What Drives Farmland Conversion: Farm Returns Versus Urban Factors?

(Draft Version—Do Not Cite)

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Paper prepared for the annual meeting of the American Agricultural Economics Association, Chicago, August 5-8, 2001.

Introduction

Many people seem to feel strongly about the conversion of farmland to urban uses. Recently, conversion of farmland to housing provoked terrorists on Long Island to burn construction sites to call attention to the issue, injuring some firefighters in the process (CBS news). This issue has also attracted considerable attention from federal, state and local governments. State and local farmland preservation organizations used public funds to purchase permanent conservation easements on 819,000 acres of U.S. farmland between 1974 and February 2000 (American Farmland Trust). This area is equivalent to about one tenth of one percent of all U.S. farmland. Perhaps the largest public outlays for farmland preservation come in the form of higher housing costs incurred as a result of zoning and development restrictions enacted by local governments to prevent what they believe to be "excessive" farmland conversion.

Farmland loss to urban development and farmland preservation programs have received considerable attention in economic literature (see Nickerson and Lynch), as well as in the mainstream media. A newer concern in the United States, particularly evident among the agricultural community, is the conversion of farmland to environmental habitat[1]. For example, in September 2000, the California Farm Bureau Federation, along with other parties, brought a lawsuit against the Cal-Fed Bay Delta Program on the grounds that the Program had not adequately considered the impact on agriculture of its plan to acquire and permanently convert about one million acres of farmland and hundreds of thousands of acre-feet of water for environmental purposes (California Farm Bureau Federation).

What do we know about farmland conversion? Most of the work that has been done by economists has focused primarily on the effects of farmland loss. The general consensus has been that there is little or no evidence to suggest that farmland conversion will significantly decrease food security or damage the economy, and that the strongest argument for preventing conversion is an aesthetic one (see for examples, Beattie, Gardner, or Kuminoff, Sokolow and Sumner). Yet this has not decreased the extent to

[1] Concern about "excessive" farmland conversion to forests is an issue that is well established in Sweden and other northern European countries (Drake).

which people are concerned about conversion and are willing to devote resources to prevent it. If the primary motivation behind farmland preservation efforts is aesthetic, and assuming that aesthetic value of farmland is a luxury good, we would expect resources devoted to preventing conversion to continue increasing as society becomes wealthier.

Despite the continued interest in farmland conversion, there has been relatively little effort to describe what causes it. Perhaps this is because it seems obvious to most people that conversion is caused by some combination of income growth, population growth, and farm returns. But there is no consensus on how these factors interact to decrease farmland, which ones are most important, or how to model the process. A better understanding of how these forces interact to generate conversion could lead to more efficient policy and more informed decision making on the farmland conversion issue.

In this paper we use an analytical and econometric approach to analyze the farmland conversion process. We begin by describing some problems with the data that are commonly used in discussions of this issue, and we introduce a unique data source for California that is more detailed and more appropriate for analyzing farmland conversion. A theoretical model and some empirical observations are discussed, and then we perform an econometric exercise to explain farmland conversion as a function of population growth, real estate markets, the agricultural-urban edge, and farm returns. Our analysis yields some insight into the farmland conversion process that is of general interest and particularly applicable to other states with large populations and farmland acreage.

Farmland Conversion Data

The *Census of Agriculture* and the *Natural Resources Inventory* are the two sources that seem to be most frequently used to track farmland conversion in the United States. Although these may be the only widely available sources of agricultural land use data their definitions and methods make the data questionable for use in tracking conversion.

Through comparison with aerial photography and GIS mapping we have found that they are poor and even misleading proxies for farmland conversion in California.

The *1997 California Census of Agriculture* shows a decrease in "Land in Farms" of 2.9 million acres since 1987. The *1997 Natural Resources Inventory* shows a decrease in farmland during the same period of about 1.3 million acres. Meanwhile, data generated through aerial photography and GIS mapping by the source we use for our analysis, the California Department of Conservation Farmland Mapping and Monitoring Program, indicate that total farmland conversion between 1988 and 1998 was only about 0.5 million acres.

The main incentives for using the *Census of Agriculture* (Census) in discussion of farmland conversion are that its data are easily accessible, go back at least a century for most states, and are available at both the state and county level. However, there are several reasons why the Census is a poor indicator of farmland conversion. First, the Census does not attempt to measure farmland conversion to any particular use and a decrease in its "Land in Farms[2]" (LIF) statistic does not necessarily imply there has been any actual conversion. The definition of LIF was frequently changed prior to 1974 to remove many of the smallest farms from Census statistics, causing the series to overstate the actual decrease in farmland. In addition, LIF includes federal grazing land leased by ranchers but not federal grazing land used by permit. This creates a particularly important definitional problem for tracking farmland conversion because trends in federal grazing land may overshadow more permanent changes in privately owned agricultural land. This happened in California as a result of the 1994 Desert Protection Act. The Act transferred about 1.3 million acres of federal grazing land that had previously been leased to ranchers by the Bureau of Land Management to the National Park Service, which continued to allow ranchers to use the land, but by permit instead of lease. According to

[2] "Land in Farms" is a measure estimated by the National Agricultural Statistics Service and reported in the *Census of Agriculture* and in the annual publication *Farms and Land in Farms*. The actual statistic reported in these publications differs in that the number in *Farms and Land in Farms* is adjusted to reflect an undercount, while the number published in the Census is not. See the *California Census of Agriculture*, Appendix C for more detail.

Census definitions, this land would have been counted as LIF in 1992 but not in 1997 although there was no actual change in the land or its use.

A second source that is widely used to track land conversion is the Natural Resources Conservation Service, *Natural Resources Inventory* (NRI). Unlike the Census, the NRI does attempt to track land conversion between specific uses. However, its definitions focus more on vegetative cover than on land use. For example, it includes as “rangeland” grazing land, as well as certain types of low growth vegetation that may never have been grazed or have had any connection to agriculture. Thus its conversion statistics may overstate the true extent of land used for agriculture that is converted to another use.

California is unique among the states in that it has a state government program designed for the sole purpose of tracking and reporting agricultural land use and conversion. The California Department of Conservation Farmland Mapping and Monitoring Program (FMMP) uses aerial photography, GIS mapping and field checking to biennially track changes in land use at the county level. Unlike the Census and NRI, FMMP differentiates between farmland converted to urban uses and farmland converted to “other” uses, which include idled land, wetlands and wildlife habitat. FMMP also tracks land that is converted from “other” land to agriculture.

Table 1 shows land conversion in California between agricultural and non-agricultural uses from 1988 to 1998. About 316,000 acres of crop and grazing land were converted to urban use, while another 312,000 acres were converted to wetlands and wildlife habitat, or idled for at least 4 consecutive years. 190,000 acres were converted from idle farmland, wetlands and wildlife habitat to urban uses. Anecdotal information suggests that much of this land was previously farmland that was idled in anticipation of development. While 628,000 acres were taken out of agriculture between 1988 and 1998, 145,000 acres were converted to agriculture either from land that was previously idled or from wetlands and wildlife habitat. Thus, the net conversion out of agriculture during this period was about 483,000 acres. In 1998 California had about 26.7 million acres of privately owned agricultural land. Thus, the development of 483,000 acres between 1988 and 1998 resulted in conversion of about 1.8 percent of the developable agricultural land base.

Table 1: California Land Conversion, 1988-1998*

From:	Agriculture	"Other"	Agriculture	"Other"
To:	Urban	Urban	"Other"	Agriculture
1988-90	101,915	65,767	85,232	46,301
1990-92	71,131	47,358	89,896	32,019
1992-94	37,305	21,109	30,934	12,363
1994-96	44,180	19,861	37,050	18,374
1996-98	61,622	36,150	69,153	35,958
Total	**316,154**	**190,245**	**312,265**	**145,015**

* These figures reflect small upward adjustments made to the FMMP data to reflect places where they undercount conversion according to the definition used by Kuminoff, Sokolow, and Sumner.

The FMMP-based estimate for farmland conversion during 1988-98 (483,000 acres) is less than half the amount of conversion reported by the NRI during 1987-97 (1,289,000 acres), and less than one fifth the decrease in "Land in Farms" reported by the Census between 1987 and 1997 (2,899,000 acres). Because the differences between these three measures are largely a result of the way that public and private grazing land is defined, states with a higher ratio of grazing land to cropland will be more likely to have large amounts of conversion reported by the NRI and large decreases in "Land in Farms" relative to actual farmland conversion. Thus any national analysis of farmland conversion trends should be extremely cautious in using Census and NRI statistics, as should any analysis of a state with significant grazing land.

Theoretical Model of Farmland Conversion

The main theoretical effort to model farmland conversion to urban uses was done by Muth in 1961. He constructed a model showing how two industries (agriculture and housing in his example) compete for land in a von Thünen plain. Under a number of restrictive assumptions he showed that in the event of growth in income or population the direction of conversion between agriculture and urban land will depend on the relative demand elasticities of local housing and agricultural products. In particular, Muth showed that urban areas will expand outward when the demand curve facing surrounding agricultural producers is highly elastic. Despite the mathematical rigor and intuitive results of Muth's model, some of its assumptions do not seem accurate today. For example, it assumes the price of housing decreases as one moves further away from the center of a city, contradicting the current fact of affluent suburbs and low-density rural residential areas. In addition, the model does not incorporate zoning and development restrictions, which we believe to be important in our empirical example. It would take considerable space to formally revise and extend his model to reflect our empirical example, and little would be gained over an analytical approach. Therefore, although we proceed with a reasoning that is similar to Muth's we do not attempt to apply his theoretical model directly.

We envision a landowner choosing between using land for farming in the current period, and retaining the option to convert in the future, versus an irreversible sale to one of two non-farm uses, environmental open space or urbanization. Given the choice to sell, the landowner will consider the expected future agricultural value of the land for its productive lifetime, its value for conversion to urban or environmental use in the current time period, and its option value for conversion to urban or environmental use in the future. In other words, this is a dynamic optimization problem with the landowner maximizing expected net present value across use and sales of land, and across time. Other factors that might affect the decision to sell are relocation costs if the landowner lives on the land that is to be converted, emotional attachment to the land, environmental ethics, and other difficult-to-measure personal factors.

At the regional level zoning and development restrictions will be an important factor in the extent of urban development. From the perspective of a social planner faced with the static problem of allocating land across various uses in a region during one time period, zoning and development restrictions would be modeled as a constraint. But over time these restrictions may depend on conversion and be determined endogenously. This could be reflected in a theoretical model by a simultaneous equation system of dynamic optimization equations that estimated conversion as a function of development restrictions and other factors, and development restrictions as a function of conversion and other factors. This exogenous-endogenous issue may also apply to population and income growth, as changes in these variables may lead to farmland being converted to urban uses, as well as depend on it. In an empirical application the variables that are actually modeled as endogenous may depend largely on the time frame.

Empirical Considerations

In the past there have only been brief attempts to construct econometric models of farmland conversion. For example, in a short section and appendix of a recent paper on food security and farmland preservation Tweeten outlined an econometric exercise that used state-level Census data from 1949-1992 to estimate changes in cropland as a function of the ratio of gross farm income per capita to overall per capita income, farm population per square mile, and urban population per square mile. To estimate the impact of farm factors on conversion, Tweeten expressed the predicted change in cropland due to farm factors (farm population and the ratio of farm income per capita to overall per capita income) as a percentage of total change in predicted cropland. He found that, overall, farm factors accounted for 74 percent of U.S. farmland conversion, concluding that "the implication of this modest and preliminary statistical analysis is that lack of farm economic viability rather than urban encroachment is the principal reason for cropland loss." Although he did not show results for specific states in his paper, Tweeten notes that farm influences were lowest relative to urban influences in the Mountain and West Coast regions, and also in New England, Arkansas and Florida. The lowest quartile, which included California, was estimated to have had between 0 and 71 percent of its change in cropland due to farm related sources. Other examples of brief econometric analyses on this topic include Ramsey and Cortey, and Kahn.

We expect that in California, and other states with large urban populations, conversion out of farmland is due mainly to urban factors, not farm income. Much of the state's recent urban expansion has been in areas that were previously farmed. The price offered for conversion to urbanization on any agricultural parcel of land is typically much larger, generally by an order of magnitude, than its agricultural or environmental price. For example, bare ground sold for development in California's urbanizing areas regularly exceeds $40,000 per acre, considerably more if urban improvements are in place. The average agricultural land prices in the state are much smaller—$1,050 for grazing land and $5500 for fruit, tree-nut and vegetable areas (NASS, 2000). In extreme cases farmland can be much more expensive. Napa County vineyards, for example, have sold for as much as $90,000 per acre. But, even this extremely high price of agricultural land is dwarfed by the price of Napa land for homesite development, as much as $1.5 million per acre (California Chapter of the American Society of Farm Managers and Rural Appraisers (CCASFMRA)).

Given these land sale prices, we hypothesize that most agricultural landowners who have the opportunity to sell to urban development, do. Relocation cost and personal attachment to the land may be extremely important to a few landowners, but it seems unlikely that these effects would have a significant impact overall. Relocation cost is likely to be small in comparison with the difference between the land's value for urban use and for agriculture. Similarly, a landowner who simply likes to farm and enjoys being part of the agricultural landscape could take advantage of profits from an urban land sale by purchasing a larger parcel in another agricultural location.

The price of land for conversion to environmental uses seems to be much closer to the price of agricultural land. Because statewide data on agricultural land sold for conversion to environmental use were not readily available, we compared the price per acre for 49 parcels of land (17,829 acres total) purchased in the Sacramento Valley by the Wildlife Conservation Board between 1965 and 1999 (Northern California Water Association). Converting to 2000 dollars using the GDP deflator, the average price was $1393 per acre, with prices ranging from $112/acre to $7354/acre. These prices are far below the price of land for urban development but well within the price range for agricultural use. For example, in 1999 agricultural land sale prices in the Sacramento Valley ranged from $300 to $1100 for rangeland, from $1400 to $3100 for field crops, and from $2500 to $8000 for fruits, tree-nuts and vegetables (CCASFMRA).

While we suspect that urban factors are generally more important than farm returns in determining farmland conversion, it also seems likely that farm returns may affect the timing of conversion, particularly for conversion to environmental uses. For example, if an agricultural landowner expects extraordinary profits from agriculture in the following year or two with no change in the urban or environmental land markets, he may delay sale of the land to maximize profits. However, with the large difference in urban and agricultural land prices it would also seem likely that small percentage changes in the expected sale price for development could outweigh large percentage changes in expected farm returns.

One challenge in modeling farmland conversion empirically is to account for the fact that relatively few landowners have the option to sell their agricultural land for urban or environmental use at any one time. This is because their land is not located close to the urbanizing fringes of existing cities where most new development occurs, is not targeted by environmental groups that can afford permanent land acquisitions, or because conversion in that area is prevented by zoning or development restrictions. One way to address this issue is to incorporate a variable in the econometric model that accounts for spatial relationships between different land uses. (See Bockstael for discussion of the importance of a spatial perspective in modeling land conversion and economics.)

We used FMMP data and GIS software[3] to create a proxy variable for the amount of farmland that would be subject to conversion pressure at the beginning of each time period. For each county we generated a variable for the length of the border (or "edge") that urban areas shared with agriculture and other land uses. We found that there was considerable variation across counties. For example, according to FMMP data Tulare County had about 49,000 acres of urban land in 1998, while Solano County had about 53,000 acres. Yet, the total perimeter of Tulare's urban land was 875,000 meters, while Solano's urban perimeter was 525,000 meters. Moreover, in Tulare 79% of the urban perimeter (697,000 meters) was adjacent to farmland, while in Solano 67% of the urban

[3] We used *Arcview GIS 3.2* to work with the FMMP GIS data, and the *X-Tools* extension to recalculate polygon perimeters, which were not given.

perimeter (352,000 meters) bordered farmland, while the rest bordered other land and water. So although these two counties had similar amounts of urban land in 1988, the length of the agricultural-urban edge was almost twice as large in Tulare because of the geometric shape of its urban areas and location of other lands. Generally, we would expect more farmland conversion in counties with larger agricultural-urban edges, holding development restrictions and other factors constant.

Econometric Model

In our econometric model we use data on land use, urban factors and farm income to explain three different types of land conversion: agriculture-to-urban conversion, all conversion out of agriculture (conversion from agricultural land to urban land, idled farmland, wetlands and wildlife habitat), and all conversion to urban land (conversion from agriculture and "other" land to urban land). Our dataset is a pooled time-series cross section. For each type of land conversion we use FMMP data for 42 California counties. As noted above, FMMP reports its conversion data for 2-year periods. However, the development process is often time-consuming and it can take many years between the point that agricultural land stops being farmed and the point that construction actually starts (Kuminoff, Sokolow and Sumner). For example, an agricultural parcel that was sold for development in 1988 may not actually have been developed until 1991. In this case, although the land was sold in 1988 it would have been recorded as a conversion by FMMP in 1991 when aerial photographs first revealed the new development. To reflect the fact that the conversion process often takes more than two years we aggregated the FMMP conversion data into two periods, 1988-1992 and 1992-1998[4]. There appears to be a natural division between these two periods in the sense that annual conversion was much higher in the first period (see Table 1). In our regressions, conversion is measured on a per year basis.

[4] The mapping done by FMMP is on a crop year basis, so the 1988-1992 conversion period, for example, includes conversion during the second part of 1988, all of 1989, 1990, and 1991, and the first part of 1992.

We attempted to create independent variables that would capture the effects of conversion pressure along the urban edge, farm income, the price of agricultural land for development, and population growth. Conversion pressure along the urban edge is estimated as the length (in meters) of the border shared by urban land and the type of land being measured as conversion in the dependent variable (*EDGE*). To account for variation in the amount of agricultural and other land by county we also included the initial stock of land being converted as an independent variable (*STOCK*). We would expect both *EDGE* and *STOCK* to be positively correlated with farmland conversion.

The variables for farm income (*GFIADEV*) and the price of agricultural land for development (*HPDEV*) were both measured as deviations in the conversion period from recent trends. The idea is that if there is an increase in the price of agricultural land for development during the conversion period, which the landowner expects to be temporary, she will be more likely to convert. Likewise, a spike in farm income that is expected to be temporary would provide an incentive for the landowner to delay conversion. We use data on gross farm income per acre from the California agricultural commissioners' annual summary reports as a proxy for actual farm income. Of course, farmers are most concerned with net farm income, and by using gross farm income we are implicitly assuming that expenditures remained relatively constant during our study period or that gross and net farm income are highly correlated. We constructed a proxy for conversion prices of farmland from data on annual median prices of single-family homes provided by the California Association of Realtors for 16 different regions in the state. We matched each of the 42 counties in our sample with the region that we judged would best reflect the real estate market in that county. Here, the implicit assumption is that higher median prices of single-family homes is an indication of greater pressure for urban development and is correlated with higher prices for agricultural and other land for urban development. Gross farm income and median housing price were both converted to year 2000 dollars using the GDP deflator. The effect of population growth on conversion was included in our model as the annual increase in population for each county *(aPOP*), using data from the demographics branch of the California Department of Finance.

For each of the three types of land conversion, the econometric model was estimated using ordinary least squares estimation with 42 county observations over two time periods. A dummy variable was included to test for differences between the two time periods. The model assumes that farmers have perfect expectations of future farm income and the price of agricultural land for conversion. Our econometric specification, in a preliminary linear form, is shown below.

$$C_{i,t} = {}_0 + {}_1 EDGE_{i,t} + {}_2 STOCK_{i,t} + {}_3 GFIADEV_{i,t} + {}_4 HPDEV_{i,t} + {}_5 \Delta POP_{i,t} + {}_6 t + \varepsilon_{i,t}$$

Where, i = ($County_1$,…….,$County_{42}$), and

$$t = \text{dummy variable for second time period} = \begin{Bmatrix} 0 & \text{for} & 1988-1992 \\ 1 & \text{for} & 1992-1998 \end{Bmatrix}.$$

C = Conversion per year in County i and period t.

$EDGE_{i,t}$ = Length of the border in County i between urban land and the stock of land that is measured as a flow by the dependent variable in the first year of conversion period t.

$STOCK_{i,t}$ = Stock of the land in County i measured as a flow by the dependent variable in the first year of conversion period t.

$$GFIADEV_{i,t} = \left[\left(\frac{\sum_{n}^{m} GFIA}{(m-n)} \right) - \left(\frac{\sum_{n-4}^{n} GFIA}{5} \right) \right], \quad HPDEV_{i,t} = \left[\left(\frac{\sum_{n}^{m} HP}{(m-n)} \right) - \left(\frac{\sum_{n-4}^{n} HP}{5} \right) \right], \quad \text{and} \quad \Delta POP_{i,t} = \frac{(POP_m - POP_n)}{(m-n)},$$

where,

GFIA = gross farm income per acre,
HP = median housing price for single family homes,
POP = population,
n = first year of period t,
m = last year of period t.

In addition to the previously mentioned caveats, the preliminary model shown above does not account for the effect of zoning and development restrictions. Thus, the empirical question we are testing is whether farm returns or urban factors are important enough as determinants of farmland conversion to appear statistically significant given our proxy independent variables, omitted variables, and assumption of perfect expectations.

Preliminary Results

Our preliminary results (shown in Table 2) suggest that urban factors, not low farm income, have been the main cause of farmland conversion and new urban development in California. Whether we considered conversion from agriculture to urban land, all conversion out of agriculture, or all conversion to urban land, edge length and population growth were statistically significant and positively correlated with conversion. The dummy variable for the 1992-1998 conversion period was also statistically significant for each measure of conversion, but negatively correlated with conversion. It can be seen from Table 1 that annual average conversion in every category was larger during 1988-1992 than 1992-1998.

The importance of edge effects may explain why the stock of land did not appear statistically significant in conversion to urban development. FMMP data show that only a small share of the stock of agricultural and other land is converted to urban use in any period. Overall, about 2% of California's agricultural land base was converted to urban use between 1988 and 1998. Because most new urban development occurs along the edges of existing urban areas this development would be reflected in the econometric model by the urban edge variable, not the stock variable. This reasoning is consistent with the observation that the stock variable is statistically significant for the conversion measure that includes agriculture-to-other conversion, because this conversion is not necessarily related to urbanization and may not occur near the edge of existing urban areas.

The proxy variable for temporary change in farm income was not statistically significant in any of the conversion measures. Given the large difference between prices of agricultural land for crops and for urban development, it is not too surprising that farm income was not a significant determinant of agriculture-to-urban conversion or of all conversion to urban land.   We would expect that even large percentage changes in temporary farm income could be outweighed by small percentage changes in price of land for urban development. However, it is somewhat surprising that farm income did not appear to be a significant determinant for conversion out of agriculture, because that measure includes cropland left idle or converted to wetlands and wildlife habitat, which we would expect to be more dependent on farm income.

Another surprising result was that the proxy variable for temporary changes in price of agricultural land for urban development was not statistically significant in any of the measures of conversion. This may be an indication that our proxy measure is too rough to approximate the sale price of agricultural land for urban development.

One partial explanation for the similarity in results between the three measures of conversion is that agriculture-to-urban conversions are included in all three measures. However, it seems unlikely that this one type of conversion is the only factor driving the results. As Table 1 shows, between 1988 and 1998 there was almost as much agriculture-to-other conversion as agriculture-to-urban conversion.   Conversion from other-to-urban was also significant during that period.

Table 2: Preliminary Results from Land Conversion Model
(t-statistics in parenthesis)

	Ag-to-Urban	Ag-to-Urban + Ag-to-Other	Ag-to-Urban + Other-to-Urban
EDGE	2.35E-03	2.87E-03	1.72E-03
	(6.81)	(5.24)	(5.64)
STOCK	-1.67E-04	8.81E-04	2.69E-05
	(-1.01)	(3.37)	(0.2)
GFIADEV	1.01E-02	-0.1	-0.11
	(9.08E-02)	(-0.58)	(-0.69)
POP	1.01E-02	2.80E-02	2.17E-02
	(2.64)	(4.61)	(3.2)
HPDEV	-4.64E-03	-4.56E-03	-3.55E-03
	(-1.38)	(-0.85)	(-0.78)
t = 1992-1998	-557.08	-773.27	-669.11
	(-2.46)	(-2.15)	(-2.18)
Constant	206.63	60.63	129.59
	(0.89)	(0.17)	(0.46)
R-Square	0.56	0.62	0.71
Adjusted R-Square	0.53	0.59	0.69
N	84	84	84

Conclusions

Our preliminary results suggest that urban factors, not low farm income, have been the primary cause of recent farmland conversion in California. The importance of edge effects as a determinant of farmland conversion and of increased urbanization may be of particular interest to city planners and farmland preservation organizations. We expect that these results would also apply to many other states that have a combination of large urban populations and large amounts of agricultural land. But our model does not yet take into account important factors such as zoning and development restrictions and we believe our independent variables can be better specified to account for factors that affect the timing of conversion. Our paper and presentation at the AAEA meetings in August will include a revised model that incorporates and discusses these important factors. Thus, the results in this version of the paper should be treated as highly preliminary.

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