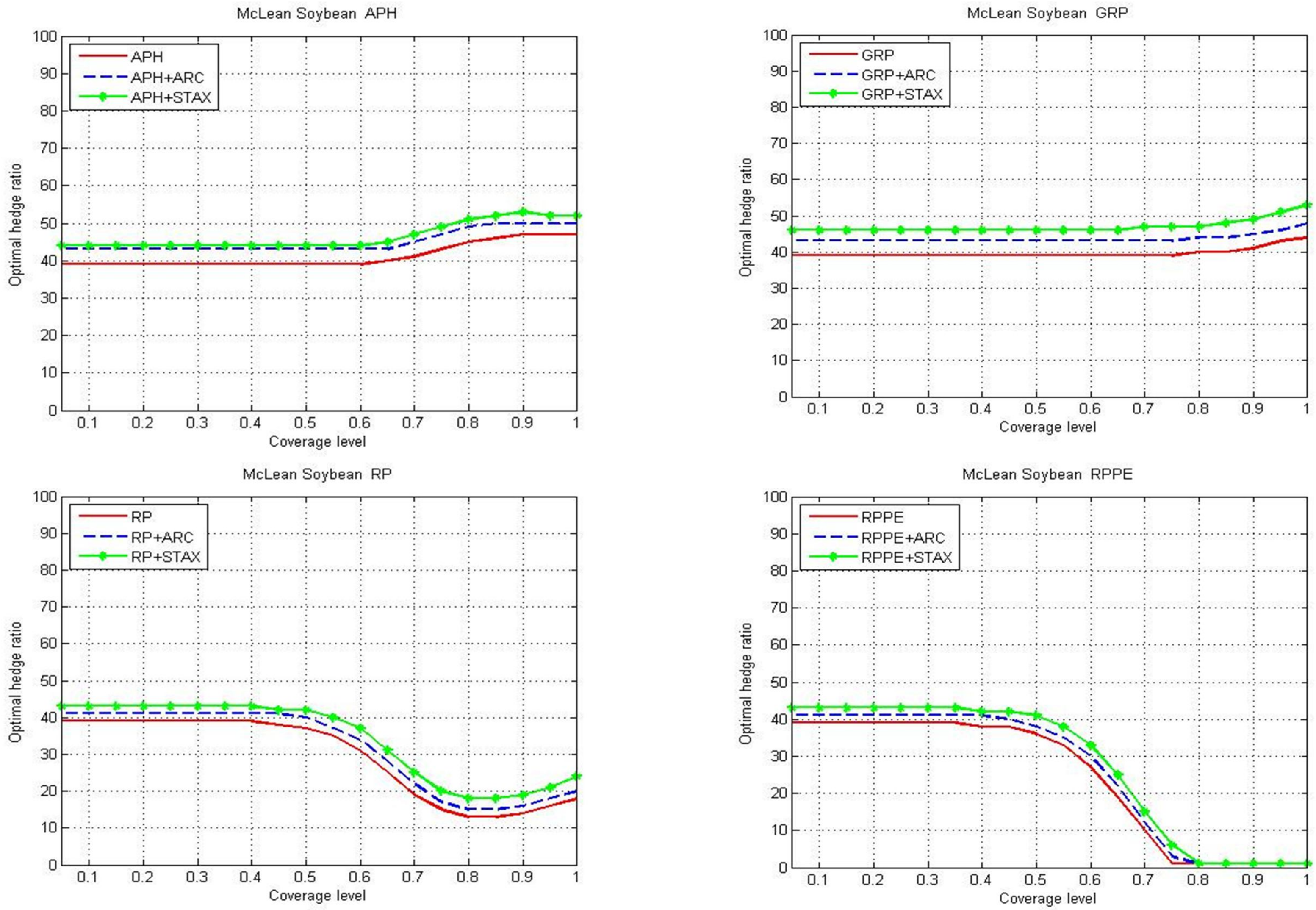

Figure 2: Optimal hedge ratios for Soybean Crop in McLean County

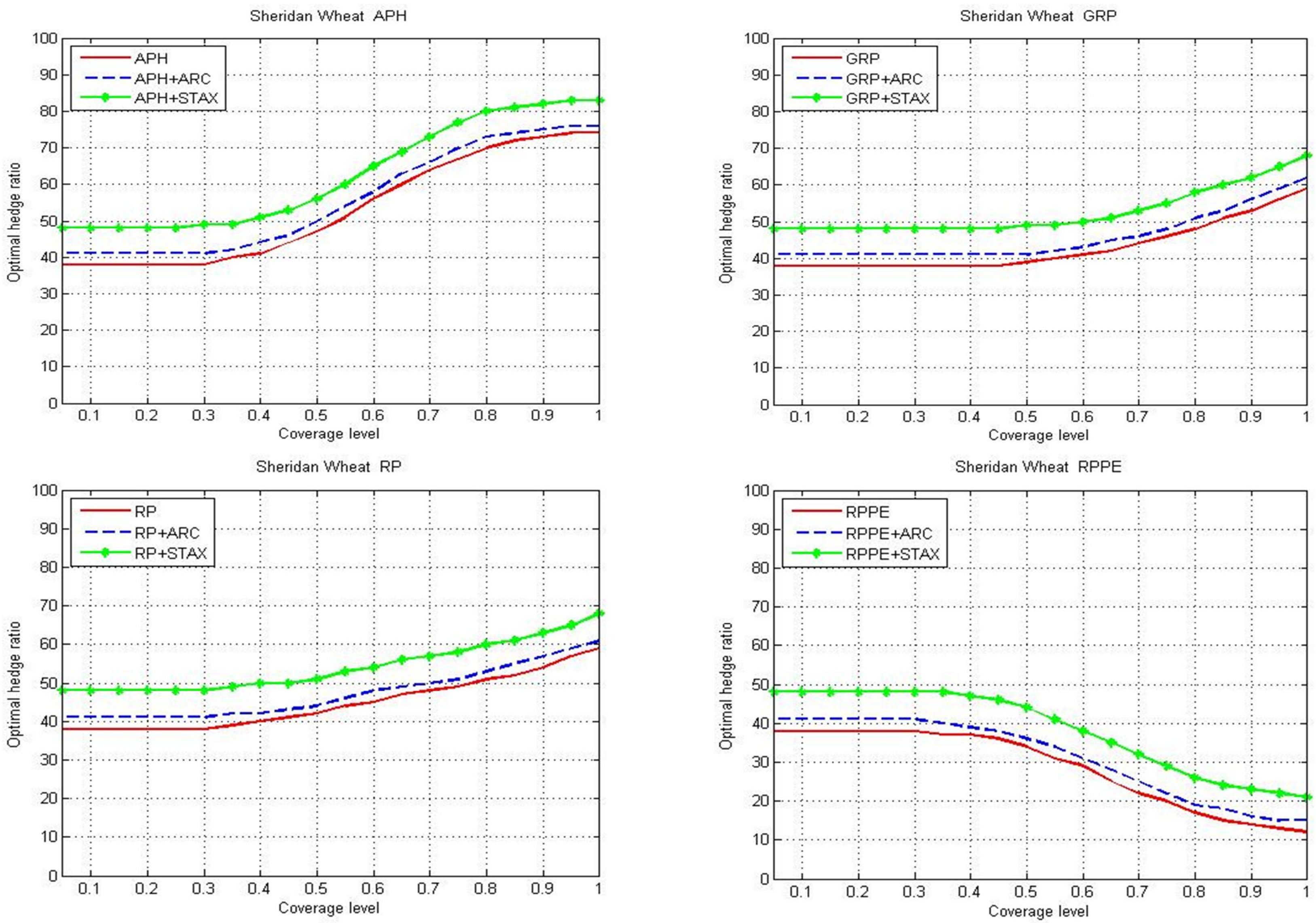

Figure 3: Optimal hedge ratios for Wheat Crop in Sheridan County

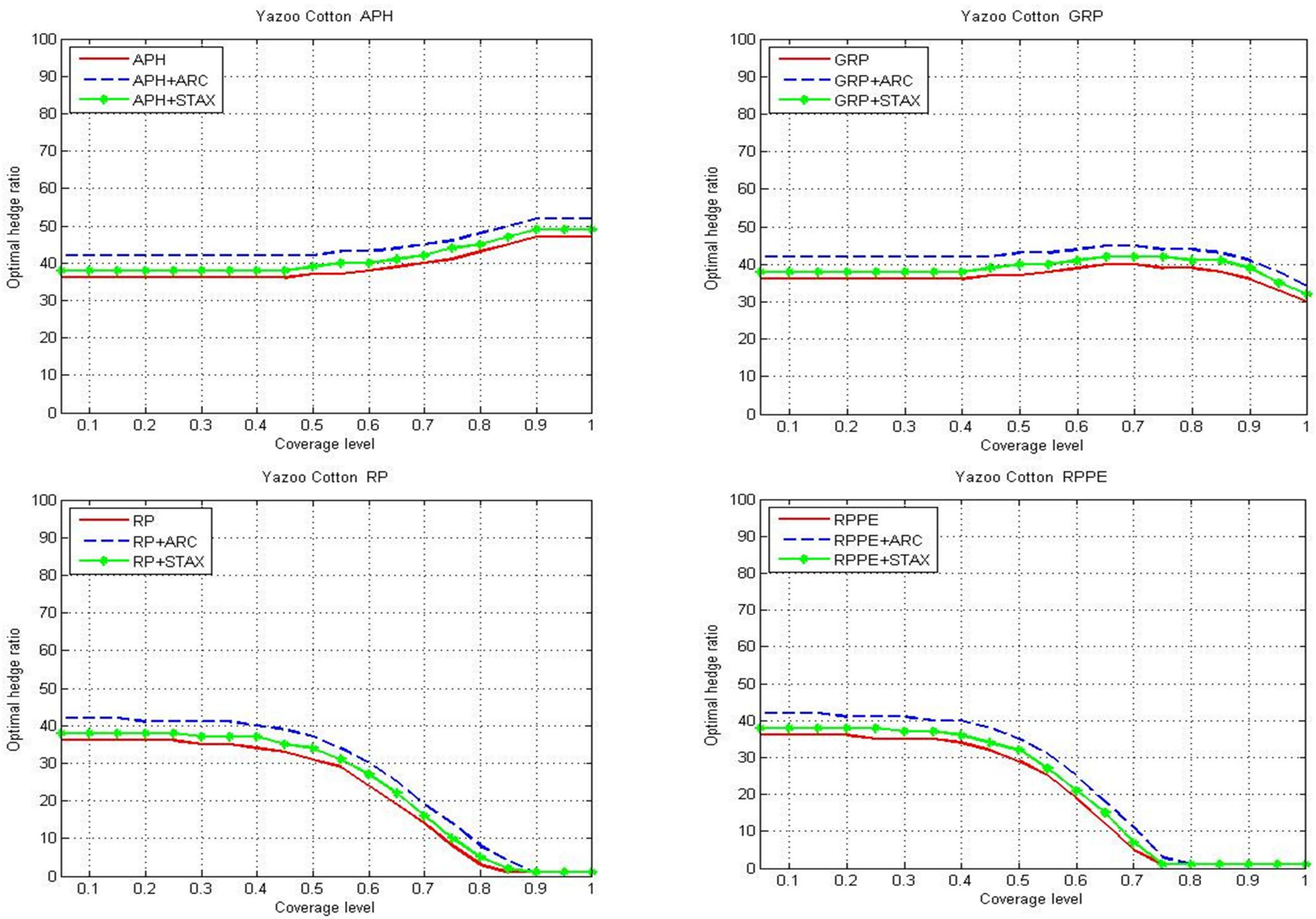

Figure 4: Optimal hedge ratios for Cotton Crop in Yazoo County

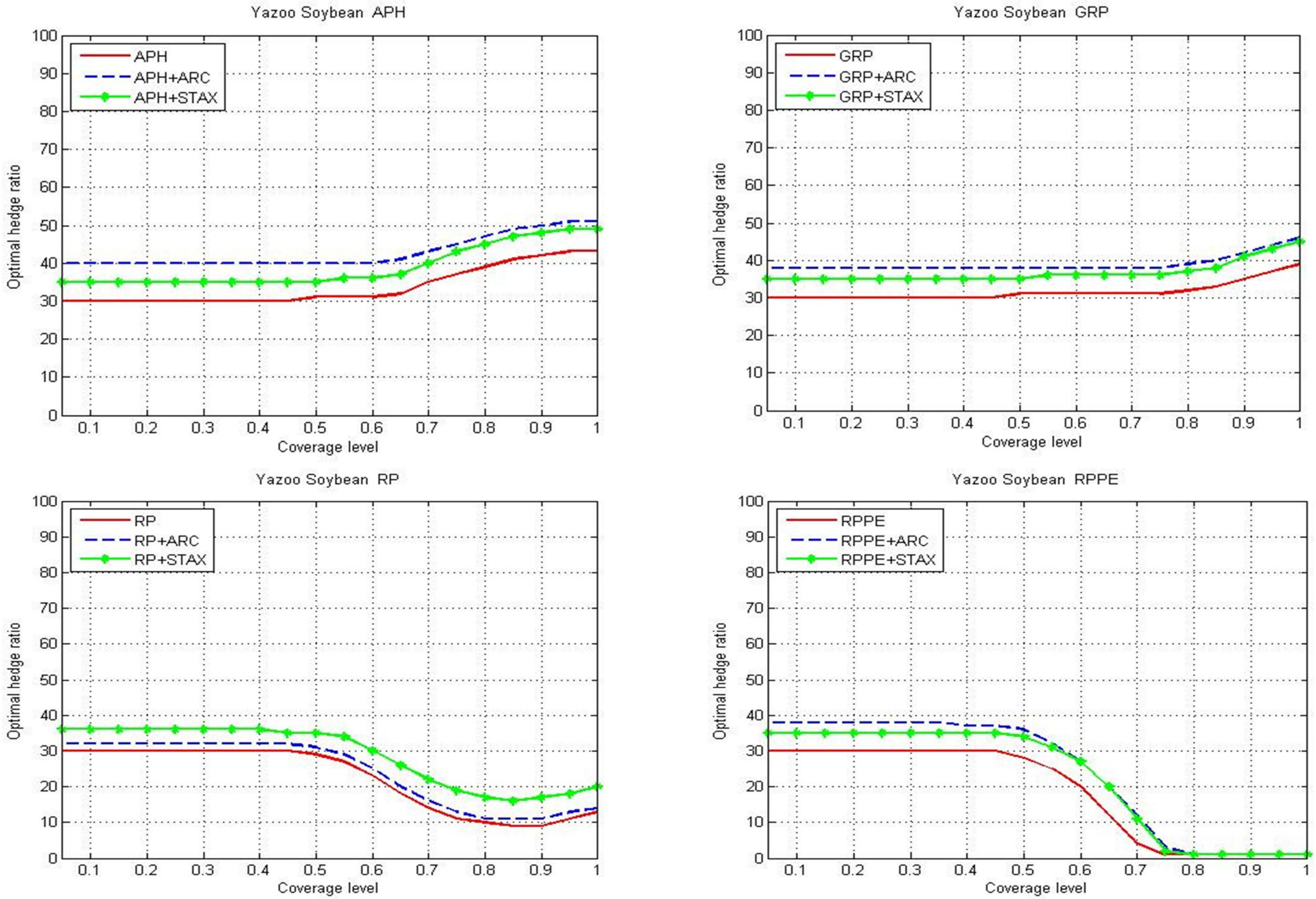

Figure 5: Optimal hedge ratios for Soybean Crop in Yazoo County