CARD Agricultural Policy Review
IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY
Ames, Iowa • Winter 2015

Assessing Food Security in Tanzania in the Next Decade

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CARD ECONOMIST Beghin and USDA ERS have been collaborating to advance USDA ERS' annual *International Food Security Assessment.* The *Assessment* provides a 10-year outlook of the state of food insecurity in 76 low- and middle-income countries with a strong focus on the interface between income distribution within the population and food insecurity.

This collaboration with CARD brings a more systematic approach into the *Assessment* by introducing price information, price and income responses in consumption, which vary by level of poverty, food quality heterogeneity across income deciles, and consistent aggregation of the demand by deciles into a market demand. The new approach relies on a food demand system consisting of four categories (major grain, other grains, roots and tuber, and an aggregate all other food) in grain equivalent.

For each food category, the new approach developed for the *Assessment* explicitly incorporates a measure of the decile income distribution and its impact on food demand by decile and at the aggregate level. Further, the approach incorporates variable food quality, with quality increasing with increasing income across deciles.

Various qualities of a given food category are aggregated into an average-quality equivalent that leaves country-level consumption unchanged, but reflects consumer choices over quality. Prices faced by different consumer deciles vary accordingly with quality, with lower-income deciles consuming cheaper calories than higher-income deciles. Quality scaling in the approach uses a reference consumption level based on national food survey data that FAO publishes annually in *State of Food Insecurity* (SOFI). This reference consumption level focuses on the bottom decile and represents a credible level of consumption in grain equivalent for the poorest segment of the population in the country under consideration.

Tanzanian food market
Photo by Roxanne Clemens

The new methodology introduces an explicit link between domestic and international markets and the imperfect connection between the two because of sizable trade and transaction costs. Interior markets of these countries are somewhat insulated from what is happening at the border or capital cities where trade takes place. High transportation costs and other sizeable frictions impede prices from equalizing geographically. The methodology uses international price projections from USDA's international agricultural outlook. These projected world prices and exchange rates movements are then used to project future domestic prices faced by consumers in these countries, while accounting for the imperfect transmission between markets, various taxes, and transportation costs.

Using these projected prices, population, and income and exchange rates projections from international agencies, food consumption is projected for 10 deciles for a decade (2013–2023). Food security is assessed by comparing projected food consumption for low-income deciles with a target caloric level corresponding to food security. Deciles with an average food consumption falling below these food-secure levels are deemed food-insecure. The new approach also provides a more direct estimate of projected food insecurity based on national survey statistics collected in SOFI and characterizing food distribution in these countries.

This article reports estimated food consumption and food insecurity in Tanzania for 2013–2023 based on

actual food market information of 2012. This article presents food projections and key determinants of food consumption growth for the key staple grain in Tanzania and the projected state of food insecurity in Tanzania.

Based on the SOFI information and other FAO data on food availability, the per capita food availability for the first decile of Tanzanian population in 2012 is estimated at 138 kg of grain equivalent (rounded) per year (about 1,239 calories per day). This minimum reflects the quality adjustment incorporated in the new method, such that the calibrated food demand is set to 138 kg in the base year for the lowest decile. Over time, this minimum consumption is projected to grow slowly, following the projected distribution of food availability in the country, again based on the SOFI parameters and projected income growth, decreases in prices, and appreciation of the Tanzanian currency making food cheaper over time. Figure 1 shows the projected consumption for decile 1 (and other deciles) in kg of grain equivalent per year.

As income per capita is projected to increase over time in Tanzania, consumption is also projected to increase despite the prevailing income inequality, which is maintained unchanged in the projection. Food consumption per decile is shown in Figure 1. The four bottom deciles are projected below the threshold of 234 kg for some (deciles 3 and 4) or all years (deciles 1 and 2).

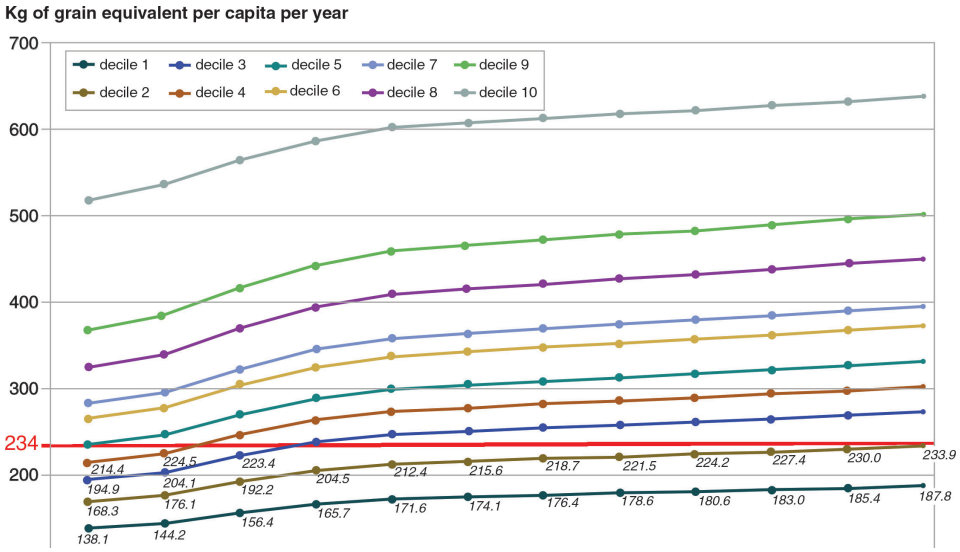

Figure 1. Projected total food consumption in grain equivalent by income-based population decile in Tanzania

Decomposing the growth of food demand

The projected growth of food demand in Tanzania is decomposed by major sources of changes—average per capita demand growth and population growth. Per capita demand growth is further decomposed in terms of income response and price response of consumers (decomposed into a real world price response and real exchange rate response). Concretely, for corn, the major grain consumed in Tanzania, aggregate food demand is projected to increase by 76 percent in the projected decade, given the growth of projected real income per capita (+18 percent), real world price for corn (-49 percent) real exchange rate (-22 percent), and population (+35 percent). Per capita demand for corn is projected to grow by 30 percent given the outlook of lower prices, stronger currency, and higher income. The interaction of population growth (the largest predictor of projected food demand) and per capita demand is responsible for 11 percent of total demand growth.

The decomposition of demand growth per capita indicates that change in the real world price of corn, after being scaled down by the price response of consumers and the presence of frictions in markets, is still a large contributor to per capita demand growth (14 percent growth of per capita demand). The projected real appreciation of the Tanzanian currency leads to 6 percent growth of per capita food demand. Finally, income growth contributes 9 percent growth of per capita demand.

Food security assessment

The projection of food demand by income decile allows for the analysis of food insecurity in terms of "access," which estimates if people can purchase enough food to be food secure.

Two approaches are used. First, we use the decile food demands and compare them with nutritional targets (1,800 and 2,100 calories) to determine whether a given income group would be considered food

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[The Iowa Agriculture Demand report for this issue of the *Agricultural Policy Review* is available in the online version only]

Table 1. Projected Food Insecure Population in Tanzania (Estimated with two food security thresholds and two methods)

Year		2012	2013	2018	2023
Average per capita daily calorie intake	Projected	2,430	2,538	3,105	3,306
Food insecure population 1800 calorie target	Lognormal approach	11,571,381	10,088,020	4,581,702	3,718,825
Percent of population falling below 1800	Lognormal approach	24.67%	20.90%	8.26%	5.86%
Food insecure population 1800 calories	USDA decile approach	14,073,830	9,652,388	5,545,134	6,346,112
Percent of population food insecure 1800 calories/day	USDA decile approach	30%	20%	10%	10%
Food insecure population 2100 calorie target	Lognormal approach	18,944,397	17,198,274	9,541,100	8,267,888
Percent of population falling below 2100 calories/day	Lognormal approach	40.38%	35.64%	17.21%	13.03%
Food insecure population 2100 calorie target	USDA decile approach	18,765,107	19,304,777	11,090,269	12,692,225
Percent of population food insecure 2100 calories/day	USDA decile approach	40%	40%	20%	20%

secure. USDA has used this approach with the 2,100-daily calorie threshold and an 1,800-calorie target alternative for sedentary people. There is no universal standard for food security but these two targets are plausible.

In this decile method, if the estimated decile food demand falls below the target the entire income group is counted as food insecure. Aggregating the people in these food-deficit income deciles provides the number of food-insecure people. Hence, the variation in food-insecure population changes by 10 percent increments when population deciles come in or out of food insecurity. Figure 1 informally illustrates this method. All deciles falling below the red line of 234 kg are deemed food insecure. One can also gauge the food gap between the target and consumption level by decile. The gap provides an indication of the depth of the insecurity. Table 1 presents the projected population that would be insecure.

The second method uses an estimate of the food distribution (assumed lognormal) within the population based on distribution parameters provided in SOFI, which are updated to reflect the projected mean food availability over time. This second approach is more refined as it provides an estimate of the share of population falling below a preset threshold.

Table 1 shows the estimates of food insecure population projected over the decade (2013, 2018, and 2023). Both approaches concur that population in the first decile will remain food insecure even under the low threshold of 1,800 calories. Under the more stringent criterion of 2,100 calories, people in the two bottom deciles will remain food insecure in 2023. The decile approach overstates the share of population (20 percent) that is food insecure compared to the distribution-based estimate of 13 percent. Assessing future food security remains an imprecise exercise!

Further readings:

Beghin, J.C., Birgit Meade, and Stacey Rosen. 2014. "A Consistent Food Demand Framework for International Food Security Assessment." CARD Working Paper 14-WP 550. *http://www.card.iastate.edu/publications/synopsis.aspx?id=1229*

Rosen, Stacey, Birgit Meade, Keith Fuglie, and Nicholas Rada. 2014. *International Food Security Assessment, 2014-24*. Food Security Assessment Situation and Outlook No. (GFA-25) June 2014 *http://www.ers.usda.gov/publications/gfa-food-security-assessment-situation-and-outlook/gfa25.aspx.* ■

Late-1990s Climate Shift Impact on Corn Yield in Iowa

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THE NEXT advance in climate science will come out of experiments in forecasting shifts in climate regimes—an extended period of time in which weather conditions have consistent range, such as the Dust Bowl years or the Little Ice Age. A climate regime shift results in a new range of weather conditions for an extended period, so being able to predict a regime shift allows planners to anticipate an emerging weather risk profile that would be expected to persist for 20–30 years. One way a regime change occurs is when slowly varying ocean surface temperatures change from warm to cold. In the Corn Belt, summer rainfall is influenced over 20–30 year periods by two recurring ocean surface temperature patterns: the Pacific Decadal Oscillation (PDO) (Hu and Feng 2001) and the Atlantic Multidecadal Oscillation (AMO) (Hu et al. 2011). Together they have four phases of warm and cold conditions that result in four different spatial patterns for drought risk across the United States (McCabe et al. 2004). While climate scientists will focus on decadal forecast capability for broad temperature and rainfall patterns, the more immediate question for agriculture is, how have climate regime shifts affected yield?

Our approach is to evaluate corn yield response to the late-1990s climate regime shift. From 2000 to 2014, weather volatility produced corn yield shocks that dominated market prices, particularly in 2008, 2010, 2012, and 2013. In 2014, the absence of poor growing conditions sent the corn market down to prices last seen in 2006–2007. The objective of this research is to determine whether corn yield shocks during 2000–2012 resulted from different weather extremes than experienced in 1980–1992.

We develop an empirical model that relates a logarithm of county-level corn yield to temperature, rainfall, and soil moisture. This means our model predicts the change of yield rather than yield itself. We use model predictors based on corn phenological stage development (Table 1) in order to examine interaction among weather extremes, such as 2011 when wet conditions in spring were followed by dry and hot conditions in summer. Model parameters are estimated by the method developed in Yu and Babcock (2011).

Data

Corn production and planted acres are obtained for all 99 Iowa counties from the US Department of Agriculture National Agricultural Statistics Service, and yield is constructed as corn production divided by planted acres. Daily temperature and rainfall data are obtained from values in a one-eighth degree grid dataset produced by an interpolation routine applied to daily measurements of more than 10,000 stations across the United States (Maurer et al. 2002). Temperature and rainfall are aggregated to county scale.

Soil moisture is not widely measured. We use EPIC model version 1102-64

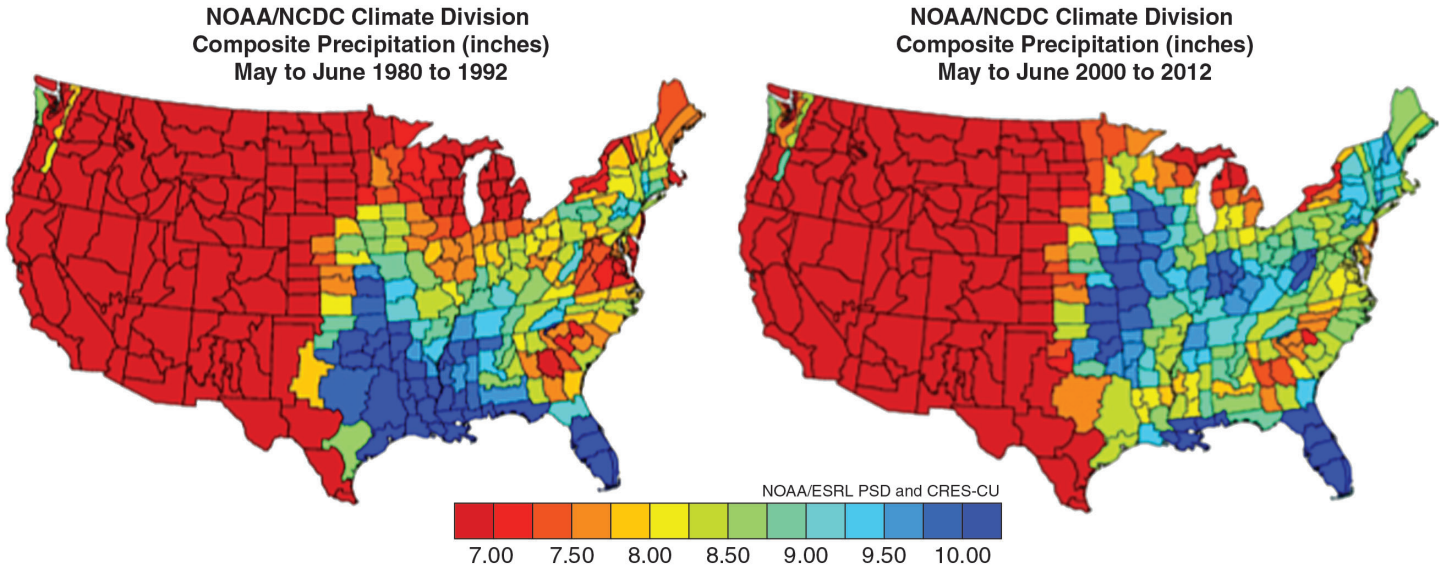

Figure 1. May–June average rainfall for 1980–1992 (left) and 2000–2012 (right) for crop reporting districts.

Table 1. Names and descriptions for predictor variables

Variable Name	Variable Description
Year	Calendar year of yield report
May-Jun T	**May through June average temperature (°C)**
Jul-Aug T	***July through August average temperature (°C)***
May-Jun R	***May through June average daily rainfall (mm)***
Jul-Aug R	*July through August average daily rainfall (mm)*
May 1st SM	**Simulated soil moisture on May 1st (mm)**
July 1st SM	***Simulated soil moisture on July 1st (mm)***

Note: Bold indicates period mean values for 1980–1992 and 2000–2012 are statistically significant at 95 percent level. Italics indicates years with July–August T > 24.92 have mean values for 1980–1992 and 2000–2012 that are statistically significant at 95 percent level.

(Izaurralde et al. 2006) to produce a 1980–2012 simulation of soil moisture at 48,084 points from the 1997 Natural Resources Inventory (NRI) from western Minnesota through central Illinois. Each NRI point is provided the 1980–2012 gridded daily weather from the grid point nearest the NRI centroid.

Results

We evaluate weather changes between 1980–1992 and 2000–2012 by comparison of mean values of the predictors. We compute mean values for the entire thirteen year period and focus on volatility with means for only hot-dry summers within the periods. Period mean values are statistically different for all variables except July–August rainfall. The mean growing season conditions in 2000–2012 compared to 1980–1992 began with drier May 1 soil moisture and progressed to wetter and cooler May–June, wetter July 1 soil moisture, and a cooler July–August. Weather during these two regimes is different, but the yield effect of these factors is mixed, resulting in the model predicting a 2.33 bu ac^{-1} net increase in state average yield. For reference, the model estimates a yield trend of 1.56 bu ac^{-1}, such that the yield effect of the 1990s regime shift is equivalent to 1.5 years of advancement in technology.

We point out some aspects of spring rainfall increase, because it presents complicated tradeoffs for machinery decisions, drainage, timeliness of planting, and resilience to summer drought. The change in spring rainfall is not unique to Iowa (Figure 1), but is a large pattern shift across the Corn Belt. In Iowa, yield loss from late planting occurs after May 10–14, such that expected yield loss at May 31 is 10 percent and 30 percent on June 15 (Farnham 2001). Negative correlation between average suitable fieldwork days from April 1 to May 15 and average April–May rainfall in Iowa during 1976–2010 is clear, and a linear regression predicts a reduction of 2.2 fieldwork days for every one inch increase in April–May rainfall. The increase of 1.3 inches in Iowa average April–May rainfall suggests a decrease of roughly three suitable fieldwork days.

We are highly interested in how the climate regime affects yield volatility, and we focus discussion on years with high temperatures in July–August. The role of July 1 soil moisture and July–August rainfall in ameliorating high temperature yield effect is clear in our model predictions. The percent yield loss in Iowa under high July–August temperature drops from 26.25 percent to 10.89 percent if both soil moisture and rainfall are abundant in July–August. Weather during hot-dry summer years is statistically different during the two periods for all variables except May–June rainfall and May–June temperature (Table 1). Comparing 2000–2012 to 1980–1992, the average hot-dry summer growing season sees 2.5 inches more rainfall in spring—adding 0.66 inches to the July 1 soil moisture reservoir—and summer sees 1.5 inches more rainfall and temperatures one degree Fahrenheit cooler. The yield impact of different growing seasons for hot-dry summers is substantial. Our model predicts smaller yield losses from cooler July–August temperatures, more July–August rainfall, and more July 1 soil moisture of 12.6, 11.9 and 4.5 bu ac^{-1}. The effect of May–June rainfall is positive, because of the positive yield effect from July 1 soil moisture, despite its impact on planting delay. The net yield effect of all weather factors during hot-dry summers is a reduction of yield loss by 25.3 bu ac^{-1}.

Final thoughts

The results show the power of knowing yield effects under climate regimes, and it suggests substantial value to forecasts of climate regime shifts if they prove to be skillful. Iowa agriculture can suggest priorities to this work. An immediate priority is clear from the historical sequence of PDO and AMO phases that suggest a combination could occur within the next decade that has higher drought risk. There is urgency for agriculture, then, to identify differences in weather seasonality under past climate regimes and translate this to yield effects. We can then evaluate whether the recent trend of wet springs is characteristic of past regimes, and what types of investments can be made when a regime shift occurs.

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Nitrogen Management under Uncertainty: An Investigation of Farmers' Decision Processes

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DES MOINES Water Works has recently threatened a lawsuit against three upstream Iowa counties they claim are responsible for excessive nitrate loading in the Raccoon and Des Moines rivers. Excess nitrate loads, which must be reduced before water is safe to drink, is reported to have cost Des Moines taxpayers upwards of $1 million in 2013. The cost of nitrate removal, which could include investment in new treatment capacity, will continue, and may grow, unless steps are taken to reduce nitrate runoff from agriculture. While such water treatment is costly, yield losses may be more costly if rates are capped by regulations. The problem is complicated because of uncertainty over weather and soil conditions producers face when making their nitrogen use decisions. Furthermore, weather largely dictates how much of the applied nitrogen leaves the fields.

Our research is, in part, motivated by a crucial question in the nutrient management challenge: what steps can and should be taken to address nitrate runoff from Iowa's agricultural fields? Economists have studied pollution in agricultural-based economies for decades, typically attacking the problem by positing a model of fertilizer application practices and from this model designing policies that provide incentives to either lower application rates or adopt management practices that reduce nitrogen and phosphorous fertilizer runoff. Earlier research has relied on strong assumptions about the decision processes used by farmers when making fertilizer choices. The reason for doing so is that no one has asked farmers how they choose application rates, methods, and/or timing of application. The potentially serious problem is that if assumptions for underlying decision processes are wrong, it is likely that the policy recommendations derived from the model will also be wrong, or at least less effective than if the actual decision processes were known.

Our work turns the standard approach on its head. In fall 2014, our research team designed and implemented a survey that focuses directly on understanding the real-world decision processes used by central Iowa farmers. The survey asked several rather unorthodox, but revealing, questions about the nature and extent of the uncertainty that producers face, their subjective beliefs about the yields they expect on the field that they manage, the impact of different nitrogen application rates on yields, the role of weather variability, and a host of other questions all geared toward developing a clearer picture of the thought process behind nutrient management decisions.

Why is this important? We suspect—and our survey results seem to show—that real-world fertilizer decisions are impacted to some extent by judgmental bias, use of decision heuristics, and various other deviations from the decision models that have been used in previous research. That is, farmers' decisions do not necessarily conform to the often-assumed benchmarks based on models that do not incorporate such biases. This is not surprising given what is found in a wide body of research into real-world decision making under uncertainty and complexity of the decision. We are now developing economic models to inform policy that build on what we have learned, with real-world decision processes at their core. We are confident these models will identify better avenues for reducing the negative impacts on Iowa's valuable water resources, in a way that allows Iowa's agriculture industry to continue to thrive.

In the cab of a corn harvester, a technician checks readings on a digital yield monitor. Photo by Scott Bauer (USDA).

Survey of farmers and study findings

In an effort to understand how producers form their nitrogen decisions, we examined what they believe about the relationship between nitrogen and yields and how that relationship changes as weather and nitrogen are varied. Using a web-based survey delivered to members of a central Iowa cooperative, we elicited producers' beliefs based on their individual experiences and situations. The survey was designed to allow each producer to characterize his/her belief

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Mandatory GMO Labeling?

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GENETICALLY ENGINEERED (GE) crop varieties have been prominent in US agriculture for many years. First commercialized in the 1990s, they were rapidly adopted by farmers. By 2014, 93 percent of corn and 94 percent of soybean acres were planted with these varieties. Favorable reception of these products was never universal, as objections were voiced by some segments of the public; however, it seems fair to say that the acceptance of this new technology was smoother in the United States than elsewhere. This conclusion has been tested over the last few years by an increased public awareness and activism intended to bring about new legislative action on genetically modified organisms (GMOs), as GE products are often called. Such efforts have specifically aimed to introduce state-level requirements for mandatory food labeling of GMO content. Proposition 37, put to California voters in 2012, squarely aimed at mandating such labeling. Although defeated at the polls, it brought much publicity to this issue. Similar initiatives were also narrowly defeated in the states of Washington (2013) and Colorado and Oregon (2014). However, Vermont enacted mandatory GMO labeling legislation in 2014, and Maine and Connecticut have approved bills that would trigger such labeling under certain conditions (related to neighboring states also mandating GMO labeling), and several other states are considering similar actions. Are we witnessing the dawn of mandatory GMO labeling in the United States, and would that be a desirable outcome?

Proponents of mandatory GMO labeling articulate a number of justifications, starting with the view that consumers have a "right to know." Consumers, it seems, agree. An Associated Press-GfK poll carried out in December 2014 found that 66 percent of the public favors requiring food manufacturers to label products that contain GMO ingredients, with only 7 percent of Americans opposing the concept. What could be wrong with the right-to-know rationale in this setting? After all, we live in an information age, and we are getting used to having instant access—with our computers, tablets, or smartphones—to an amount of information that was unfathomable only a few years ago.

It helps to start by asking why one might want to provide this information. The general presumption, of course, is that more information is better, and more information should help consumers make better choices. Support for mandatory labeling then hinges on the belief that information concerning GMO content is relevant to consumers because the health safety of these products has not been conclusively proven (related concerns may refer to the environmental impacts of GMOs and/or ethical objections to products perceived to be unnatural). The facts, however, are not in agreement with this perspective. GE products have been widely studied in the process of being approved for cultivation and marketing. Extensive data concerning biotech corn, soybean, wheat, potato, rice, sugar beets, papaya and many other products, have been reviewed by the FDA for two decades and the conclusion has invariably been that products from GE varieties are substantially equivalent to their traditional counterparts. In particular, there is no science-based reason to presume that the products containing GMOs marketed to date are less healthy for consumers. This general conclusion has been reached independently by the review process in many other countries. The need to alert consumers of potential health risks is just not there, it seems.

Note that the foregoing discussion has changed the spotlight from the right to know to the "need to know." Why not ignore the latter and require GMO labeling simply because it appears that many consumers favor the notion? At least two observations are germane

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USDA/Photo by Scott Bauer

Characterizing and Comprehending Land Use Change in the Loess Hills Region

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REGIONAL LAND use change has important implications for ecosystems and the local human population. Metropolitan areas (MAs) are placing increasing emphasis on amenities and the environment when seeking to attract high income workers and their employers. Our interest is in characterizing land use change in Iowa's Loess Hills Ecoregion (ILHE) that skirts both Sioux City and Council Bluffs MAs. ILHE is a distinctive landform of silty soils up to 200 feet high that were wind deposited just east of the Missouri River floodplain. Covering about 0.7 million acres, the Loess hills stretch north about 200 miles (usually no wider than 15 miles) from Holt County, Missouri, to Plymouth County, Iowa and are largely under private ownership. Although the soils are rich, cultivation has been difficult so that the region contains more than 50 percent of Iowa's remnant prairie. However, technologies that allow cropping on steeply sloped and highly erodible terrains, increasing agricultural prices, and pressure for urban development have led to concerns about habitat loss conversion and fragmentation (Farnsworth et al. 2010).

Figure 1 illustrates the landform, within the red boundary, and also land uses as of 2013. In this article we will consider land use change in the ILHE and seek to place shifting land use patterns in the region in perspective with changes across the state as a whole. Data used are primarily from Cropland Data Layers (CDL) 2001–2013 as obtained from the United States Department of Agriculture (USDA).

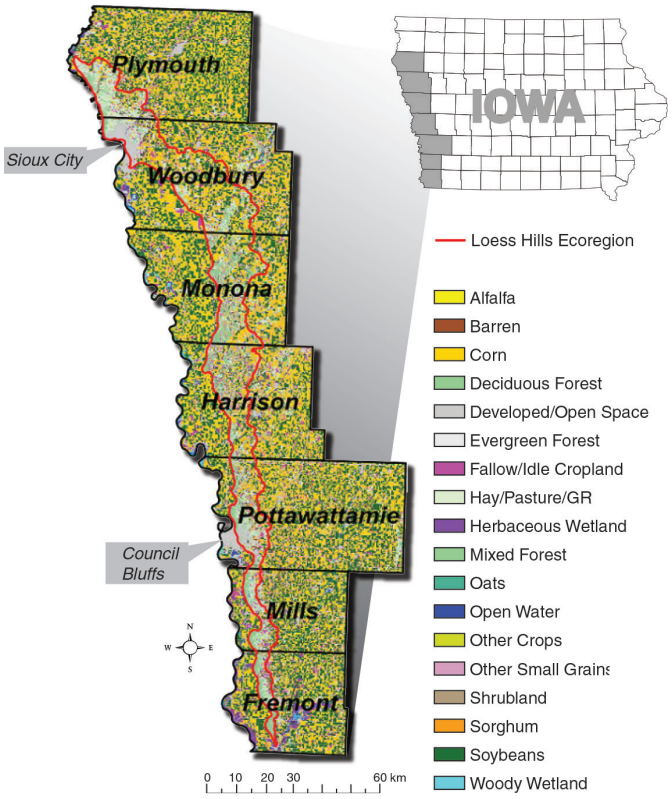

Figure 1: Iowa's Loess Hills Ecoregion, as defined by Iowa Dept. of Natural Resources (DNR).

Land Use Change in the Loess Hills Ecoregion

There has been little net change in cumulative agricultural acres (predominantly corn and soybeans) between 2001 and 2013. However, within-cropland dynamics are revealing. Corn is the only crop to have gained acreage from 2001 to 2013. Among non-agricultural uses, the Grass/Pasture/Hay (henceforth, grass) acres have declined, seemingly overgrown by deciduous forests.

Much of the corn acreage that moved out of cropping between 2001 and 2005 went into grass and fallow cropland, a pattern that was reversed in the subsequent five years, such that corn was 32,000 acres higher in 2010 than in 2001. High corn acres were sustained in the 2010–2013 period through declining soybean acres. While shifts occurred into grass and fallow cropland categories, grass acres have fallen due to outward transitions into the deciduous forests category where invasive eastern red cedar is a problem. Because CDL classification protocols for developed acres have substantially evolved through these years, CDL data do not directly allow for an assessment of change to this category. In a separate query that appropriately adjusted for the redefinitions, we found a 2.6 percent increase in ILHE development acres (from 25,494 acres to 26,163 acres) over the 2001–2013 period. We had expected a larger increase.

Since the CDL data are less reliable for gauging changes in the developed land category, we also created land transition tables (not shown) using point-level National Resource Inventory data, a distinct data set, for the seven counties that enclose the ILHE. These data hold that corn/soy (58 percent) have contributed more acres to urbanization than have pasture/hay (27 percent) and Conservation Reserve Program (CRP) (15 percent) categories from 2001 to 2010. In 2001, 80 percent of land in the seven counties were under either corn or soybeans, 13 percent were in pasture/hay and 3 percent were in CRP, thus acres entering development in these counties were

disproportionately drawn from non-crop uses.

Land Use Change in Iowa

At the national level, corn and soybean acres planted and harvested have increased during the first decade of the twenty-first century (Wallender et al. 2011). The large majority of Iowa's most productive land has long been under cultivation in a corn-soybean rotation. National Agricultural Statistics Service land use data depict little change in total corn and soybean acreage between 2001 and 2013 in Iowa and in the seven Loess Hills' counties. Data also highlights a shift toward corn within corn-soybean rotations, especially in the seven Loess Hills counties.

A further change has been in acreage enrolled in CRP. Enrollment peaked at above 2 million acres in the mid-1990s before settling in the 1.5–2 million interval up until recent cutbacks in the national enrollment cap and higher commodity prices during 2007–2013. The seven Loess Hills' counties CRP acreage trends are quite similar to those in the entire state; however, CRP acreage rose faster in the seven Loess Hills' counties until the mid-1990s, and the seven county decline in post-2007 CRP acres has also outpaced Iowa. It is noteworthy that fallow cropland has apparently increased in the ILHE despite a decline in CRP acres for the seven counties.

Discussion

Satellite-data based assessments of land use changes in developed areas, grassland, and fallow cropland categories should be treated with caution (Kline et al. 2013), and so our emphasis has been on changes in row cropping. About half of the landform's area is under tilled crops while significant amounts of previously cropped land are also under expiring CRP contracts. The advent of reduced till and glyphosate seed technologies has likely meant that the area's difficult terrain is becoming less problematic for cultivation. Crop production has increased in profitability since 2000—according to Iowa State University's annual rental rate survey, average cropland rental rates in the seven county region have increased from $119/acre in 2002 to $273/acre in 2014. We are therefore somewhat surprised to conclude that more land has not been converted to row-crop agriculture in the area.

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function about how yield responds to nitrogen. The survey responses were then used to develop a structural model of farmer-level nitrogen management decision-making.

Studies by psychologists and behavioral economists almost invariably find that people are overconfident. A form of overconfidence relevant to agricultural production is unrealistic optimism—the belief that really good outcomes (e.g., exceptional yields) will occur despite objective evidence to the contrary. Our survey does not indicate overconfidence is prevalent among the central Iowa farmers surveyed. However, we do find some evidence of unrealistic optimism regarding yield expectations among a subset of the farmers we surveyed. A roughly equal-sized group of respondents are pessimistic about yield expectations, that is, they expect lower yields than those estimated by independent data sources. On average, the farmers we surveyed expect to harvest only slightly more bushels per acre than is predicted by historical data.

Preliminary analysis suggests that farmers overstate the impact nitrogen has on corn yields. Using data from Iowa State research farms, which have been used to study the role of nitrogen on corn yields for decades, we estimate the actual impact of an increase in nitrogen on average yield. Our survey asked farmers their perceptions about the yield response to added nitrogen on the fields that they managed, and the results show farmers believe that the decline in expected yield due to a nitrogen reduction is generally larger than the rise in expected yield due to a similar increase in nitrogen applied.

A crucial question we seek to answer is, do farmers' subjective beliefs about nitrogen-corn yield relationships match the objective data or the agronomic models and advice that they receive? Our preliminary findings suggest the answer to this question is no. For approximately 30 percent of the farmers in our survey, the expected incremental increase in yield from an increase in nitrogen applied exceeds the objective estimate that was attained from the research farm data.

Implications for managing nitrogen

In summary, the early indication is that there may exist stark differences between farmers' subjective beliefs about nitrogen's effect on yield and the assumed relationships that underlie current nitrogen recommendation systems.

For example, we find that farmers may perceive yield and profit gains from added nitrogen that simply do not exist based on past data. If our results hold, this finding could have important implications for designing policies to manage nutrients. For example, perhaps an effective first policy step toward improving water quality is to provide farmers with better information about the impacts of nitrogen on yields and on their bottom line. More generally, understanding the fertilizer-yield relationship as perceived by producers can help inform nutrient policy design and also the extension services provided to producers. As state leaders, farmers, and other stakeholders begin to address the issues surrounding nutrient management and reductions of agricultural runoff, having a clear understanding of the decision processes used by producers will be key. Evidence-based policymaking needs to take into account the behavior and attitude of farmers to be effective, and designing policies without such information could result in policy that is not only inefficient but also ineffective. ■

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at this juncture. First, new label information would inevitably crowd other facts and claims already present, thereby competing for limited consumer attention. Consumers inevitably deal with information overload in many ways, including rule-of-thumb decision processes. If they are accustomed to seeing mandatory disclosures only when their need is unquestionable (e.g., tobacco packaging warning messages), consumers may rationally infer that if a GMO label is required it must be because these products are objectively risky. In other words, a mandatory GMO label may end up stigmatizing products carrying it, regardless of the objective truth, and turn off consumers. Somewhat paradoxically, precisely because GE products remain somewhat controversial despite the ample scientific evidence, the need-to-know perspective is of paramount importance vis-à-vis the right-to-know argument.

Other economic considerations are also in order. Mandatory GMO labeling would be costly to society. Such costs take a number of forms. Food manufacturers, conscious of the stigma of GMO labeling, might reformulate many of their products, substituting GE ingredients with less desirable yet non-GMO alternatives (e.g., palm oil instead of soybean oil). This costly process would be exacerbated if GMO labeling were mandated by some states and not others, requiring the food system to implement identity preservation and segregation activities currently unnecessary. Such costs could add up to nontrivial amounts. A University of California study in 2012 concluded that Proposition 37 could have increased food manufacturing costs by more than

$1 billion per year. Not surprisingly, strong objections to such mandatory labeling have been registered in the food industry (the Grocery Manufacturers Association, along with other industry groups, promptly filed suit in June 2014 against Vermont's new GMO labeling requirements).

So, should the non-GMO preferences of some consumers be ignored? Not necessarily. The alternative to mandatory GMO labeling is voluntary labeling of a product's non-GMO status. Indeed, consumers who wish to avoid GE ingredients in their food already have the ability to do so by purchasing certified organic food or food products manufactured without GE ingredients (as certified by third-party organizations such as the Non-GMO Project). Voluntary labeling of such attributes has the virtue of being incentive-compatible: the higher costs of non-GMO food is paid by the consumers who actually elect to avoid GE products. Furthermore, voluntary labeling is consistent with the long-standing philosophy of FDA regulation concerning food labels. Indeed, the prevailing legal perspective is that federal law preempts state law in these matters. About twenty years ago federal courts overturned the Vermont mandatory labeling of milk produced with recombinant bovine somatotropin, arguably a close precedent to the current GMO labeling issue.

The unnecessary costs of implementing mandatory GMO labeling, noted earlier, underscores the emphasis on efficiency dear to economics. In this context, a subtler "dynamic efficiency" notion is worth pondering as well. This relates to the flow of new technologies and products that results from sustained investment in research and development activities. Mandatory GMO labeling in the absence of a science-based reason to do so could stigmatize these products and drive investments away from the development of new GE products. Companies that are committed to biotechnology innovations in agriculture, such as Monsanto and other agro-biotech firms, are understandably worried about the prospect of mandatory GMO labeling, and have spent heavily to publicly oppose state ballot initiatives over the last few years. But it should be clear that society at large has a stake in this innovation process. As we confront the food security challenges of a world faced with a major population increase, limited natural resources, and climate change, it is imperative that the potential contribution of scientific research and new technologies be exploited to its fullest impact.

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In the end, the debate about mandatory GMO labeling rekindles questions about the appropriate regulation of new products and new technologies. The experience of the European Union (EU) with GE innovation in agriculture provides a sobering reminder of the destructive power of questionable regulations. Whereas the EU-wide risk assessment of GE products by the European Food Safety Authority (EFSA) typically reaches the same conclusions as its US counterpart, adoption of GE varieties in the EU is hampered by a general political unwillingness to follow EFSA's science-based findings, and by other EU and member-state policies (including mandatory GMO labeling and coexistence measures) that make farmers' adoption of GE varieties all but impossible. The end result: in 2014, 180 million acres of land were planted to GE varieties in the United States, whereas only 0.25 million acres with GE varieties were planted in the entire EU.

Protecting the public from new risks remains a paramount objective of public regulation. This is why new GE varieties undergo extensive review as part of their pre-market authorization, with specific roles for the USDA, EPA, and the FDA. This process is, and arguably must remain, science-based. Once new GE varieties are approved, post-market regulations such as mandatory labeling have a doubtful role, and may serve little purpose beyond impeding the adoption of new, efficiency-enhancing technologies and new products. ■

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