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Balancing Agricultural Development Resources: Are GM and Organic Agriculture in Opposition in Africa?

Ari Novy, Samuel Ledermann, Carl Pray, and Latha Nagarajan
Rutgers University

Organic agriculture has been promoted vigorously by many civil and donor organizations engaged in agricultural development in Africa. Certified organic products are grown in more than half of African countries, targeted mainly towards export markets. In contrast, adoption of GM agriculture has been met with skepticism in much of Africa, with only three African countries approving GM crops for commercial planting. In this article, we empirically tested several factors that may explain African attitudes toward GM and organic agriculture. To test these factors, we used a newly generated dataset on agriculture, trade, and development indicators for a subset of African countries. We found that African countries' openness to GM agriculture is significantly predicted by variables for wealth, organic agricultural area, colonial legacy, past rejection of GM, and the percentage of the country under land protection. Interestingly, our analyses reveal that openness to GM agriculture is positively correlated with the abundance of organic agriculture. We also show that Europe has exerted significant influence on African acceptance of GM via colonial legacy and advisory positions.

Key words: GM adoption, organic agriculture, Africa.

Introduction

Sustained growth in agricultural production in Africa has not kept pace with other developing regions of the world; yet many have argued that increased agricultural production is fundamental to overall development and economic growth in Africa (e.g., Diao, Headey, & Johnson, 2008). Two policy solutions that have been trumpeted as potential routes of development are adoption of genetically modified (GM) agriculture and organic agriculture. Organic certifiers specifically forbid certain technologies from being implemented (such as GM crops and synthetic fertilizer use) as a part of organic agriculture. GM supporters and other intensive agricultural advocates often dismiss organic farming because of its perceived inefficiency. These polarized views have the potential to influence policy makers towards prioritizing one specific agricultural technology over the other. Restricting the range of options available to countries seeking to advance agricultural development may be counterproductive. In this article we examine whether African countries are adopting organic agriculture at the expense of GM or vice versa and specifically evaluate some of the hypotheses from recent literature which suggest that European influence is disproportionately responsible for African attitudes about GM agriculture.

The Case for Organic

Advocates of organic agriculture in developing countries cite many potential benefits of the technology. These include sustained food security, environmental health (with special focus on soils), farmer health benefits, decreased input costs, access to premium or lucrative markets, preservation of local knowledge, and rural development. A diverse set of consumer preferences in developed countries is spurring the demand for increased organic production and generating profits in developing countries. For example, by 2001 Latin America exported more than 80% of its organic output, with a market value of over US $115 million (Raynolds, 2004). In Latin America and Caribbean countries alone, there are about 220,000 organic producers cultivating nearly 6.4 million hectares, accounting for nearly 20% of global acreage under organic production. These countries are the major suppliers of organic products to US markets (Willer & Kilcher, 2009). Continuing the trend, Argentina added nearly 400,000 hectares of additional land under organic production from 2008 to 2009, making its 4.4 million hectares of organic land the largest in the developing world (Willer & Kilcher, 2011). Furthermore, demand for organic agriculture has been strong and sustained through recession, with 2009 statistics from the Organic Trade Association (OTA) indicating that US organic food sales grew twice as fast as their conventional counterparts, reaching a nearly 4% market share (OTA, 2010).

These demand-based successes in other parts of the world have led development organizations to attempt replication in Africa. Donors such as the Swedish International Development Agency (SIDA) conceived of the project Export Promotion of Organic Products from Africa (EPOPA) to provide technical and financial assistance towards expanding organic cropland and certification of organic products. In Uganda alone, EPOPA helped to certify 87,000 smallholder farms as organic from 2004-2008. The export value of organic products from these organic farms in Uganda was valued at over US$25 million in 2006/2007 (Taylor, 2010).

An important feature of organic farming is that it aims to improve overall farm productivity sustainably while addressing environmental concerns (Bengtsson, Ahnstrom, & Weibull, 2005; International Federation of Organic Agriculture Movements [IFOAM], 2009). It is estimated that global adoption of organic agriculture has the potential to sequester 32% of anthropogenic greenhouse gas emissions (Jordan, Müller, & Oudes, 2009). Organic agriculture is also attractive for resource-poor communities because it requires fewer high-cost off-farm inputs than conventional agriculture given access to premium paying markets in Europe or North America (Hillocks, 2003). In an in-depth study of organic coffee growers in tropical Africa, Bolwig, Gibbon, and Jones (2009) found that participation in organic certification and the application of recognized organic techniques both resulted in net increased profits (75% and 9% for each component, respectively) for farmers when compared to farming systems that are "organic by default" (i.e., low input but not certified organic). Thus, organic agriculture has the potential to earn higher profits (through price premiums) and sustained, higher yields than the existing low-input agriculture being practiced in African countries, potentially while bolstering food security in marginal environments of Sub-Saharan Africa, though the necessity for further research is acknowledged (Halberg, Sulser, Høgh-Jensen, Rosengrant, & Knudsen, 2005).

One such research effort, led by the Research Institute of Organic Agriculture (FiBL), consists of 15-20 year field trials comparing organic and conventional systems in Kenya (maize-vegetable-fruit rotation), Bolivia (cocoa), and India (cotton). Results from the Indian trials on cotton will be particularly interesting since they include GM cotton in addition to organic and conventional methods. Though these trials began in 2007, preliminary results indicate lower cotton yields for organic during the conversion phase, which may be offset economically by the organic price premium. Eventually, the medium- to long-term results from these studies will serve as one of the first systematic comparisons between organic and conventional farming methods in developing countries (FiBL, 2010).[1]

The Case for GM

Advocates for GM in developing countries similarly cite the potential benefits of increased yield and profits, simpler farm management, and environmental and human health benefits. The economic benefits of GM in developed countries are well established, though limited to those countries that have embraced the technology. For example, for the harvest years from 1996 to 2000, GM crop farm income benefits in the United States were $7.5 billion for soybeans and $2.7 billion for maize. In Canada (the other major GM crop producer among the developed countries), the main GM crop canola (rapeseed) benefited from an additional $790 million over the same period (Brookes & Barfoot, 2006). GM advocates cite that developing countries can follow suit. For example, income gained by planting GM soybean in Argentina was calculated at $300 million in 2001 (Qaim & Traxler, 2005) and has led to greater adoption of low and no-till farming (United Nations [UN] Food and Agriculture Organization [FAO], 2004). The current generation of GM crops has also been shown to have positive farmer health effects associated with a decrease in toxic pesticide use. In China, GM cotton farmers suffer pesticide poisoning up to six times less frequently than farmers of non-GM cotton (Pray, Huang, Hu, & Rozelle, 2002).

In South Africa, GM maize may be reducing cancer rates and decreasing cases of neural tube defects since insect resistant GM maize results in a decrease of the mycotoxin fumasin in the food supply (Pray et al., unpublished manuscript). Finally, advocates tout the potential benefits from next generation GM crops, which are poised to provide a myriad of benefits to consumers—including increased nutritional content—though regulatory hurdles are substantial (e.g., Dawes & Unnevehr, 2007). The next generation of GM crops is also being designed to mitigate crop performance under environmental stresses such as drought (e.g., Penissi, 2008; Yang, Vanderbeld, Wan, & Huang, 2010).

1. *For updates on the research results, see http://www.systems-comparison.fibl.org/.*

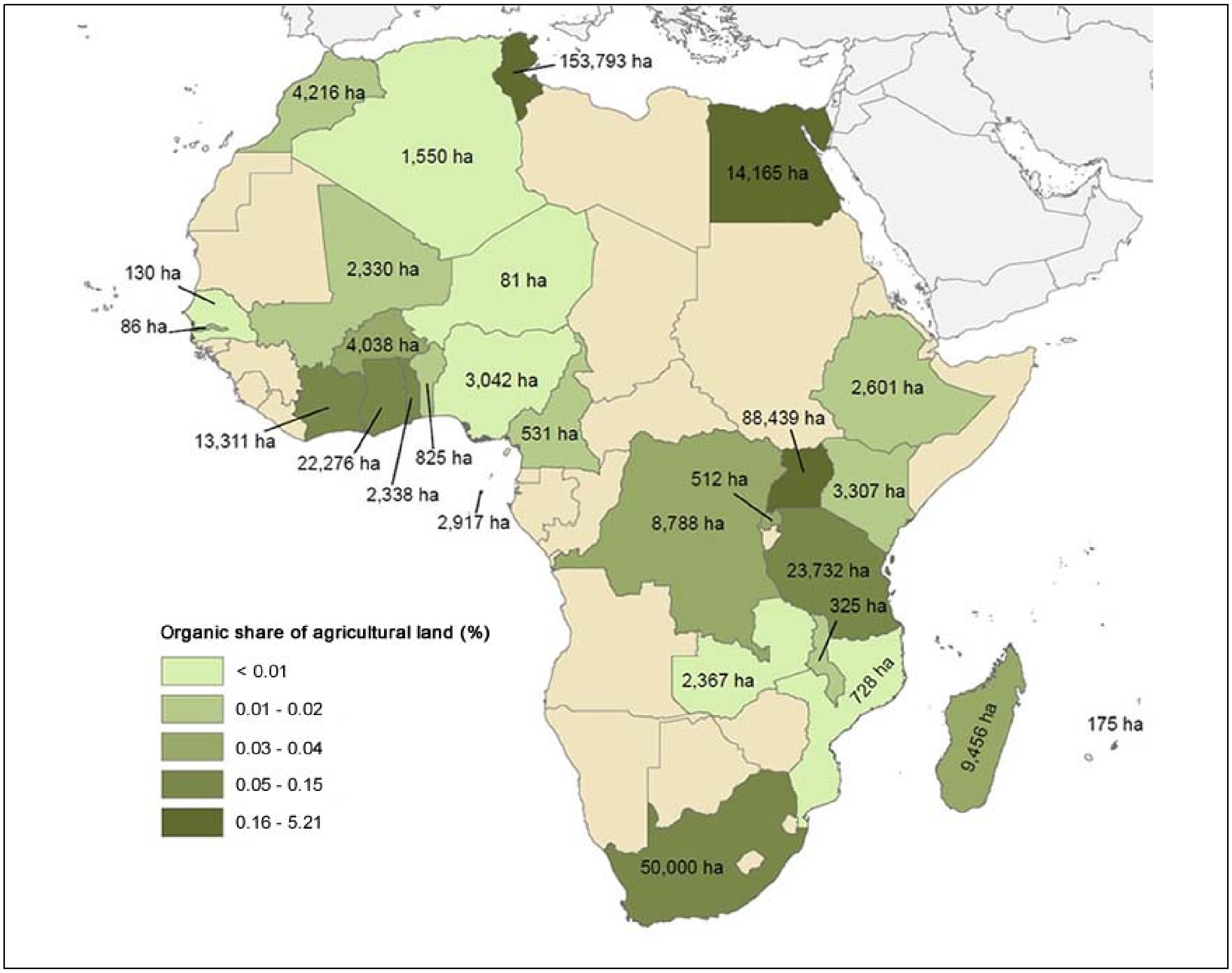

Figure 1. Map of the organic share of agricultural lands and total organic area (hectares) for the African countries included in the IFOAM database.

Data adapted from Willer, Yussefi-Menzlerand, and Sorensen's IFOAM/FiBL survey (2008).

The Controversy

Both GM and organic crops have been the subject of intense controversy. The major criticism of organic agriculture is that widespread adoption would lead to diminished yields in comparison to conventional agriculture. This has been hotly disputed (e.g., Avery, 2007; Badgley et al., 2007; Badgley, Perfecto, Chappell, & Samulon, 2007) but is a fundamental point considering the agricultural development mandate of feeding an additional two billion people worldwide over the next 30 years (UN FAO, 2004). Opponents of GM claim that the technology will wreak environmental havoc, worsen food security and lead to a corporate takeover of agriculture in general (UN FAO, 2004). Organic certification organizations are strongly opposing GM as a viable strategy or technology. Both the Codex Alimentarius and IFOAM define organic to exclude GM technology. In short, advocates for both organic and GM agriculture believe their approaches to be justified and are highly skeptical of the opposing view.

Many agricultural development organizations are active in encouraging organic agriculture in Africa. According to its website, IFOAM advocates for organic agriculture in 26 African countries (IFOAM, n.d.). Certified organic products are being grown in more than half of African countries (Figure 1). In contrast, GM agriculture has been met with skepticism in much of Africa. There are currently only three African countries that are producing legally approved GM agricultural products. According to the Center for Food Safety, four African countries have banned GM outright and another

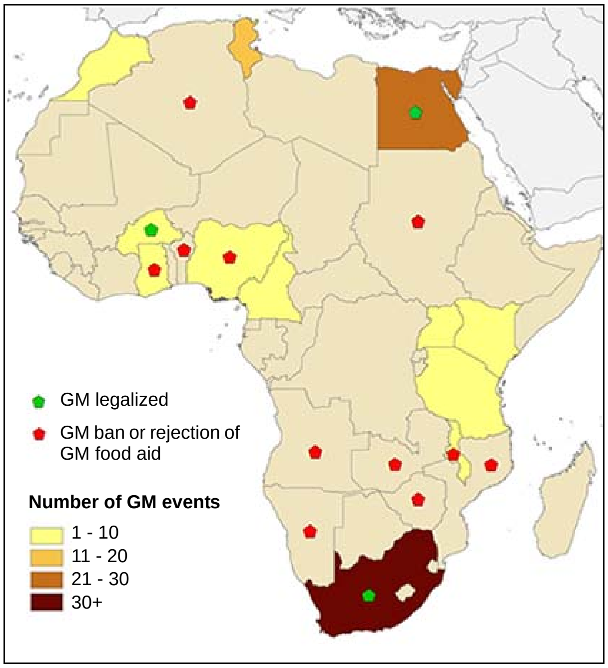

Figure 2. Map of the number of GM events in each African country. African countries which have legally commercialized GM agriculture or have instituted a GM ban or rejection of GM food aid are also indicated.

Data adapted from FAO-BioDeC database (UN FAO, 2011a) and Center for Food Safety (2005).

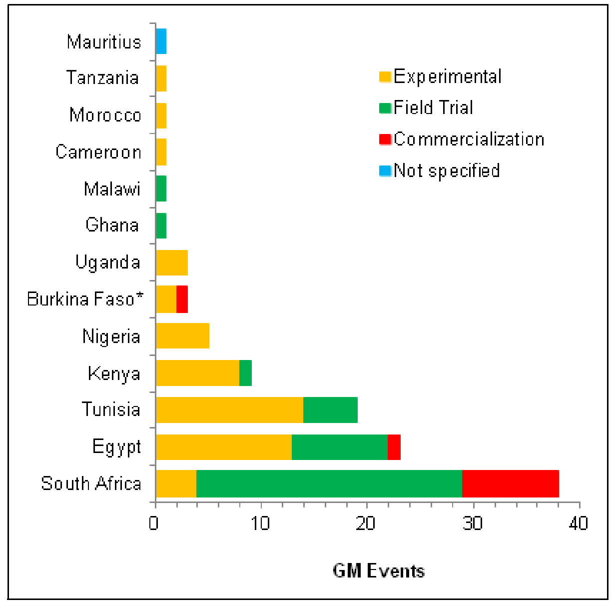

Figure 3. Number of GM events in each African country with known experimental, field trial, or commercialization of GM crops.

Source: UN FAO (2011a)

** known commercialization occurred after 2007 (James, 2010)*

seven have rejected GM grain as food aid (Ahlenius, 2006; Figure 2).

Paarlberg (2008) has studied the views of both GM and organic proponents in Africa and observed that that there is an anti-science based agriculture movement (including anti-GM) among policy elites and non-governmental organizations (NGOs) on the continent. He posits that this anti-GM attitude has been primarily exported from Europe, via European dominated NGOs, foreign assistance programs, UN programs, and commodity markets where policy makers have become risk averse to new agricultural technologies. He accuses those in wealthy countries who push the precautionary, anti-science based approach to agricultural development in Africa of denying the same agricultural path out of poverty that was utilized by the developed countries and has been working in South America and Asia. This article is meant to test some of Paarlberg's (2008) arguments using available economic data and to determine if the work by environmental advocates in Africa comes at the expense of GM agriculture. Given recent developments—with a boom in organic agricultural production in Africa—we also juxtapose the rise in organic vis-à-vis the adoption of GM agriculture on the continent.

Data Sources and Variables

We hypothesized that GM acceptance should be primarily a function of a country's ability to invest in high-cost technologies like GM and the importance of the agriculture sector within the country. We further hypothesized that competition with organic agriculture would negatively impact GM acceptance and, drawing on Paarlberg (2008), that close ties with the European Union (including colonial influence) and environmentalist activity should also be negative predictors.

Data was generated for the following 28 African countries: Algeria, Benin, Burkina Faso, Cameroon, Chad, Congo (Dem. Rep.), Egypt, Ethiopia, Gambia, Ghana, Ivory Coast, Kenya, Madagascar, Malawi, Mali, Mauritius, Morocco, Mozambique, Niger, Nigeria, Rwanda, Sao Tome and Prince, Senegal, South Africa, Tanzania, Togo, Tunisia, and Uganda. These 28 countries were selected because IFOAM maintains information on their organic agriculture indicators. Several data sources were accessed to build the dataset for econometric estimations. Data for organic agriculture were taken from the IFOAM/FiBL report "The World of Organic Agriculture—Statistics and Emerging Trends 2008" (Willer et al., 2008). Data on GM were taken from the FAOBioDec database (UN FAO, 2011a) and James (2010). The data include commercialized GM area and

Table 1. Variables used in this study including summary statistics and source references.

Variable	Definition of variable	Mean	Std dev	Min	Max	Source(s)
Outcome or dependent variables						
GM events	Sum of the counts of approved transgenic events, field trials or commercialization events	4.14	9.87	0	40	UN FAO (2011a), James (2010)
GM area	Area under GM cultivation (ha)	87,928.57	416,827.70	0	2,200,000	UN FAO (2011a), James (2010)
% GM area	GM area as a percent of total agricultural lands	0.72	2.95	0	14.97	UN FAO (2011a), James (2010), FAO Stat (2006)
Organic area (ha)	Area under certified organic cultivation	14,810.43	33,238.33	0	154,793	Willer et al. (2008)
% organic area	Organic area as a percent of total agricultural lands	0.31	1.01	0	5.21	Willer et al. (2008)
# of organic farms	Total number of organic farms	7,533.73	18,655.30	5	86,952	Willer et al. (2008)
Explanatory or independent variables						
Pop	Population (thousands, 2009)	30,291.89	33,000.22	163	154,729	WTO (2011)
GDP	Gross domestic product (million US$, 2009)	41,852.07	69,630.93	193	285,983	WTO (2011)
lnGDP	Natural log of GDP	9.57	1.59	5.26	12.56	WTO (2011)
TPC	Trade per capita (US$, 2007-2009)	1,130.46	1,720.69	122	7,913	WTO (2011)
Trade to GDP ratio	(2007-2009)	73.92	22.56	39.3	120.7	WTO (2011)
Merch exports	Merchandise exports (million US$, 2009)	9,312.64	16,576.31	9	62,603	WTO (2011)
Ag as a % of merch exports	Agricultural products as a percentage of merchandise exports (2009)	35.51	23.96	0.3	87.7	WTO (2011)
Merch exports to EU	Merchandise exports to European Union as a percentage of total exports (2009)	35.96	20.20	2.7	74.3	WTO (2011)
EU trade dummy	Value of 1 assigned if the EU is the main export destination (2009)	0.65	0.49	0	1	WTO (2011)
Ag as a % of merch imports	Agricultural products as a percentage of merchandise imports (2009)	18.41	8.94	7.4	36.8	WTO (2011)
Road network density	Total Road Network Density (Km roads/sq Km land area)	0.16	0.19	0.01	0.94	International Road Federation (2006)
Average fertilizer use	Mean Fertilizer Use Intensity (kg/ha, 1996-2003)	8.61	8.86	0.5	31.8	Morris, Kelly, Kopicki, & Byerlee (2007)
Adult illiteracy rate	Adult illiteracy rate (% aged 15 and above, 1999–2007)	40.10	19.22	12	73.8	US CIA (2009)
AgGDP	Agricultural sector GDP (million US$, 2009)	6,939.50	10,073.89	28.95	50,698.2	WTO (2011), US CIA (2009)
AgGDP%	Agricultural sector as percentage of GDP	27.58	13.33	2.5	52	US CIA (2009)
% of pop urban	Urban population (% of total, 2010)	39.86	16.71	13.3	67.3	UN Development Programme (2009)
% ag workers	Percent of workforce in agriculture	62.67	27.32	9	90	UNDP (2009)
% of country protected	Percent of terrestrial area protected according to IUCN definition	11.37	7.33	1.3	27.7	UNEP-WCMC (2010)
Cattle density	Cattle heads/ha (2008)	364.65	388.34	5.1	1,440.7	UN FAO (2011b)
Environmental NGOs	Number of environmental NGOs listed in the UN directory	25.46	19.33	2	81	UN (2011)
Colonial power = British dummy	Value of 1 assigned if the country's former colonizer was Great Britain	0.36	0.49	0	1	
Ban of GM dummy	Value of 1 assigned if the country has either rejected GM food aid or has a GM moratorium in place	0.21	0.42	0	1	Center for Food Safety (2005)

the number of approved GM events (defined as the sum of approved experimental, field, and commercial events within each country; see Figure 3 for an illustration).

One of the problems encountered in attempting to econometrically analyze the impact of GM agriculture in Africa is that only three African countries currently have commercialized GM crops. Since the process for approving a GM crop can take many years (depending on each country's biosafety regulations), we hypothesized that GM events may be a more meaningful metric in understanding the current state of African attitudes towards GM agriculture, thus enhancing our ability to relate GM status within African countries to other variables.

Table 1 lists and defines all variables utilized in this study and also reports each variable's summary statistics and source. Most variables are simple metrics taken from publications and publically accessible databases, though three additional variables represent calculations or counts we made. Specifically, we calculated % GM area by dividing total GM area by the total agricultural area for each country; natural log of GDP—a standard procedure when dealing with economic analyses—so that the outlier effect, in our case South Africa, would not overshadow other observations during analysis; and we counted the number of environmental NGOs that have been registered and recognized according to a UN directory (UN, 2011) as a proxy for environmental organization activity within each country. We created an EU-trade dummy variable to indicate countries for whom the EU is the main merchandise export destination, a British-colonial-power dummy to represent countries who were once British colonies, and a ban-of-GM dummy to represent countries that have either rejected GM food aid or have a moratorium on GM in place.

Econometric Estimation

Analysis of the data was conducted in two stages. All analyses were conducted in SAS 9.2. The first stage consisted of correlation analyses designed to gain a better understanding of the dataset and test the relationships between GM and organic agriculture. We ran a correlation analysis of the three GM variables (GM events, GM area, and % GM area) against all other variables in the dataset to test if GM prevalence is negatively correlated with organic prevalence and to explore which other variables may be significantly correlated to GM. A similar analysis was also used to test the association of the three organic agriculture variables (organic area, % organic area, and # of organic farms) to all other variables. These correlation analyses were used to determine which of the GM and organic agriculture variables captured the most significant information with respect to our independent variables. This further guided us to test appropriate econometric models that could explain the adoption of organic and GM agriculture in Africa.

The second stage of analysis consisted of two models designed to test our specific hypotheses of the factors promoting GM acceptance and prevalence of organic agriculture. To test these hypotheses, two different econometric methods were deployed and adjusted to the properties of their respective hypotheses and dependent variable of interest.

The first model estimated African openness to GM by assigning the variable GM events as the dependent variable. Given that numerous countries have had zero GM events (i.e., have chosen not to pursue any GM trials or commercialization), the variable's distribution resembles a Poisson distribution. As a consequence, we chose to run basic count models—Poisson and negative binomial estimations—to account for overdispersion of the dependent variable in question.

The second model estimated the existence of organic agriculture in terms of area under certified organic cultivation (in hectares) in each African country. This analysis used an ordinary least square regression (OLS) model to determine the factors affecting the existence of organic agriculture.

Results

Correlation Analyses

Tables 2 and 3 show the results of the various correlation analyses performed. The GM events variable captured all of the significant relationships that were also found by correlation with GM area and % of GM area. The GM events variable was most highly correlated ($p<0.01$) with GDP, lnGDP, merchandise exports, and % of agricultural workers. It was correlated ($0.01<p<0.05$) with organic area, average fertilizer use, and the British colonial dummy variable. GM events was weakly correlated ($0.05<p<0.10$) with trade per capita (TPC), agriculture as a percentage of merchandise exports, and adult illiteracy rate. All of these correlations were positive except for agriculture as a percentage of merchandise exports, adult illiteracy rate, and percentage of workers in agriculture. Organic area was the most informative variable of the organic variables, capturing most of the significant relationships within the organic class of variables excluding lnGDP, merchandise export to the

Table 2. Correlation analyses of GM agriculture variables vs. all other variables.

	GM events	GM area	% GM area		GM events	GM area	% GM area		GM events	GM area	% GM area
Org area	0.457	0.199	0.179	**Merch exports**	0.629	0.617	0.573	**% of pop urban**	0.287	0.229	0.173
	0.015	0.309	0.363		<.001	0.001	0.001		0.139	0.242	0.379
	28	28	28		28	28	28		28	28	28
% org area	0.044	-0.056	-0.065	**Ag as a % of nerch exports**	-0.343	-0.174	-0.103	**% ag workers**	-0.584	-0.402	-0.343
	0.824	0.776	0.743		0.086	0.396	0.616		0.004	0.057	0.109
	28	28	28		26	26	26		23	23	23
Num org farms	-0.012	-0.017	-0.017	**Merch exports to EU**	0.029	-0.124	-0.167	**% of country protected**	-0.286	-0.117	-0.099
	0.959	0.941	0.939		0.891	0.553	0.424		0.157	0.569	0.631
	22	22	22		25	25	25		26	26	26
Pop	0.308	0.103	0.082	**EU trade dummy**	0.252	0.113	0.052	**Cattle density**	0.200	-0.085	-0.031
	0.111	0.603	0.677		0.214	0.583	0.800		0.308	0.666	0.875
	28	28	28		26	26	26		28	28	28
GDP	0.793	0.675	0.631	**Ag as a % of merch imports**	-0.277	-0.266	-0.284	**Environm ental NGOs**	0.028	-0.025	-0.043
	<.0001	<.0001	<.001		0.171	0.189	0.160		0.886	0.899	0.830
	28	28	28		26	26	26		28	28	28
lnGDP	0.569	0.360	0.334	**Road network density**	0.040	0.135	0.106	**Colonial power = British dummy**	0.397	0.241	0.203
	0.002	0.060	0.083		0.840	0.493	0.593		0.037	0.217	0.300
	28	28	28		28	28	28		28	28	28
TPC	0.354	0.287	0.254	**Average fertilizer use**	0.446	-0.070	-0.070	**AgGDP%**	-0.506	-0.350	-0.318
	0.065	0.139	0.191		0.043	0.763	0.763		0.006	0.068	0.100
	28	28	28		21	21	21		28	28	28
Trade to GDP ratio	-0.013	-0.111	-0.166	**Adult illiteracy rate**	-0.378	-0.253	-0.177	**AgGDP**	0.141	0.069	0.196
	0.947	0.575	0.399		0.052	0.203	0.378		0.473	0.727	0.318
	28	28	28		27	27	27		28	28	28

For each box the top value is Pearson's Correlation Coefficient, the middle value is the p-value, and the bottom value is the number of observations used to compute that correlation. Blue highlighted boxes indicate a correlation where $p<0.01$, green where $0.01<p<0.05$, and yellow where $0.05<p<0.10$.

European Union, and the British colonial dummy. Overall, these organic variables showed fewer and less significant correlations with the other variables in the dataset than the GM variables. Organic area was also correlated to GM events. It was weakly correlated to agriculture as a percentage of merchandise exports, adult illiteracy rate, and percentage of workers in agriculture. All of these correlations were negative except for GM events.

Count Models

Table 4 shows two count-based models designed to estimate the number of GM events within a given country.[2] Given that 15 of the countries sampled had no GM events, a negative binomial model (see Model I) is preferred since it adjusts for overdispersion, which occurs when the model violates the Poisson assumption that "for a given set of values on the explanatory variables, the variance of the dependent variable is equal to its mean" (Allison, 1999, p. 251). In our study, we have a mean of 4.14 GM events per country, with a variance of 97.39, which is nearly 25 times the mean. This large variance is attributable to the large data range, with South Africa reaching 40 GM events. This unusual data

2. *Using maximum likelihood, estimators have been proven to be consistent, asymptotically efficient, and normal as the sample size gets larger. Given our small sample size, caution needs to be used in interpreting the p-values. We consequently follow Allison (1999), who urges "caution in interpreting p-values and confidence intervals when samples are small. Despite the temptation to accept larger p-values as evidence against the null hypothesis in small samples, it is actually more reasonable to demand smaller values to compensate for the fact that the approximation to the normal or chi-square distributions may be poor" (p.34).*

Table 3. Correlation analyses of organic agriculture variables vs. all other variables.

	Organic area	% organic area	# of org farms		Organic area	% organic area	# of org farms		Organic area	% organic area	# of org farms
GM events	0.457 0.015 28	0.044 0.824 28	-0.012 0.959 22	**Merch exports**	0.183 0.351 28	-0.091 0.646 28	-0.114 0.613 22	**% of pop urban**	0.198 0.311 28	0.314 0.103 28	-0.417 0.053 22
GM area	0.199 0.309 28	-0.056 0.776 28	-0.017 0.941 22	**Ag as a % of merch exports**	-0.244 0.229 26	0.169 0.409 26	0.009 0.968 20	**% ag workers**	-0.356 0.095 23	-0.362 0.089 23	0.257 0.320 17
% GM area	0.179 0.363 28	-0.065 0.743 28	-0.017 0.939 22	**Merch exports to EU**	0.247 0.233 25	0.394 0.051 25	-0.209 0.391 19	**% of country protected**	-0.231 0.256 26	-0.304 0.131 26	0.031 0.898 20
Pop	-0.021 0.914 28	-0.190 0.333 28	0.120 0.596 22	**EU trade dummy**	0.196 0.338 26	0.208 0.308 26	0.064 0.789 20	**Cattle density**	-0.091 0.646 28	-0.134 0.496 28	0.095 0.674 22
GDP	0.158 0.423 28	-0.098 0.619 28	-0.091 0.688 22	**Ag as a % of merch imports**	-0.355 0.075 26	0.330 0.100 26	-0.306 0.189 20	**Environmental NGOs**	0.096 0.626 28	-0.211 0.280 28	0.180 0.423 22
lnGDP	0.256 0.188 28	-0.453 0.016 28	0.071 0.754 22	**Road network density**	-0.019 0.924 28	0.180 0.359 28	-0.044 0.844 22	**Colonial power = British dummy**	0.131 0.506 28	-0.116 0.557 28	0.418 0.053 22
TPC	0.316 0.102 28	0.065 0.742 28	-0.173 0.441 22	**Average fertilizer use**	-0.266 0.244 21	-0.246 0.282 21	-0.178 0.495 17	**AgGDP%**	-0.337 0.079 28	-0.275 0.157 28	-0.052 0.817 22
Trade to GDP ratio	0.246 0.206 28	0.041 0.836 28	-0.191 0.396 22	**Adult illiteracy rate**	-0.341 0.081 27	-0.371 0.057 27	-0.178 0.429 22	**AgGDP**	0.291 0.133 28	0.024 0.905 28	0.310 0.161 22

For each box the top value is Pearson's Correlation Coefficient, the middle value is the p-value, and the bottom value is the number of observations used to compute that correlation. Green highlighted boxes indicate a correlation where 0.01<p<0.05, and yellow where 0.05<p<0.10.

range, combined with the small sample size, appears to explain why some overdispersion tests proved surprisingly insignificant given the observed difference between the mean and variance.[3] As a result, we have also reported a second model—Poisson (see Model II), which does not adjust for overdispersion. In general, these estimators should be consistent (Wooldridge, 2006), yet produce biased standard errors. Three main explanatory variables of interest changed from statistical significance to weak or no significance depending on the model used. First, the percentage of protected area was weakly significant (p=0.092) in the Poisson model, yet not significant (p=0.156) in the negative binomial model. Second, the dummy for countries that banned GM food or aid was significant (p=0.005) in the Poisson model, and remained weakly significant (p=0.072) in the negative binomial model. Third, AgGDP was weakly significant (p=0.060) in the Poission model, yet not significant (p=0.583) in the negative binomial model.[4] We should note that removing the explanatory variable of lnGDP did result in significance for the AgGDP variable for both models. Although the two variables are clearly correlated, calculation of the variance inflation factor (VIF) showed no significant multi-

3. *The Alpha value, for example, was insignificant in Model I. However, rerunning the predictors without an intercept in an OLS regression [a method by Cameron and Trivedi (1996) as outlined by Liu and Cela (2008)], we find statistically significant overdispersion.*

4. *These findings on significance are also confirmed when we adjust for overdispersion via a Pearson chi-square correction of the parameters as outlined by Allison (1999).*

Table 4. Results of the count-based models (Negative Binomial and Poisson) of the factors predicting GM events in Africa.

Models predicting GM events in Africa						
Dependent variable	GM events					
Model Number	I (n=26)			II (n=26)		
Estimation method	Negative Binomial			Poisson		
Explanatory variables	Coeff	S.E.	Sig	Coeff	S.E.	Sig
lnGDP	(+)0.719	0.174	***	(+)0.693	0.107	***
AgGDP	(+)0.012	0.702	ns	(+)0.023	0.012	*
Organic area	(+)0.016	0.004	***	(+)0.016	0.003	***
British colonial dummy	(+)1.756	0.497	***	(+)1.531	0.348	***
% of country protected	(-)0.050	0.035	ns	(-)0.055	0.032	*
Ban of GM dummy	(-)1.264	0.702	*	(-)1.568	0.556	***
Intercept	(-)7.451	1.854	***	(-)7.074	1.248	***
Pseudo R-sq	0.927~			0.962~		
McFadden's R-sq	0.358			0.824		

**: p<0.1; **: p<0.05; ***: p<0.01; ~: calculated by squaring the correlation coefficients between y and y-hat (Wooldridge, 2006).*
Note: The main difference between the above two models is that adjusting for overdispersion in the negative binomial model lowers the significance of the variables AgGDP, % of country protected, and Ban of GM dummy.

collinearity. In terms of their overall significance, both models are highly significant ($p<0.01$). Furthermore, we calculated a pseudo r-square by squaring the correlation between the predicted and observed values, as well as using McFadden's method of comparing log-likelihoods of fitted and null models. These approximations of goodness-of-fit demonstrate the ability of our models to explain differences in the dataset despite the relatively small sample of countries which had GM events.

OLS Regressions

Table 5 depicts the results from four ordinary least squared regressions. We originally included the variables lnGDP and AgGDP in these models; however, neither variable was significant in any of the models, and resulted in poorer model fit, so neither was ultimately included. Model III includes 26 countries, including Tunisia. Since Tunisia has nearly twice the organic area (more than half of which is under olive cultivation) as the next African country, Models V and VI were calculated excluding Tunisia. In Model III, only GM events is positive and weakly significant ($p=0.05$), yielding an overall weakly significant model. As an alternative to excluding Tunisia, we created Model IV using a log-transformed dependent variable. This model, out of all four, is superior both in fit, with an adjusted r-square of 0.359, and significance. Since the British colonial dummy was not significant (as Tunisia is a former French colony), it was excluded from this particular model.

In Model V, neither the model nor any of the variables are significant. By removing GM events, whose estimates have a significant correlation with former British colonies, Model VI yields improved significance: the British colonial dummy (without Tunisia) is now weakly significant ($p=0.051$), while agricultural imports (as a percentage of merchandise imports) has improved in significance, though still insignificant ($p=0.12$). In general, our ability to predict organic area appears much weaker than our ability to predict GM events. Nevertheless, GM events is a consistently positive predictor and agricultural imports is a consistently negative predictor of organic agriculture throughout the models. The only explanatory variable that changes signs (i.e., not consistently a positive or negative predictor), is the British colonial dummy, which can be easily explained by the special case of Tunisia, as discussed further below. Calculation of VIF showed no significant multicollinearity in any of the models.

Discussion

Openness to GM and Organic Agriculture

Initially, one of the most pressing issues we faced when approaching this analysis was deciding how to quantify organic and GM agriculture within a country. Organic agriculture is relatively straightforward since statistics on both the number of farms and their areas are available for many African countries. GM agriculture is more complicated since only three African countries (Egypt,

Table 5. Linear regression analysis results where organic area (as a continuous variable) is the dependent variable, with GM events, agriculture (as a percentage of imports), and former British colony dummy as explanatory variables.

Models predicting organic area in Africa												
Dependent variable	Organic area (in 1000 ha)											
Model number	III (n=26)			IV (n=26)			V (n=25)			VI (n=25)		
Estimation method	OLS (with Tunisia)			OLS LN (with Tunisia)			OLS (w/out Tunisia)			OLS (w/out Tunisia)		
Explanatory variables	Coeff	S.E.	Sig	Coeff	S.E.	Sig	Coeff	S.E.	Sig	Coeff	S.E.	Sig
GM events	(+)1.398	0.686	*	(+)0.078	0.034	**	(+)0.380	0.41	ns	-	-	
Ag as a % of merch imports	(-)0.982	0.732	ns	(-)0.097	0.039	*	(-)0.589	0.415	ns	(-)0.653	0.408	ns
British colonial dummy	(-)6.024	13.727	ns	-	-	-	(+)11.890	8.12	ns	(+)15.090	7.33	*
Intercept	(+)29.77	16.58	*	(+)9.31	0.83	***	(+)14.84	9.55	ns	(+)16.22	9.4	*
Adjusted R-sq	0.168			0.359			0.209			0.214		

**: p<0.1; **: p<0.05; ***: p<0.01*

Burkina Faso, and South Africa) currently grow commercialized GM crops. Egypt and Burkina Faso each grow only one GM crop (maize and cotton, respectively, and only since 2008) so the industry is not only highly restricted, but immature. This would make a comparison between GM and organic area a shallow analysis, with a case study approach clearly preferable. Instead, we chose to look for a measure that could capture a country's openness to GM crops. The FAO database and statistics from the International Service for the Acquisition of Agri-biotech Applications (ISAAA; James, 2010) provided the opportunity to tabulate a count of GM events in many African countries. This tabulation includes contained trials, field trials, and commercialization events. It seems reasonable to assume that countries which are working through a regulatory process to approve GM trials, even if they have not granted commercial approval, are somewhat open to the idea of GM and are certainly more open to GM than a country that has not allowed any trials. We were unaware of any measure of openness to GM agriculture being estimated in this way, so we ran correlation analyses of all three GM variables against all of the other variables in the dataset to validate the use of GM events as a meaningful indicator. Since GM events had the same relationships with the other variables as the GM agricultural area measurements revealed those relationships with greater statistical significance, and even uncovered relationships in the dataset not discernible using the other GM variables, we concluded that GM events is a useful and more informative variable than the variables GM area and % GM area. We therefore utilized GM events as the dependent variable in the subsequent regression analyses.

Since coalitions generally in favor of organic are skeptical of GM and vice versa, we initially hypothesized that organic and GM would be negatively correlated. The correlation analyses revealed that this was not this case. In fact, GM events was significantly positively correlated with organic area. Based on these findings, we must reject our initial hypothesis. At the national policy level, GM and organic agriculture are able to coexist within African countries. This is evidenced by South Africa being the largest producer of GM crops and the third-largest producer of organic crops by raw area. In fact, the general correlation between GM events and organic area seems to indicate that countries serious about agricultural development are serious about it regardless of the technology being employed. Tunisia has the most area under organic cultivation in Africa and, although it has not commercialized a GM crop, it has the third-most GM trials underway.

Predicting Openness to GM Agriculture

In order to further explore the attributes which may be leading African countries to accept or reject GM crops, we set up regression models to econometrically explain the occurrence of GM events in African countries. Unsurprisingly, GDP (either in terms of absolute or agricultural GDP) was an important positive predictor of GM events in the model. GM is an advanced technology that requires significant expenditure for research, development, and regulation, as well as a level of purchasing power by its customers: farmers. As in the correlation analyses, prevalence of organic area was also an important predictor. Though this initially seemed paradoxical, it is important to recognize that certified organic production (as we have included in our dataset) is primarily destined for export markets. Therefore, infrastructure (such as functioning ports) and access to foreign markets (including export- and investor-friendly policies) are necessary preconditions. These features are likely to be related to a country's overall economic strength and may be behaving similarly to GDP as an indicator of GM events.

We were interested in testing Paarlberg's (2008) hypothesis that close proximity to Europe, and the accompanying desire to trade with Europe, facilitate the export of European GM sensibilities to Africa. We hypothesized that if market factors do explain GM prevalence in Africa, we should see a negative relationship between the importance of the European Union as a trading partner and the presence of GM events. In the correlation analyses, neither merchandise exports to the European Union nor an EU trade dummy correlated with GM events. In an earlier version of our regression model, merchandise exports to the European Union were weakly and negatively predictive of GM events. This relationship lost significance when we eventually included a dummy variable for former British colonies (which we discuss further below) and trimmed our models in order to lose as few observations as possible due to incomplete data. We interpret this lack of significance, and subsequent exclusion from our model, as evidence that EU consumer markets, while potentially having a significant impact on a subset of countries, are not primary drivers of African countries' decisions to avoid exploration of GM agriculture.

Instead, our model found that protected area within a country and an expressed ban of GM (either in terms of an outright ban of the technology or a refusal of GM grain as food aid) were weakly significant, negative predictors of GM events. If a country had a ban on GM food or aid by 2005, we would expect it to have 79%[5] fewer GM events in 2007, holding all else constant. Paarlberg (2008) argues that European governments have persuaded African countries to adopt a highly precautionary attitude towards GM. In our model, GM bans are unsurprising negative predictors of GM acceptance. Though nearly tautological, this relationship offers the most direct example of European influence over GM attitudes in Africa. It is well documented, for example, that Zambia refused 100,000 tons of food aid, in the form of GM maize grain, during the 2002 Southern African famine in part because of consultation with European scientists over potential health effects of the grain (Herrick, 2008). This was a precautionary stance indeed, considering that other countries had already been consuming GM maize since 1996 without adverse effect and Oxfam estimated that up to 26% of Zambia's population was threatened by famine in 2002 (Zerbe, 2004).

Our variable % of a country protected was weakly significant and had a negative impact on the occurrence of GM events. According to our model, for each extra percent of land held under protection, we would expect to see 5%[6] fewer GM events in that country. If protected area is thought of as a proxy for government interest in environmental preservation (possibly as a source of foreign exchange via tourism), it is not entirely surprising that it would be a negative predictor of GM since many environmental groups involved in preservation are firmly anti-GM. The more interesting inquiry revolves around the question of why African environmental groups and governments have adopted the view that GM is anti-environmental. Paarlberg (2008) argues that NGOs are members of a broad transnational movement against GM. If we hypothesize that protected area within a country is correlated with the number of environmental NGOs, then we can see a clear relationship whereby successful environmental NGOs push for more protected areas and less—or no—GM. Bates and Rudel (2000) did observe a positive association between the number of local environmental groups and protected areas in tropical countries (including African countries), though the association was not present for international environmental NGOs. However, Bradshaw and Schafer (2000) note that international NGOs work through local partners, who often defer to the larger organizations. Since many international, environmental NGOs are decidedly anti-GM (including Friends of the Earth and Greenpeace), there is strong potential for their local African partners to adopt similar views. Therefore, we interpret our model as revealing a potential signal of international environmental movement opposition to GM which may be carried by already present environmental NGOs who have been successful in spurring land preservation and believe that GM is anti-environmental. We believe that our environmental NGO variable did not directly capture this effect because it was

5. *Calculated as 100*[e^(-1.568)-1]=-79.15.*

6. *Calculated as 100*[e^(-0.055)-1]=-5.35.*

based on an incomplete list of NGOs compiled by the UN.

In summary, although motivations for preserving land are complex and often stimulated by financial or political, as opposed to environmental interests, the possibility exists that (international or local) advocacy for successful land preservation may create synergies for active opposition to GM agricultural development in Africa. However, the causal relationship between anti-GM activism and anti-GM policy must be rigorously examined. As Takeshima and Gruère (2011) note, the presence of anti-GM lobbying in Africa may be more associated with preexisting conditions already unfavorable to the introduction of GM, such as insufficient scientific and institutional capacity, than the successful exertion of political influence.

One of the most significant explanatory variables from Model I was the British colonial dummy. The model implies—holding all else constant—that the expected number of GM events for a former British colony is estimated to be 479%[7] higher than for a non-British (in this case mainly French or Portuguese) former colony. Based on a survey of related literature, we believe that our dummy variable is actually capturing present differences that originated during the colonial period. We cite the following two explanations for the increased occurrence of GM events among former British colonies. First, according to Grier (1999), improved development outcomes of former British colonies (as contrasted with countries with other former colonizers) were not attributed to superior infrastructural development by the British but were instead a result of human capital improvements. Specifically, the remnants of decentralized rule, increased education, and commitment to free trade were shown to be important aspects of British colonialism leading to better outcomes for their former colonies. Second, the common law system left in former British colonies has been argued to have a positive influence on development (e.g., Acemoglu, Johnson, & Robinson, 2000). Protection for investors was shown to be better and corruption lower in common law countries, though these effects have not gone uncontested (Lee & Schultz, 2009). Recent analysis has shown that the positive effects of common law due to British colonization disappear when sub-Saharan Africa is analyzed independently of other British colonial areas, but the positive effects on human capital, observed from a comparison of French colonial influence, remain significant (Agbor, Fedderke, & Viegi, 2010).

In summary, former British colonies achieved higher levels of development in Africa, possibly due to human capital improvements and legal system structure. As an advanced technology with complex legal and regulatory issues, GM would benefit from this colonial legacy. Therefore, the adoption of GM could be viewed along a route of technology diffusion, shifting from the most developed nations to rapidly advancing, emerging nations, such as the BRIC bloc. Though our analysis suggests that the legacy of British colonialism in Africa aids in the diffusion of GM technology, it could also be stated that the legacy of French colonialism in Africa presents an impediment to diffusion of GM technology since the vast majority of non-former British colonies were French.

Predicting Organic Agriculture

Our models predicting organic agricultural area were not nearly as successful as our GM models, with the logged version of organic area in Model IV yielding the highest overall significance. In this model, GM events was a strong predictor of organic area similarly to organic area being predictive of GM events. Given that many of the GM events have taken place since the initiation of organic agricultural exports, it appears that GM events did not slow down the expansion of organic production, but rather increased alongside.

One variable which proved to be a unique predictor (though varying in significance across all four of the organic area models) was agriculture as a percentage of merchandise imports, which had a negative relationship. This seems logical when assuming that a country that is food insecure would have a high percentage of its imports as agricultural products. A country that is a net-food importer would have less interest in devoting productive agricultural land to organic products destined for an export market. Analogous to our earlier discussion of GDP, a country that is importing large quantities of agricultural products might also lack the infrastructure or policies necessary to support a thriving agricultural export market.

The British colonial dummy was also a weak predictor of organic once we excluded Tunisia. Tunisia, as a former French colony, is a unique case, with more than half of its organic production in olives owing to its Mediterranean climate, low labor costs compared to other olive-producing countries, and access to a lucrative export market. This should serve as a reminder that

7. Calculated as 100[e^(1.756)-1]=478.92.*

organic agriculture, and indeed all agriculture, is highly responsive to the specifics of environmental conditions and local practices. Tunisia also stands apart in Africa in that it has a sophisticated organic institutional framework, which is subject to national law (Willer et al., 2008).

Conclusions and Further Research

Overall, our dataset did not prove nearly as informative about trends in organic agriculture in Africa as it did for GM agriculture. The strongest relationship discovered for organic was its correlation to GM, the inverse relationship of that which we already described. This is meaningful primarily since it indicates that there is not nearly the kind of competition between the two technologies as the polarized public debate would suggest. Some of the failure to explain organic agriculture with national-level data may stem from the fact that organic farming is rarely centralized or regulated at the national level in Africa (Tunisia being the only exception). GM, on the other hand, is highly centralized and regulated by national governments as it involves large capital expenditures, complex regulatory regimes, and cooperation with multi-national corporations or other international agencies. Organic agriculture could be characterized as having a greater diversity of participants, with varying motivations, and fewer technological and capital access barriers: it can be promoted by either large-scale intervention led by a multinational company contractor or small-scale intervention led by an NGO that would like to work within a single village community. Therefore, GM agriculture is likely to be more responsive to (or dependent on) thresholds of national development, as measured in our indicators, than organic agriculture, whose production is likely to be more responsive to subnational differences.

In summary, we have made a concerted effort to empirically test a range of arguments explaining the lagging and differential development of GM agriculture in Africa. Our variables capturing relationships with Europe as an export partner did not significantly explain GM prevalence. Contrary to one of Paarlberg's (2008) assertions, it does not appear that African countries are highly motivated by fear of losing access to EU markets should they develop GM agriculture, although it is important to note that many of the GM technologies deployed most recently (as in the case of Burkina Faso with Bt cotton) are in the non-food sector. However, Paarlberg's (2008) thesis that Europe has exerted significant influence gains traction via two mechanisms. First, we show that the legacy of British colonialism is a significant factor. Based upon a review of the development literature, it seems that this relationship is most likely explained by the legacy of colonialism via human capital development, as opposed to continued cultural ties, but we should not discount cultural ties entirely. The vast majority of African countries that were not under British colonization were under French colonization. Europe is not unified in its opposition to GM technology. For example, France is more opposed to GM agriculture—expressed either as government votes against GM within the European Union or as a percentage of public acceptance—than Great Britain and many other European countries (Kurzer & Cooper, 2007). Therefore, there remains the possibility that both formal and informal relationships between European countries and their former colonies could lead to differing attitudes toward GM agriculture commensurate with differing attitudes among European countries themselves.[8] Second, we show that a GM ban or refusal of GM food aid is a negative predictor of GM events, though we should note that these bans do not follow colonial legacies. Of the six countries in our dataset that have instituted a GM ban, three were British colonies and three were French. Nevertheless, it has been well documented that in at least some of these cases, the GM bans were at least partially arrived at after consultation with European advisors. This could represent one route by which, as Paarlberg (2008) notes, European countries have discouraged the deployment of more advanced farm science that could meet Africa's agricultural needs.

Contrary to our initial expectations, our research shows that at the national level, organic and GM agriculture are not antagonistic technologies. Extending from our findings, it seems that African countries that are serious about agricultural development appear to consider, and in some cases deploy, both organic and GM technologies. This apparent pragmatism is welcome news. When observing the world agricultural debate from a distance, it can often appear that there is a paralyzing polarity between those labeled as "environmentalist" and those labeled as "conventional" agriculturalists, with organic advocates in the environmentalist camp and GM advocates in the conventional camp. The reality seems much more nuanced. It is

8. *Given the central role of policy makers, France's colonial policy of assimilation and educating African leaders in French universities might have played an important role, although with a generational 'passing of the torch' this might be of lesser importance.*

unclear if this is an indication of a shift away from the so-called anti-science agricultural agenda that Paarlberg (2008) implicates in the low adoption of GM in Africa, or part of a general softening of some organic and environmentally minded development experts on more integrated approaches using advanced technologies. There have recently been several prominent scientists, including organic advocates, who are raising the idea of including GM in allowable organic practices (e.g., Ammann, 2008; Ronald & Adamchak, 2008). Similarly, the Bill and Melinda Gates Foundation, which is a major supporter of advancing access to pro-poor agricultural biotechnology in Africa, has provided a grant to FiBL to develop and promote an organic field manual for African small-scale farmers.[9] In any case, it is heartening to have evidence that at the national level, African countries are at least willing to engage in rational, pragmatic thinking and are not completely dominated by any particular ideology, though it must be noted that this process has not advanced as quickly in Africa as in Latin American and Asia.

Though important information has been generated in this analysis, the limitations of the dataset must be acknowledged. Both GM and organic agriculture have a relatively short history in Africa. Furthermore, even in the countries which do have reliable measurement of these technologies, neither form of agriculture makes up more than 3% (and in most cases less than 1%) of total agricultural production (except in Sao Tome and Principe, an island nation, which has over 5% of its agricultural land in organic farming). Therefore, caution must be exercised when using this dataset to infer large-scale trends in agriculture or agricultural policy over an entire continent. This analysis will most likely best serve as a preliminary indicator of which trends economists and development scholars should continue to examine as African agricultural strategies mature.

We consequently propose three further avenues of inquiry: First, drawing on Paarlberg (2008), we might attempt to further quantify how European actors are influencing agricultural policy in Africa via a more detailed dataset of NGO and private-sector activity. Second, our findings are limited to the national level, which masks differing dynamics of competition at the crop-specific level. While we find positive correlations between organic and GM, recent developments in India and Burkina Faso have highlighted that the feasibility of organic cotton production can be threatened by the rapid and wide-spread adoption of GM cotton production (Maiga, 2011). In addition, organic standards and GM labeling requirements have been shown to explicitly link markets for organic and GM products (Giannakas & Yiannaka, 2006). Consequently, further studies might investigate the usage dynamics of the respective technologies within specific crops at either a national or regional level. Finally, we generally share a concern for the lack of public funding in agriculture, and would favor an increase in both organic and GM funding, with particular focus on agricultural systems conducive to coexistence of both technologies. While the impact of reduced public funding on agricultural productivity is well-understood, it would be interesting to investigate its impact—via the Consultative Group on International Agricultural Research (CGIAR) and other agricultural development systems—on biotechnology and organic adoption in Africa.

9. *This is a welcome starting point, as organic agriculture research—as opposed to advocacy—is often underfunded.*

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