Supporting Information

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SI Text

Variability and Uncertainty in Value of Biocontrol Services. Aphid abundance, management strategy, soybean price, and land-use change each influence the value of biocontrol services. Here, we explore the magnitude of these effects in further detail and assess relative uncertainties in outcomes.

Aphid Abundance. Soybean aphid abundance was high in 2005 but low in 2006, resulting in large differences in the value of biocontrol services. Using the 10-year median price for soybeans (1996–2007), the value of biocontrol service across the 4 states for soybean crops grown without pesticides was \$224 ± 73 ha^{-1} (mean ± SEM) in 2005 but only \$19 ± 6 ha^{-1} in 2006, nearly a 12-fold difference (Table S1). This difference occurs because potential yield gains from the action of natural enemies are smaller in years of low aphid abundance. Since 2000, years of high and low aphid populations have frequently alternated, supporting our use of the mean estimates from 2005–2006 to project the value of biocontrol services to the landscape scale. If future studies determine that soybean aphid outbreaks occur with greater or lesser frequency, the overall value of biocontrol services will shift, becoming smaller with decreasing frequency of aphid outbreak.

Management Strategy. Under IPM and assuming the 10-year median price of soybean, the value of the ecosystem service is much lower than under biological control alone. For example, in 2005 the value of biocontrol services under IPM was \$23 ± 6 ha^{-1}, ≈10-fold less than the \$224 ± 73 ha^{-1} value under biocontrol alone (Table S1), because IPM producers limit the total potential for aphid damage to the crop by spraying at recommended thresholds. In 2006, when aphid populations were low, the ecosystem service value was more similar under both management strategies, \$24 ± 5 under IPM versus \$19 ± 6 ha^{-1} under biocontrol.

Under IPM, the variability in the value of biocontrol services between years is substantially less than under biocontrol alone. Part of the value comes from yield savings and part from a reduction in the number of required sprays. The presence of natural enemies reduced the proportion of sites requiring treatment from 100% to 70% in 2005 and from 62% to 0 in 2006. This reduction in sprays resulted in an average savings of \$7 ± 4 ha^{-1} (as a component of the total value of the ecosystem service) in the high aphid year of 2005 and \$15 ± 3 ha^{-1} in the low aphid year of 2006 when fewer sprays were required.

Soybean Price. The overall ecosystem service value is directly proportional to soybean price in the biocontrol scenarios where all value is caused by reduced yield loss. The 2007–2008 projected soybean price of \$380 Mg^{-1} (\$10.40 bu^{-1}) is >80% higher than the 10-year median price of \$210 Mg^{-1} (\$5.60 bu^{-1}), so the calculated values of the ecosystem service are increased proportionately from \$224 + 73 to \$406 ± 132 ha^{-1} in 2005 and from \$19 ± 6 to \$35 ± 10 ha^{-1} in 2006. The impact of increased soybean price is less than proportional in the IPM scenarios, where a significant proportion of the value of ecosystem services is caused by saved pesticide sprays. In this scenario, the total value of the biocontrol service increased 52% to \$35 ± 9 ha^{-1} in 2005 and 33% to \$32 ± 7 ha^{-1} in 2006.

Land Use Change. Using 10-year median or 2007–2008 projected soybean prices, the value of biocontrol services with increased corn declined by 1.2- to 2-fold in relation to the corresponding 2005–2006 scenarios (Table S1). In the IPM scenarios under increased corn, the value of biocontrol services attributable to saved pesticide sprays was \$5 ± 3 ha^{-1} in 2005 and \$11 ± 4 ha^{-1} in 2006.

Landscapes with increased corn acreage support sharply lower biological control, but this relationship is likely to vary over space and time. Hence, we conducted a sensitivity analysis to explore the value of biocontrol services if reductions in BSI caused by increased corn acreage were only half as large on average as those that we actually observed in 2005–2006 (i.e., a slope of −0.65 versus −1.30 from regression of BSI versus proportion corn; Fig. 1*A*). The 50% lower BSI-response scenario resulted in greater values of biocontrol service, which translate into smaller declines in biocontrol services under increased corn (Table S2). The greatest difference was in the 2005 biocontrol value estimate, which was 42% higher in the lower BSI-response scenario than our base scenario, i.e., \$156 ± 51 ha^{-1} versus \$110 ± 32 ha^{-1} for the low price and \$283 ± 93 ha^{-1} versus \$199 ± 58 ha^{-1} for the high price. Under the lower BSI-response slope scenario, all other comparisons showed smaller increases in the value of biocontrol services ranging from 7% to 30%. Thus, even relatively large variation around our original estimate of the BSI to corn area relationship does not alter our core finding that increased corn decreases biocontrol services in the surrounding landscape.

Summary. Estimated values of the ecosystem service of biological control can vary sharply between years as a result of differing aphid abundance (≈12-fold) and differing management strategies (≈10-fold). In contrast, price sensitivity analysis led to 1.3- to 1.8-fold differences and landscape change to 1.2- to 2-fold differences in the value of biocontrol services. A 50% more conservative estimate of the effect of increased corn on BSI led to a 7–42% increase in the value of biocontrol services under landscape change. Given these sources of uncertainty and variability, our results should not be used as fixed predictions of the exact dollar value of this ecosystem service. Rather, they should be used to inform the direction and relative magnitude of landscape change on the economic value of biological control as an ecosystem service. Despite this caveat, the significance of the regression between corn acreage and biocontrol services, coupled with the strong empirical basis of the data and assumptions used in the model framework and the established predictive power of submodels, suggest that a negative impact of increased corn acreage on biocontrol in surrounding crops is highly likely and should be considered in the development of policy regarding the production and processing of biofuels.

Table S1. Estimated value of soybean aphid biocontrol service for 2 management strategies under years of high (2005) and low (2006) aphid abundance in 4 states (Iowa, Michigan, Minnesota, and Wisconsin)

			2005–2006 landscape		Projected landscape with increased corn	
Management strategy	Year	*N*	10-year median soybean price, $ ha^{-1}*	2007–2008 projected price, $ ha^{-1}†	10-year median soybean price, $ ha^{-}*	2007–2008 projected price, $ ha^{-1}†
Biocontrol	2005	10	224 ± 73	406 ± 132	110 ± 32	199 ± 58
	2006	13	19 ± 6	35 ± 10	15 ± 5	28 ± 9
	Overall	23	108 ± 38	196 ± 68	57 ± 17	103 ± 31
IPM	2005	10	23 ± 6	35 ± 9	18 ± 3	29 ± 5
	2006	13	24 ± 5	32 ± 7	18 ± 4	23 ± 5
	Overall	23	24 ± 4	33 ± 6	18 ± 3	25 ± 3

Values are given for historic and 2007–2008 price levels of soybean and actual 2005–2006 and biofuel-influenced landscapes.
*1996–2007 median soybean price \$210 Mg^{-1} = \$5.60 Bu^{-1} (U.S. Department of Agriculture Economic Research Service).
†2007–2008 projected soybean price \$380 Mg^{-1} = \$10.40 Bu^{-1} (U.S. Department of Agriculture Economic Research Service).

Table S2. Sensitivity analysis showing estimated value of biocontrol services if reductions in BSI caused by increased corn acreage was only half as large on average as those observed in 2005–2006

Management strategy	Year	*N*	Value of biocontrol service (mean ± SEM)	
			10-year median soybean price, $ ha^{-1}*	2007–2008 projected price, $ ha^{-1}†
Biocontrol	2005	10	156 ± 51	283 ± 93
	2006	13	18 ± 6	32 ± 10
	Overall	23	78 ± 26	141 ± 63
IPM	2005	10	19 ± 5	31 ± 7
	2006	13	23 ± 5	29 ± 7
	Overall	23	21 ± 4	30 ± 5

Results shown for 2 management strategies under years of high (2005) and low (2006) aphid abundance.
*1996–2007 median soybean price \$210 Mg^{-1} = \$5.60 Bu^{-1} (U.S. Department of Agriculture Economic Research Service).
†2007–2008 projected soybean price \$380 Mg^{-1} = \$10.40 Bu^{-1} (U.S. Department of Agriculture Economic Research Service).