Impact of Powerlines on Cost of Crop Production

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A field study was conducted to determine the direct costs incurred by crop producers whose fields are traversed by overhead electric transmission lines. Primary data were collected on the machinery time loss working around powerline support structures, the crop area loss beneath support structures, and yield loss beneath powerlines. Results indicate that the cost of time loss and area loss are affected by the support structure's location in the field and its orientation to the crop rows. The single greatest cost is due to cotton yield loss beneath a 500-kv wire.

Increased urban and rural demand for electric services has been accompanied by a growth in the number of electric transmission lines which cross the countryside. Inevitably, lengthy segments of these powerlines pass directly through productive agricultural land. The objective of this study was to determine the direct costs incurred by crop producers whose fields are traversed by overhead electric transmission lines. The impact of two types of transmission lines (115/230-kv wooden H-pole, 500-kv steel lattice tower) on the production costs of five field crops (cotton, rice, soybean, grain sorghum, and double-cropped wheat-soybeans) is assessed based on a field study in Eastern Arkansas. These results should provide information useful in negotiating settlements whenever right of way is sought for the construction of new electric transmission lines, or whenever cropland traversed by powerlines is sold or leased.

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Hypothesized Effects

Previous powerline studies have been designed around the hypothesis that powerlines create direct costs for farmers due to one or both of the following effects:

1. A powerline support structure is a physical obstruction that impedes machinery field operations and precludes a certain area from being cropped (pole effects).

2. The electric transmission lines themselves have a negative impact on crop yields either by causing crop stress due to a high-voltage electromagnetic field or by impeding aerial application of agrichemicals to the growing crop (wire effects).

The hypothesized pole effects identified above result in two types of losses for the crop producer: (1) Time loss—a support structure impedes field operations, resulting in increased labor and machinery time (required to work around support structures) throughout the cropping season. (2) Area loss—a support structure precludes a certain area directly beneath it from being planted or harvested, resulting in decreased crop production. By contrast, the hypothesized wire effects result in yet another potential loss: (3) Yield loss—depressed or reduced yields may occur in the vicinity of the powerline due either to ineffective application of agrichemicals by airplane or due to crop stress caused by electromagnetic field beneath transmission wires.

Previous Studies

Previous investigations have used a variety of methods to assess time and area loss caused by an electric transmission line support structure in a field (pole effects). Separate studies sponsored by Ontario Hydro[10] and Doane Agricultural Service[3] used field-collected data to determine how support structure size, structure location in the field, orientation of the structure to row-crops, size of machinery complement, and type of crop grown affected area loss and time loss in crop production. Gustafson et al.[6] used low-altitude aerial photography of 2,803 support structures over 17 powerline segments in the Midwest in order to relate land loss from crop production to type, size, placement, and orientation of support structures. Fortin and Vigneault[4] describe the development of a computer program that simulates land loss and time loss based on parameters obtained from field data and laboratory simulation studies. A set of related studies conducted for the American Electric Power System investigated the impact of high-voltage electromagnetic field on crop yields and biological processes (wire effects). Hodges and Mitchell[8] measured plant height and dry matter of oats, corn, and soybeans at distances ranging between 50 and 300 ft from an experimental 895-kv powerline. In a similar study, Greene[5] measured plant height and dry weight, chlorophyll content, germination and cell division of corn, wheat, soybeans, rye and onions at points near and at 900 ft from a high voltage wire. Neither study demonstrated negative effects on crop yield or development due to the powerline.

Amstutz and Miller[1] conducted farm interviews over a 2-year period to determine whether a 765-kv powerline affected livestock behavior and production on 11 Indiana farms. Similarly, Hodges and Mitchell[9] report a "visual" inspection made along 204 mi of a 765-kv line through agricultural land in Indiana. None of the observation parameters—which included the incidence of crop pests and disease, farm management practices, and evidence of soil compaction—was found to be influenced by the presence of a transmission wire. Finally, a pilot study by Osborn et al[11] used small plot yield samples in producer-grown cotton and soybean fields in Arkansas to determine whether wire effects caused depressed yields near a 115-kv powerline. No significant effects on crop yields were detected.

Field Study: Data Collection

For the present study, field data were collected in four counties of Eastern Arkansas during the 1983 cropping season to estimate the direct costs of additional time to complete field work and the crop area loss caused by powerline support structures. In addition, although the previous studies cited above refuted the hypothesized electromagnetic field wire effect, data were collected that would enable the present study to test whether yield loss could be associated with cotton, rice or soybean grown beneath a 500-kv powerline. Typical management practices for two of these crops—cotton and rice—include aerial application of inputs and might affect crop yields, if ineffectively applied due to the presence of a 500-kv powerline. Consistent with the finding of Osborn et al[11] no yield-loss costs were hypothesized for crops growing beneath a 115/230-kv powerline and, hence, no data on potential yield loss beneath 115/230-kv powerlines were collected.

Time loss. In order to determine time lost maneuvering machinery around powerline support structures, a total of 108 time-and-motion-studies (TMS) were conducted between April and November. All TMS were conducted during normal on-farm field operations involving 33 different farm operators. The number of TMS conducted around steel lattice towers and wooden H-poles was 72 and 36, respectively. In addition to the time difference required to work around each structure, other relevant information was recorded:

1. Structure location. Location of each structure was designated as being in the "interior" or along the "edge" of the field. "Edge" included all structures located in the headland, corner or along the side of the field within 50 feet of a fencerow. "Interior" included all other structures.

2. Structure orientation. The orientation of the support structure to the direction of the crop rows and/or field traffic was designated as being either parallel, perpendicular or diagonal. If machinery flows were at 90% (180°) to the wide dimension of a structure, orientation was perpendicular (parallel). All other orientations were designated diagonal.

3. Implement size. Machinery implements sampled had effective operating widths ranging from two-row cotton pickers to 32 ft disks. All operating widths were aggregated into the three groupings: small (width less than 14 ft); medium (greater than or equal to 14 ft but less than 25 ft) and, large (greater than or equal to 25 ft), corresponding to 4-, 6-, and 8-row equipment, respectively.

4. Field operation. TMS were conducted for a total of 17 different field operations ranging from primary tillage to harvest operations. Similar operations were later aggregated into six groupings for purposes of analysis: primary tillage, disking, seed-bed preparation, planting-seeding, crop maintenance, and harvest.

Area loss. The total area lost from crop production directly beneath a powerline support structure was measured for 28 steel lattice towers and 21 H-poles shortly after harvest in the fields of 41 different farm operators. In addition to the area lost from production, the type of crop, structure location in the field (interior, edge) and structure orientation to crop rows (diagonal, perpendicular, parallel) were also recorded.

Yield loss. Small plot yield samples were collected in 34 producer fields just prior to harvest in cotton, rice, and soybean fields traversed by a 500-kv powerline. For each crop, one half of the small plots were randomly located in a zone directly below ("under") the powerline and the other half were randomly located in a zone 150 ft away from ("away") the powerline. Sampling procedures followed guidelines established by the Arkansas Crop Reporting Service.

For cotton, a total of 120 yield plots (60 under, 60 away) were collected in seven producer cotton fields. Yield samples were air-dried for a minimum of 2 weeks before weighing. For rice, 150 (75 under, 75 away) samples were collected in 12 producer fields; for soybeans, 152 (76 under, 76 away) samples were collected in 15 fields. Rice and soybean samples were air-dried and threshed using a small-plot portable thresher. Sample weights were corrected for moisture content and temperature using appropriate conversions.

Results

Time loss. Table 1 provides a summary of the results of the TMS conducted to determine time loss working around transmission line support structures. The average increase in time required to work around a steel lattice tower, regardless of structure location, structure orientation, machinery size, or type of field operation, was 70 seconds per field operation per structure.

Unlike structure orientation, the location of a tower in the field did have significant impact on the time loss factor. Structures located on the edge of the field required half again as much time to work around as did those located in the field interior (94 vs. 62 seconds/field operation/structure).

Although average time loss increased with the size of machinery implements, no significant difference was detected between small, medium, and large equipment. When time loss was evaluated for alternative field operations, however, significant time differences were revealed between primary tillage and disking and between primary tillage and planting/seeding.

The average increase in time required to work around all H-poles in the study was under half the time loss recorded for steel towers (32 vs. 70 seconds, respectively). In addition, the impact of structure location and orientation on H-pole time loss was the reverse of that described for steel towers. Whereas location had no significant impact on time loss, H-poles with a parallel orientation resulted in just over one half the time loss of H-poles with a diagonal or

Table 1. Machinery Time-Loss Working Around Powerline Support Structures by Structure Location, Structure Orientation, Machinery Size, and Field Operation

Subsample	Steel Tower		Wooden H-Pole	
	Time Loss[1]	n[1]	Time Loss	n
Structure location				
Interior	62[a2]	54	35[a2]	28
Edge	94[b]	18	22[a]	8
Structure orientation				
Diagonal	77[a]	28	42[a]	9
Perpendicular	65[a]	37	42[a]	10
Parallel	70[a]	7	22[b]	17
Machinery size				
Small	56[a]	8	13[a]	2
Medium	66[a]	40	27[a]	20
Large	82[a]	24	42[a]	14
Field operation				
Primary tillage	36[a]	8	37[ab]	3
Disking	86[b]	15	51[ab]	5
Bed preparation	69[ab]	9	25[a]	9
Planting/seeding	102[b]	9	47[b]	3
Crop maintenance	71[ab]	13	28[ab]	6
Harvest	57[ab]	18	26[ab]	10
All structures	70	72	32	36

[1] Time loss and n are the subsample mean (seconds/field operation/structure) and number of observations, respectively.
[2] Time-loss values with different superscripts indicate significant difference between means within each subsample at the 5% level of significance.

Table 2. Area Loss Beneath Powerline Support Structures by Crop, Location of Structure in Field, and Orientation of Structure to Row Crop

Subsample	Steel Tower		Wooden H-Pole	
	Area Loss[1]	n[1]	Area Loss	n
Crop				
Cotton	2,273[2]	6	708[2]	3
Rice	1,832	4	538	4
Soybeans	2,545	18	584	14
Structure location				
Middle	2,320	24	594	20
Edge	2,599	4	567	1
Structure orientation				
Diagonal	2,469	16	630	8
Perpendicular	2,114	8	570	12
Parallel	2,412	4	576	1
All structures	2,359	28	593	21

[1] Area loss and n are the subsample mean (feet^2/structure) and number of observations, respectively.
[2] No subsample means of area loss were significantly different from each other at the 5% level of significance.

perpendicular orientation (22 vs. 42 seconds/operation/structure). Unlike steel towers, a perpendicular H-pole 14 ft wide provides little opportunity for "farming through" given the size of modern farming equipment.

No significant time difference was detected among the three machinery size categories for wooden H-poles. However, field operations included under the bed preparation category did result in significant time differences from the planting/seeding operation.

Area loss. Table 2 provides a summary of the postharvest field measurements taken to determine the amount of uncropped area around powerline support structures. The average unharvested area for all steel towers in the sample (2359 ft^2) was approximately four times the unharvested area beneath H-poles (593 ft^2). No significant difference in area loss was detected due to structure location, structure orientation, or type of crop grown.

Yield loss. Table 3 summarizes the results of the yield study conducted to determine whether crop yields are affected by the presence of a 500-kv powerline. Results of the statistical analysis are also presented in Table 3. A linear regression model was estimated for each crop subsample in order to provide a two-way analysis of variance explaining yield variation due to field differences and the presence of the overhead transmission line.

Among the three crops analyzed, only cotton showed a significant yield difference at the 5% level of significance. Cotton yields under the powerline averaged 506 lbs of lint compared with 593-lb yield 150 ft away from the powerline, i.e. a 15% yield decrease. On a field-by-field basis, cotton yields under the powerline ranged between 73% and 100% of yields away from the powerline. For the rice and soybean samples, some of the individual fields showed higher yields under the powerline, whereas other fields had higher yields away from the powerline. Nevertheless, while there was a significant yield difference between fields, no significant yield difference was detected for rice or soybeans within fields due to wire effect.

Estimated Cost of Time, Area and Yield Loss

Cost of time loss. Because each crop grown has a different set of field operations and management practices associated with it, the annual cost of time loss per support structure will vary from one crop to another. These annual costs of time loss were estimated by integrating the TMS field data of Table 1 with crop enterprise machinery budgets[2] of major crops produced in eastern Arkansas.

Procedures for estimating the cost of time loss for each crop were as follows: First, each field operation defined in each crop budget was classified into one of the six field operation categories identified in Table 1. Next, the time loss from each category was multiplied by the hourly machine cost to arrive at the increased cost per field operation per structure. Finally, estimates of increased time/structure/season and the increased cost/structure/season for steel towers and wooden H-poles were obtained by summing across all field operations defined in each enterprise budget for each crop.

The estimated cost of time loss regardless of structure location in the field is summarized for each crop under the column headings "All" in Table 4. In addition to costs on a crop-by-crop basis, Table 4 provides an "average" cost of time loss weighted by the relative acreage of major crops grown in eastern Arkansas.

Cost of area loss. The area lost from crop production directly beneath and around a powerline support structure is an income loss which represents a cost to producers that will be greater in years of high crop yields and prices than in years when yield and crop prices are low. The annual costs of area loss presented in Table 5 were estimated using 10-year average crop yields and 5 year average seasonal prices adjusted to 1983 dollars. Although area loss measurements were taken neither for wheat nor for grain sorghum in the field study, costs were nevertheless estimated for these crops consistent with the finding that crop type has no significant impact on uncropped area (Table 2).

Cost of yield loss. Decreased cotton yields beneath 500-kv electric transmission lines result in a loss of potential income, which is a cost to the cotton producer. The average annual cost of this yield loss was estimated using a 10-year average lint yield for eastern Arkansas and 5-year seasonal average prices for lint and cottonseed adjusted to 1983 dollars. On a per-steel-lattice-tower basis, the estimated cost of cotton yield loss is $85.25/year. This annual cost of yield loss accounts for both the loss of lint and cottonseed within the 1.46 acre area extending beneath the transmission wires supported by each steel lattice tower.[a] Because no significant yield loss was detected in rice or soybean fields, potential income loss due to the wire effect was not computed for these crops beneath a 500-kv wire. In addition, costs of yield loss beneath a 115/230-kv powerline were assumed to be zero, consistent with findings reported by Osborn et al.[11]

Total annual cost of powerline. Previous sections present estimates of the costs of time, area and yield loss based on field data collected in Eastern Arkansas, Tables 6 and 7 sum these cost estimates and provide an accounting of total costs incurred per support structure per cropping season. Separate cost estimates are given for two steel tower locations (interior, edge) and two H-pole orientations (parallel, nonparallel) in addition to total cost averaged across all structures. Tables 6 and 7 incorporate yield loss costs for cotton based on field data collected in both the present study and an earlier Arkansas study reported by Osborn et al.[11]

With regard to Tables 6 and 7, several points are noteworthy. First total annual direct cost per steel lattice tower ranged between $15.71 for a structure located in the interior of a sorghum field to $123.81 for a 500-kv structure located on the edge of a cotton field. Similarly, wooden H-poles resulted in annual costs ranging between $5.10 for a parallel pole orientation in a sorghum field and $14.22 for a nonparallel (diagonal or perpendicular) pole orientation in a double-cropped wheat/soybean field.

Second, the total annual direct powerline costs incurred with cotton production overwhelm the total costs incurred with other crops grown under a 500-kv line. This is due to the magnitude of yield loss costs relative to the costs of time loss and area

Table 3. Sample Means and Analysis of Variance Results for Cotton, Rice, and Soybean Yields at Points Under and 150 Feet Away From a 500-kv Powerline

	Cotton	Rice	Soybeans
No. of fields sampled	7	12	15
No. of yield samples	120	150	152
Units	lbs. lint	bu.	bu.
Mean yield, all	549.4	117.0	28.75
Mean yield, away	593.3[a]	113.9[a]	28.26[a]
Mean yield, under	505.6[b]	119.9[a]	29.24[a]
Difference (under-away)	−87.7	+6.1	+.97
Ratio (under/away)	0.85	1.05	1.03
Analysis of variance[1]			
Field effect, partial F	3.41	17.36	15.16
F-distribution, df	(6,112)	(11,137)	(14,136)
Significance level	0.0040	0.0001	0.0001
Wire effect, partial F	9.26	2.56	0.54
F-distribution, df	(1,112)	(1,137)	(1,136)
Significance level	0.0029	0.1122	0.4619

[1] Analysis of variance results are based on a linear regression model estimated for each crop yield sample. The model specified for each crop sample was: yield = $\alpha + \Sigma i\ \beta i$ FIELD + γ WIRE where FIELD is a binary variable for the i[th] field subsample, WIRE is a binary variable for observations under the powerline, and α, β, and γ are estimated parameters. Mean yields under and away from the wire with different superscripts indicate significant difference between each other at the 5% level of significance. Actual levels of significance for the wire and field effect are listed for each crop sample.

Table 4. Estimated Cost of Time Lost Working Around Powerline Support Structures for Five Crops, $/Structure/Season, 1983

	% Cropped[1]	Steel Tower Tower Location[2]			Wooden H-pole Pole Orientation[3]		
		Interior	Edge	All	Par	Non-Par	All
Cotton	7	$11.54	$17.49	$13.02	$4.31	$ 8.23	$6.27
Rice	21	7.28	11.04	8.22	3.34	6.38	4.86
Soybeans	43	9.24	14.01	10.43	3.25	6.20	4.72
Wheat/Soybeans	25	14.22	21.56	16.05	5.30	10.12	7.71
Sorghum	4	8.43	12.79	9.52	3.27	6.25	4.76
Average[4]	–	10.21	15.47	11.52	3.86	7.37	5.61

[1] Percentage of major crop acreage in Eastern Arkansas.[15]

[2] Values for tower locations; "interior" and "edge" reflect the average time required to work around towers in the field interior and edge (62 seconds and 94 seconds per operation) relative to the average time required for all towers (70 seconds per operation). See Table 2.

[3] Values for pole orientations; "parallel" and "non-parallel" reflect the average time required to work around poles parallel and non-parallel to crop-rows (22 seconds and 42 seconds per field operation) relative to the average time required to work around all poles (32 seconds per operation). See Table 2.

[4] Time loss costs averaged across all major crops weighted by the relative acreage of each crop grown.

Table 5. Estimated Cost of Area Loss Beneath Powerline Support Structures, ($/Structure/Season) 1983[1]

	% Cropped[2]	Steel Tower	Wooden H-pole
		2359 ft²	593 ft²
Cotton[3]	7	$21.07	$5.30
Rice	21	26.35	6.62
Soybeans (full-season)	43	9.10	2.29
Soy-wheat (double-cropped)	25	16.33	4.10
Sorghum	4	7.28	1.83
Average[4]	–	$15.30	$3.84

[1] Based on 5-year average prices for crops adjusted to 1983 dollars, and 10-year average historical crop yields for crop reporting districts 3, 6, and 9 in Eastern Arkansas.[13, 14]

[2] Percentage of major crop acreage in Eastern Arkansas.[15]

[3] Cost of area loss of cotton includes foregone returns for both lint and cottonseed production.

[4] Area loss costs averaged across all major crops weighted by the relative acreage of each crop grown.

Table 6. Estimated Total Direct Cost Incurred by the Presence of a 500-kv Powerline Supported by Steel Lattice Towers, 1983

Tower Location	Cost Category ($/tower/season)			
	Time Loss	Area Loss	Yield Loss[1]	Total Cost
Interior				
Cotton	$11.54	$21.07	$85.25	$117.86
Rice	7.28	26.35	-	33.63
Soybeans	9.24	9.10	-	18.34
Wheat/Soybeans	14.22	16.33	-	30.55
Sorghum	8.43	7.28	-	15.71
Average	10.21	15.30	5.97	31.48
Edge				
Cotton	17.49	21.07	85.25	123.81
Rice	11.04	26.35	-	37.39
Soybeans	14.01	9.10	-	23.11
Wheat/Soybeans	21.56	16.33	-	37.89
Sorghum	12.79	7.28	-	20.07
Average	15.47	15.30	5.97	36.74
All				
Cotton	13.02	21.07	85.25	119.34
Rice	8.22	26.35	-	34.57
Soybeans	10.43	9.10	-	19.53
Wheat/Soybeans	16.05	16.33	-	32.38
Sorghum	9.52	7.28	-	16.80
Average	11.52	15.30	5.97	32.79

[1] Based on the results of a yield loss study for cotton, rice and soybeans, only cotton showed a 15% decrease in yield below a 500-kv powerline. A zero yield loss for wheat and sorghum in this table is hypothesized and not based on field-collected data. Yield loss cost for cotton accounts for both lint and cotton-seed.

Table 7. Estimated Total Direct Cost Incurred by the Presence of a 115/230-kv Powerline Supported by Wooden H-Poles, 1983

Pole Orientation	Cost Category ($/pole/season)			
	Time Loss	Area Loss	Yield Loss[1]	Total Cost
Parallel				
Cotton	$ 4.31	$5.30	-	$ 9.61
Rice	3.34	6.62	-	9.96
Soybeans	3.25	2.29	-	5.54
Wheat/Soybeans	5.30	4.10	-	9.40
Sorghum	3.27	1.83	-	5.10
Average	3.86	3.84	-	7.70
Nonparallel				
Cotton	8.23	5.30	-	13.53
Rice	6.38	6.62	-	13.00
Soybeans	6.20	2.29	-	8.49
Wheat/Soybeans	10.12	4.10	-	14.22
Sorghum	6.25	1.83	-	8.08
Average	7.37	3.84	-	11.21
All				
Cotton	6.27	5.30	-	11.57
Rice	4.86	6.62	-	11.48
Soybeans	4.72	2.29	-	7.01
Wheat/Soybeans	7.71	4.10	-	11.81
Sorghum	4.76	1.83	-	6.59
Average	5.61	3.84	-	9.45

[1] Based on the results of the Arkansas pilot study,[11] no significant yield difference was detected for cotton or soybeans beneath a 115/230-kv powerline. A zero yield loss for all other crops in this table is hypothesized and not based on field data.

loss. Due to the high value of yield loss, cotton costs are three to seven times higher than for other crops.

Third, the magnitude of time loss costs relative to area loss costs varies widely in both tables. Because tower location and pole orientation affect time loss and not area loss (Tables 1 and 2), costs of time loss will comprise a greater proportion of total costs for those tower locations (edge) and pole orientations (non-parallel) that represents a more significant obstacle to machinery. It should be noted, however, that time loss costs are also relatively less important for those crops (cotton, rice) that employ significant use of aerially applied agrichemicals.

Finally, the costs incurred by H-pole powerlines are relatively small when compared to those supported by steel lattice towers. Averaged across all crops, the costs imposed by a steel tower are approximately 3 to 4 times greater than those for a wooden H-pole. This cost difference results not only from the relative size of each support structure, but also from the fact that significant yield loss was detected only under the 500-kv powerline.

Summary and Conclusion

The purpose of this study was to estimate the annual cost incurred by a crop producer whose field is traversed by a high voltage electric transmission line. Costs attributable to powerlines were hypothesized to result from pole effects (time loss, area loss) and wire effects (yield loss).

The basic findings that emerged from the field study are as follows:

1. Time loss around steel lattice towers was significantly less if the tower was located in the field interior, for wooden H-poles, the time loss was significantly reduced if the pole's orientation to crop rows was parallel. Average annual cost of time loss was $11.52/steel tower and $5.61/wooden H-pole.

2. Crop area loss beneath powerline support structures was nearly four times as great for steel towers as for H-poles. Structure location, orientation, and type of crop had no significant impact on area loss. Average annual cost of area loss incurred by producers was $15.30/steel tower and $3.84/wooden H-pole.

3. Yield of cotton growing directly beneath a 500-kv powerline was 15% less than yield in the remainder of the field. The average annual cost of this yield loss to a cotton producer was $85.25/steel tower. Rice and soybean yields were unaffected by the presence of the powerline.

Limitations of the study. The above results provide information useful in negotiating settlements whenever cropland traversed by powerlines is sold or leased, or whenever right of way is sought for the construction of new electric transmission lines. Time, area, and yield loss may not, however, account for the total costs which producers incur due to powerlines on their fields. Various studies[3,10,12] have suggested that additional costs encountered by producers result from occasional machinery collisions with structures, additional weed control beneath structures, crop damage due to maintenance entry by powerline employees, and depressed market or rental values for land on which powerlines are located. In addition, if overhead sprinkler irrigation is a feasible alternative for crop growers, then the costs incurred by powerline producers will include a potentially large foregone income if a sprinkler system is ruled out or if its design must be altered.[7]

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End Note

[a]*Based on a 10-year average lint yield of 480 lb/acre (Arkansas Crop Reporting Districts 3, 6 and 9) and a 15% yield loss under the wire. The average distance between steel towers in the study area was 1,100 feet; average outside wire-to-wire span was 60 feet. Income losses due to an average uncropped area of 2,359 ft*^{2} *directly beneath each support structure are accounted for separately as area losses.*