A12

BALANCING FOOD SECURITY AND BIODIVERSITY IN THE CONTEXT OF A CHANGING LANDSCAPE

The case of GMO corn adoption in Isabela, Philippines

*Miladis M. Afidchao**

Introduction

The burgeoning world population has exceeded seven billion amid planet Earth's decreasing capacity to replenish lost and fast-depleting natural resources. This makes food security a top concern for most countries, poor and developing countries in particular. Growing demographic pressures coupled with climate change may result in food scarcity becoming a major cause of conflicts between nations competing for survival in the future.

The close link between food security and a sound natural resource base is a fundamental natural law that should not be violated in development planning. However, the number of mouths to feed alongside the ever-increasing pace of urbanization and infrastructure build-up may see the future abandonment of ecological ideals and principles. This is already obvious in the rapid transformation of the natural landscape into a mosaic of varied land uses in almost all parts of tropical countries.

In this context, striving for food security and biodiversity conservation may no longer be pursued as mutually exclusive endeavours. While on one hand, there is the ecological imperative to preserve nature in its pristine state for aesthetics and ecosystem services, on the other there is continuous pressure on the land in the effort to lift the production of annual crops.

In all of these circumstances, food security is a primary goal that needs to be sustained, so we turn to modern technology to address the problem. We may now safely say that genetically modified (GM) corn technology has played a role in the alleviation of the food-security problem. Sadly, however, as is regularly the case in the introduction of man-made innovations, concerns about environmental impacts

* Dr Miladis M. Afidchao, Associate Professor V and Campus Director, Research for Development, Isabela State University, Cabagan, Isabela, Philippines.

and uneasiness about its effects are forced to the sidelines. This is especially the case in considering the effects of GM corn on biodiversity.

This is exemplified by the many areas that were once rich in agrobiodiversity that have been converted to monocropping of high-value industrial plantations, such as yellow corn and cassava. Moreover, an increasing variety of genetically modified (GM) crops, corn in particular, is being developed and will soon be used to convince farmers to shift from their traditional crops.

This chapter presents a strong case describing how areas of grassland, once part of natural fallow systems, have been transformed into monoculture GM corn production areas at three study sites in Isabela province, along the foothills of the Sierra Madre mountain range in northern Luzon, Philippines. These sites are a microcosm of what is currently happening in other grassland areas in the country as a result of the large-scale adoption by farmers of GM corn.

Isabela, the corn-producing province

The Philippines has a total land area of 299,404 sq. km, or about 30 million hectares, and about 33% of it, or 9,728ha, is devoted to agriculture. Corn ranks as the country's second most important crop (Moog, 2005).

The 1991 Census of Agriculture and Fisheries showed that the country had about 1.8 million maize farms and an estimated 600,000 small farming families were dependent on corn production (Maliwanag, 2000). About 12 million Filipinos prefer white corn as their main staple food while yellow corn accounts for about 70% of mixed feeds for livestock. As well as being a staple food for many Filipinos, corn is also processed into high-value products, such as corn starch, corn oil, gluten and snack foods.

In terms of the geographical extent of corn-producing areas, Isabela leads all other Philippine provinces. The eastern side of the province is a long stretch of rolling terrain lying in the foothills of the Sierra Madre mountain range. It is characterized as being under a natural fallow system, and was once dominated by tropical grasses and mixed savannah forest. However, this swathe of former grassland has been subject to continual transformation into a mosaic of varied land uses due to growing population pressure, urbanization and extensive clearing for planting yellow corn.

The province lies in the northeast of Luzon island. Climatically, the seasons are not very pronounced. It is relatively dry from November to April and wet during the rest of the year. The annual average air temperature is 27° Celsius and the average rainfall is 1700mm (Gerpacio et al., 2004). In the past, most of the corn-growing areas were located along the deltas of the Cagayan river. Being in a typhoon and flood-prone zone, these low lying flat areas are inundated every year, leaving the soil rich for corn production.

This chapter was drawn mainly from the author's PhD dissertation.[1] However, a post validation phase of the study, involving observation and data gathering, was carried out recently in three northern districts of Isabela: Cabagan, Tumauini and Ilagan (Figure A12-1).

Cabagan is one of the major corn producing towns in the region, located in the northern part of Isabela and to the east, facing the Sierra Madre mountain ranges. It is about 34km from Tuguegarao, the regional centre of the Cagayan Valley region, and about 50km from Ilagan, the capital of Isabela province. It has an estimated area of about 430sq km, or 43,000ha, and occupies about 2.43% of the province's land area.

Tumauini is about 30km north of the provincial capital, Ilagan. It has a total land area of 467.3sq km or 46,730ha, and its topography is generally level to rolling terrain. Flat lands are found along the Cagayan river, and the eastern part is generally hilly, becoming mountainous nearer to the Sierra Madre mountain ranges. Agriculture is the primary economic activity, with about 805 households dependent upon agricultural products as their major source of livelihood and income. More than 21% of Tumauini's area is devoted to cropping of rice, corn, root crops, fruit trees, legumes and some vegetables.

Ilagan, the third district, is located in the central part of Isabela province and includes the provincial capital, Ilagan town. An agriculture-based district, it produces corn, rice, vegetables and legumes. Fruits, such as bananas, are also a year-round product, especially in Ilagan's mountainous areas, and the district also produces

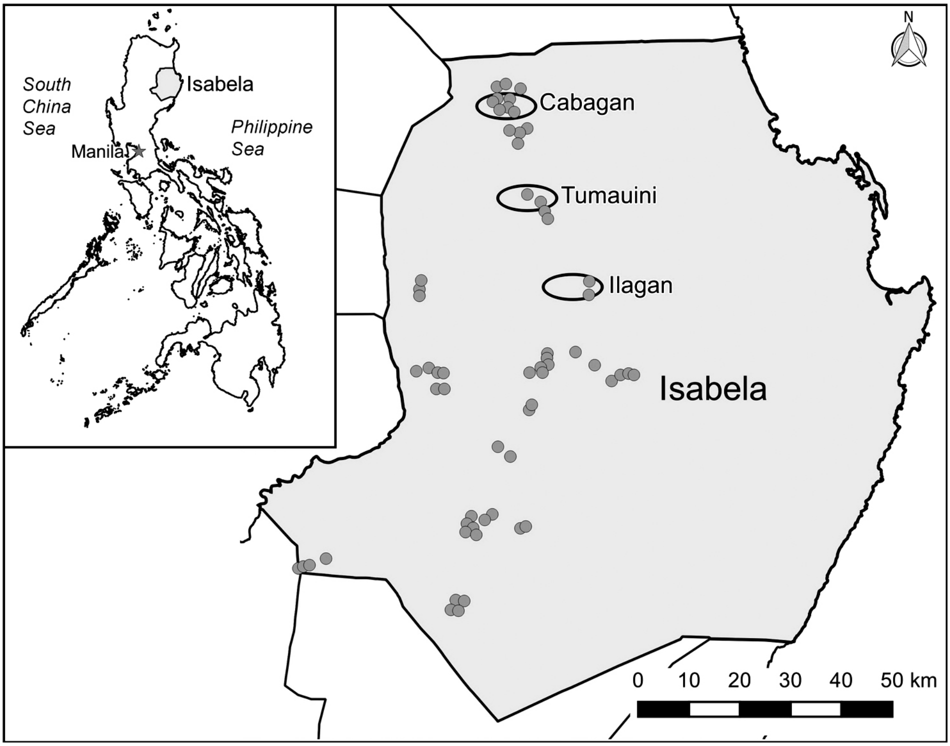

FIGURE A12-1: Location of Isabela province in the Philippines (left), and corn areas in Isabela with experimental farms where farmers' interviews were conducted for PhD research in 2011 and 2012. The three districts in which the recent validation study on GM corn was conducted are circled.

seasonal fruits such as mangos and pomelo. Of its total land area of 1,166.26sq km, 31% is committed to agricultural production. Ilagan was one of the field-test areas for Monsanto's *Bt* corn in 2001.[2]

Methodology

The data and information presented in this chapter are part of Afidchao (2013), which aimed to provide a holistic view of the impact of GM corn on the environment and on farmer adopters in Isabela province. The data-gathering methodology employed both qualitative and quantitative approaches. Specifically, in order to assess the ecological health of GM cornfields when compared to non-GM cornfields, both the biotic and abiotic factors fundamental in a stable corn agro-ecosystem were considered.

Data on biotic factors, including both floral and faunal species richness and abundance, were gathered for the assessment of cornfield ecosystems. Faunal species included all the invertebrates from three different dwelling levels: aerial/foliage insects, surface dwelling or land crawlers and below-ground invertebrates. For floral components, data on both beneficial and pest species were gathered.

The abiotic factors used as confounding variables were physico-chemical components such as soil pH and soil-nutrient contents. Overall, 250 corn farmers from 15 municipalities in Isabela province were interviewed for this study. They included farmers of *Bacillus thuringiensis* (*Bt*) corn and growers of herbicide tolerant (HT) corn, *Bt*HT corn and non-GM corn, as well as those with mixed cropping systems. Finally, to determine the economic viability of GM corn, 130 farmers, including those growing non-GM corn and *Bt*, *Bt*HT and HT corn were interviewed face-to-face and their reasons for adopting GM corn, or not adopting it, were identified.

Corn intensification as a causal factor of agricultural landscape transformation

The widespread corn monoculture intensification in Isabela, from non-GM corn to GM corn (Figure A12-2) can be considered a recent causal factor in the transformation from a forest-based ecosystem to an agricultural landscape. Coxhead et al. (2001) found that land allocation was responsive to relative crop prices and yields. Crop expansion was concomitant with land substitution and intensified input, while expansion of farm area could induce changes in crop yields. This could affect the stability of an ecosystem, specifically its biodiversity components. Many previous studies (Hodda et al., 1997; Chauvel et al., 1999; Eggleton et al., 1996; Ramirez, 2007) have shown that faunal biodiversity is affected by land-use change. In particular, Pascual and Barbier (2006) showed that soil degradation due to land-use intensification (i.e. clearing more forest on village common property) was caused by the need to intensify food production to meet the demands of an increasing population. Hence, the subsequent discussion focused on the potential impact on agrobiodiversity of

FIGURE A12-2: A hilly area in Ilagan (left) and grassland in Cabagan (right), both dominated by monocropped GM corn.

monoculture cropping, concomitant with the widespread adoption of GM corn in Isabela province.

GM corn and biodiversity

Insect-resistant Bt *corn*

Cornfields are regularly disturbed ecosystems, due to continued anthropogenic activities. As complex environments, they comprise many interacting elements (i.e. biotic and abiotic) that influence plant growth (Wright and Rich, 2004). Some of these biotic elements of great concern to farmers are pests, including grubs, wireworms, seed maggots, armyworms, flea beetles, aphids and Asian corn borers. Likewise, a number of diseases such as *Fusarium* wilt, leaf blights, anthracnose, leaf spot, stalk and rootrots and nematode attacks, pose threats to cornfield productivity. To address this concern, corn farmers regularly resort to the intensive use of pesticides. However, most pesticides have adverse effects on human health, the environment and biodiversity (de Snoo,1997; Stoate et al., 2001; Geiger et al., 2010; Waggoner et al., 2011; Yadav and Sehrawat, 2011).

Genetically modified *Bt* corn, with its 'built-in' insecticide, reduces farmers' dependence on toxic chemical-based farm inputs, thus mitigating the effect of insecticides on the environment and human health.

This study joins others in showing that *Bt* corn is effective in controlling Asian corn borer (Chen et al., 2008; Afidchao et al., 2013a). Its Cry1A protein, which is toxic to Asian corn borer, is claimed to be environment-friendly because of its highly specific target pest and to have few known adverse effects on non-target species (Glare and O'Callaghan, 2000). Further, other studies conducted in temperate countries (Sims and Martin,1997; Escher et al., 2000; Bhatti et al., 2005a, 2005b; Rauschen et al., 2009; Alfageme et al., 2010; Bakonyi et al., 2011) have provided scientific evidence of the positive environmental effects of *Bt* Cry1Ab protein and its non-toxicity to several non-target arthropods and pests. Likewise, many studies have confirmed that *Bt* corn has no adverse effects on soil-dwelling invertebrates such as earthworms, woodlice, pillbugs, Collembola and mites (Escher et al.,2000; Clark et al., 2006; Griffiths et al., 2006; Clark and Coats, 2006; Marvier et al., 2007).

However, in Isabela Province, it was found that among three invertebrate dwellers monitored in a *Bt* corn agro-ecosystem, the abundance and species richness of these non-target organisms was greatly reduced (Table A12-1). However, the abundance and richness of the same aerial and ground dwellers was positively favoured in non-GM cornfields (Table A12-2). A related study (Afidchao et al., 2013b) also indicated that non-GM cornfields that were sprayed with insecticide harboured more invertebrates than unsprayed *Bt* or *Bt*HT cornfields.

The negative impact of *Bt* corn on some groups of non-target organisms means, simply, that *Bt* protein affects other non-target organisms. This supports the findings of Lang and Otto (2010), that the *Bt* protein adversely affects Lepidopteran caterpillars.

Biodiversity inventories and assessments in cornfield agro-ecosystems in tropical countries like the Philippines, with large-scale plantations of genetically modified

TABLE A12-1: Mixed regression analyses (REML) of abundance and species richness of all invertebrates, with corn variety, soil pH, soil nitrogen (N), and soil potassium (K) contents as confounding variable/fixed factors and field within site within sampling method as a random factor.

	Mean± SD	*p-value*	*Sign B*
Total Abundance			
Variate		0.0011	⋆
Corn variety			
- Non-*Bt* corn (Intercept)	3.490 ± 1.405		
- *Bt* corn	3.146 ± 1.491	*0.0019*	⋆
- *Bt*HT corn	3.162 ± 1.382	*0.3553*	ns
Covariates			
Soil Ph		0.0126	⋆
N		0.0143	⋆
lnK		0.0072	⋆
Total Species Richness			
Variate			
Corn variety		0.0197	⋆
- Non-*Bt* corn (Intercept)	7.511 ± 4.129		
- *Bt* corn	6.824 ± 3.266	*0.0069*	⋆
- *Bt*HT corn	7.028 ± 3.113	*0.2455*	na
Covariates			
N		0.0326	(⋆)

Notes: Mean abundance per dweller was ln(x+1) transformed. SD = standard deviation. P-values in italics are of contrasts. Sign B: significance after Bonferroni correction: ⋆⋆ = equivalent to $p<0.01$; ⋆ = equivalent to $p<0.05$; (⋆) = equivalent to $p<0.10$).

Source: Afidchao et al., 2013c

TABLE A12-2: Mixed regression analyses (REML) of abundance of aerial, surface and soil invertebrates and species richness of aerial dwellers, with corn variety, corn isolines, herbicide, ln(x+1) field elevation (lnElev) and field longitude (Longi), soil organic matter (OM), soil pH and soil potassium (K) contents as confounding variable/fixed factors and fields within the site as a random factor. Only the best fitted models are given.

	Mean± SD	*p-value*	*Sign B*
ABUNDANCE			
Aerial dwellers			
Variate		0.0099	⋆
Corn variety			
- Non-*Bt* corn (Intercept)	3.885 ± 0.568		
- *Bt* corn	3.500 ± 0.540	*0.0050*	⋆
- *Bt*HT corn	3.360 ± 0.380	*0.0412*	=
Covariates			
OM		0.0533	=
pH		0.0181	(⋆)
Surface dwellers			
Variate			
Corn variety		0.4123	=
- Non-*Bt* corn (Intercept)	4.688 ± 0.625		
- *Bt* corn	4.619 ± 0.515	*0.2635*	=
- *Bt*HT corn	4.500 ± 0.486	*0.0614*	=
Covariates			
Isolines		0.0126	(⋆)
pH		0.0043	⋆
lnElev		0.0023	⋆
Longi		0.0191	(⋆)
Soil dwellers			
Variate			
Corn variety		0.0275	=
- Non-*Bt* corn (Intercept)	1.897 ± 1.035		
- *Bt* corn	1.320 ± 0.672	*0.0365*	=
- *Bt*HT corn	1.625 ± 1.068	*0.0144*	(⋆)
Covariate			
InK		0.0144	(⋆)
SPECIES RICHNESS			
Aerial dwellers			
Variate			
Corn variety		0.0089	⋆
- Non-*Bt* corn (Intercept)	7.967 ± 1.965		
- *Bt* corn	6.556 ± 2.335	*0.3061*	=
- *Bt*HT corn	7.250 ± 1.700	*0.6839*	=
Covariates			
Herbicides		0.0114	(⋆)

Notes: Mean abundance per dweller was ln(x+1) transformed. SD = standard deviation. Sign B: significance after Bonferroni correction: ⋆⋆ = equivalent to $p<0.01$; ⋆ = equivalent to $p<0.05$; (⋆) = equivalent to $p<0.10$).

Source: Afidchao et al., 2013c, Chapter 4, Table 8.

corn (both *Bt* and *Bt*HT), have found significant negative effects on non-target species, mostly surface and soil dwellers. These same non-target species were found in high abundance in fields growing genetically unmodified corn (Afidchao et al., 2013c). Hence, genetically modified corn and its associated agricultural regime do not always guarantee the safety of the environment. Nor do they ensure a more biodiverse corn agro-ecosystem (Afidchao et al., 2013b).

Herbicide-tolerant corn

Herbicide-tolerant (HT) corn brings several benefits, even after applications of the herbicide Glyphosate. Glyphosate is considered to be a relatively risk-free chemical because of its degradability (Cerdeira and Duke, 2006) and inability to persist in the soil. Hence, its use limits the risk of surface- and ground-water pollution (Borggaard and Gimsing, 2008). Previous research has shown that farmland arthropods benefit from HT corn (Firbank and Forcella, 2000; Dewar et al., 2003; Freckleton et al., 2004). This claim contradicts the prevailing and logical assumption that more weeds will harbour more insect species.

The Isabela farmers allow minimal to zero weed cover in their cornfields in the assumption that by eliminating competition between the corn and weeds they can ensure good growth performance from the plants. They maintain the practice that planting any corn varieties means that weeds must be eliminated, either by manual weeding or application of herbicide. Tables A12-1 and A12-2 show comparable effects of GM corn and non-GM corn in terms of the abundance and richness of cornfield invertebrates. The result supports previous findings on the absence of negative effects on farmland arthropods from HT corn (Firbank and Forcella, 2000; Dewar et al., 2003; and Freckleton et al., 2004).

However, Afidchao et al. (2013b) found that while the abundance of invertebrates in Glyphosate-sprayed cornfields was comparable to that in non-Glyphosate-sprayed fields, the species richness differed, and fields sprayed with Glyphosate exhibited a lesser number of species. In addition, weeds contributed to ecosystem balance by serving as microhabitats and food

Ageratum conyzoides (L.) [Compositae]

A common weed in the cornfields of Isabela. In Iligan district, fields growing non-GM corn showed a greater cover of this weed than fields growing genetically-modified corn. *A. conyzoides* is prone to becoming a rampant invasive weed when grown outside its native range in tropical America.

sources for some invertebrates. In related studies, Williams (1986), Free (1993) and Osborne et al. (2001) all found that flowering weeds within fields of flowering oilseed rape crops provided a considerable supply of nectar and pollen that could attract foraging bees and butterflies. These findings suggest that not all weeds should be considered pests and therefore should not be eliminated from agro-ecosystems. Afidchao (2015) found that among the most abundant and identified weed species (in terms of percentage of weed cover) only nine out of 34 species were considered pests by corn farmers (Table A12-3).

Rottboellia cochinchinensis (Lour.) Clayton [Poaceae]

Corn farmers in Isabela regard this grass species, known as 'itchgrass', as a significant pest. It spreads by seed, with each plant producing up to 3,000 seeds. Elsewhere in the world, it has infested about 3.5 million hectares of cropping land in Central America and the Caribbean. This study found that it appears to favour fields growing non-GM corn.

In the context of biodiversity, the continuous application of broad-spectrum herbicides is never advisable because it can contribute to a chain of bio-adverse events and ultimately imbalance the agro-ecosystem and hasten the adaptive ability of weeds to survive beyond all measures of control. The development and wide-scale adoption of herbicide-tolerant corn, concomitant with the continuous application of herbicides for easier weed management, may result only in short-term solutions to eliminating weed problems. In time, it may cause bigger problems when so called 'superweeds' – those that are tolerant to broad-spectrum herbicides – evolve by developing characteristics that enable them to survive any chemical onslaught. That such weed species may indeed evolve was supported by interviews with farmers in Ilagan, who mentioned that some weeds were able to persist even after the application of broad-spectrum herbicides.

In view of this, natural means of eliminating weeds should be encouraged and GM corn varieties developed that are so highly efficient in absorbing nutrients from the soil that they out-compete surrounding weeds and do not require the application of herbicides.

Socio-economic significance

The socio-economic benefits of using GM corn varieties must be seen from the standpoint of advantages to the producers and users, because these planting materials are exclusive and highly concealed capital assets that are tightly protected by Intellectual Property Rights.

As is the case with other commercialized seeds of genetically modified or scientifically bred 'improved' crop varieties, the strains of GM corn that are available for large-scale production are rigidly controlled by big multinational corporations. Since the GM corn seeds are good for only one single cropping phase and can only be procured from the high-technology source or its licensed distributors, farmers both small and large are at the price dictates of those who control the germplasm.

TABLE A12-3: Weeds and percentage of cover in GM and non-GM cornfields in Isabela surveyed during the dry growing season in 2010 and 2011. Underlined species are those identified as pests by corn farmers.

Weed species	*GM cornfields*			*non-GM cornfields*		
	Cabagan	*Tumauini*	*Ilagan*	*Cabagan*	*Tumauini*	*Ilagan*
Ageratum conyzoides L.	6.1	0.2	19.2	6.1	0.1	23.9
Amaranthus viridis L.	0.0	0.0	0.3	0.0	0.0	0.9
Amaranthus spinosus L.	0.0	1.0	0.0	3.4	1.0	0.0
Boerhavia diffusa L.	0.2	0.0	0.0	0.8	0.0	0.0
Borreria laevis (Lam.) *Griseb.*	0.0	0.5	3.3	1.5	1.1	7.6
Cardiospermum halicacabum L.	3.0	0.0	0.0	0.0	0.0	0.0
Celosia argentea L.	0.0	0.0	0.0	2.8	0.0	0.0
Centrosema pubescens	1.3	0.0	4.0	2.1	1.3	2.9
Cleome rutidosperma DC.	5.5	4.3	4.7	6.5	2.3	6.2
Cleome viscosa L.	0.0	0.0	0.0	0.5	0.0	0.0
Comelina benghalensis L.	9.4	3.0	1.7	6.5	1.9	0.5
Commelina diffusa Burm.f.	0.0	0.0	0.2	0.3	0.0	0.0
Cynodon dactylon L.	0.0	2.5	3.1	0.5	1.0	8.2
Cyperus brevifolius	0.0	0.0	1.0	0.0	0.0	2.1
Cyperus rotundus L.	0.5	0.8	0.0	1.4	2.5	0.0
Davallia sp.	0.0	0.0	0.0	0.0	0.0	0.4
Digitaria ciliaris Retz.	2.3	9.8	3.1	1.2	0.5	13.0
Emilia sonchifolia L.	0.0	2.8	0.0	0.0	6.1	0.0
Euphobia hirta L.	1.0	1.4	0.0	3.6	0.0	0.3
Euphorbia heterophylla L.	4.4	17.0	2.1	15.0	10.0	0.9
Heliotropium indicum L.	0.0	0.0	0.3	4.7	0.0	0.2
Hyptis capitata Jacq.		0.0	0.6	0.0	0.0	2.9
Lindernia crustacean L.	1.4	0.0	1.9	2.0	0.0	0.9
Luffa sp.	0.0	0.0	0.0	0.8	0.0	0.1
Oldenlandia diffusa	0.7	0.0	6.8	0.6	0.0	2.9
Paspalum conjugatum	1.3	0.0	0.0	0.1	0.0	0.0
Peperomia pullucida L.	0.0	0.0	0.0	0.0	0.0	0.7
Phyllantus fraternus	0.5	0.0	0.0	0.0	0.0	0.2
Physalis angulata	0.0	0.0	0.0	3.4	0.0	0.0
Portulaca oleracea L.	0.9	0.5	0.0	2.3	0.0	0.2
Rottboellia cochinchinensis	1.6	5.8	1.4	9.3	8.8	3.4
Rorippa indica L.	0.0	0.0	0.0	0.0	0.0	7.3
Stachytarpheta jamaicensis	0.0	0.0	0.5	0.0	0.0	0.5
Triumfetta bartramia L.	0.0	0.0	0.0	0.0	0.0	0.3

Source: Afidchao (2015)

In terms of social equity, this oligopolistic market for GM corn planting materials creates a big differential profit margin between suppliers and seed consumers. There is a huge disparity in profit gains between the two, and economic gains go heavily the way of the multinational controllers of the seeds, rather than to the farmer-users.

Nevertheless, many farmers have adopted GM corn production, and more are rapidly shifting away from traditional local varieties because of the significant differences in yields. The dominant GM variety of yellow corn delivered yields that were up to 33% higher than conventional varieties in the 2003 to 2005 cropping seasons. Three years later, GM corn yields were still surpassing those of conventional varieties by 5% to 22% in 2008 and 2009 (Gonzales et al., 2009).

Driving forces for adoption of GM corn

The introduction of genetically modified *Bt* Corn to Isabela province was not an instant and miraculous phenomenon that saw the GM crop spread both easily and rapidly. At first, farmers were resistant and tried to assess the potential benefits from adopting such a technology; they were only willing to believe what they saw. Later, they were attracted by the claimed pecuniary and other benefits of adopting GM corn.

After their first trials, increased yields and a great reduction in crop damage from corn borers convinced farmers that they should adopt the technology on a continuous basis. Their adoption of GM corn was influenced by the perceived economic advantages, the extent of their knowledge, the level of satisfaction and the extent of their first-hand experience (Afidchao et al., 2013d). There were also other reasons why they adopted the technology (Table A12-4). For those farmers who did not adopt GM corn, the foremost constraint was reportedly the high cost of buying seeds before each cropping season.

TABLE A12-4: Farmers' reasons for adopting GM corn in Isabela, Philippines.

Reasons for GM corn adoption[1]	Bt	Bt*HT*	*HT corn*	*P-value*
Expected to suffer corn-borer problems	3.74[a]	3.11[ab]	3.11[ab]	0.059(*)
Convinced of resistance to corn borer	3.50[b]	2.29[a]	2.29[a]	0.000***
Fitted well with existing corn-production practices	3.76[b]	2.87[a]	2.87[a]	0.002**
To reduce overall corn-production costs	3.35[b]	2.56[a]	2.56[a]	0.002**
To reduce the labour required to grow corn	3.91[a]	2.45[b]	2.45[b]	0.000***
Wanted to try it	3.74[a]	2.23[b]	2.23[b]	0.000***
Less insecticide exposure for farmers	2.91[b]	1.96[a]	1.96[a]	0.001**
Less insecticide in the environment	2.47[b]	1.71[a]	1.71[a]	0.004**

Notes: Mean ± SD and significance values obtained from univariate analyses, using type of corn cultivated by respondents as the fixed factor. The p-values show the differences in reasoning of farmers about GM corn adoption. Significance: * = $P < 0.05$, ** = $P < 0.01$, and *** = $P < 0.001$. NS = not significant. SD = standard deviation. Different superscript letters at mean values indicate significant differences in respondents ($P < 0.10$) according to post-hoc analyses using Holm-Bonferroni. [1]Scale: 5 = HA (highly agree); 4 = MA (moderately agree); 3 = A (agree); 2 = D (disagree); and 1 = HD (highly disagree)

Source: Afidchao et al. (2013d)

Economic viability of GM corn

In general, farmers who use GM corn obtain higher incomes (given the same cropping intensity and land size) and show higher economic performance than those who adopt other varieties, as found in past studies (Raney, 2006; Yorobe and Quicoy, 2006; Finger et al., 2011). As shown in Table A12-5, interviews conducted by Afidchao et al. (2014) found that the income and production outputs or yields of farmers who adopted GM corn (both BtHT and HT) were higher than those of non-adopters. However, the same study found, in using the Binder-Oaxaca analysis, that when other agronomic factors were considered, GM corn did not manifest an economic advantage and exhibited economic impacts when compared to non-GM corn.

Summary of the positive and negative contributions of GM corn

1. Genetically modified *Bt* corn helps farmers to combat pest problems involving Asian corn borer and could potentially provide both pecuniary and non-pecuniary benefits when grown in areas with high corn-borer infestation. However, the claim that GM corn, which produces *Bt* endotoxin, affects only the target species (i.e. Asian corn borer) and has no direct or indirect effects on other non-target species (Glare and O'Callaghan, 2000; Meissle et al., 2005; Lang and Vojtech, 2006; Romero et al., 2007) is not supported by local studies in Isabela, Philippines (Afidchao et al., 2013b, 2013c). These studies showed that GM *Bt* corn had non-target effects on the abundance and species richness of invertebrates in the corn agro-ecosystem. Moreover, non-GM cornfields that were sprayed with insecticide were shown to harbour more invertebrates than unsprayed GM cornfields (Afidchao et al., 2013c). These findings suggest that the biodiversity of a corn agro-ecosystem could be at risk when planted continuously with GM corn producing *Bt* endotoxin. Hence, immediate and appropriate mitigating measures are imperative, given the wide-scale adoption of GM corn technology. These measures should not only protect the remaining agrobiodiversity, but also help to preserve and maintain well balanced agro-ecosystems.
2. Monocropping of GM corn and its adoption across the Philippines could potentially diminish crop biodiversity. Other native corn varieties are now at risk of being totally eliminated from the agro-ecosystem. Considering the high economic potential and increasing adoption of GM yellow corn, the seeds of which are incapable of being recycled, traditional varieties are at high risk of extinction.
3. Social acceptance of GM corn is positive, although at first farmers resisted such a new innovation. However, when they were well informed and had experienced the benefits of GM corn, such as its high efficiency in eliminating corn borer plus its increased yields, adoption became widespread. Hence, the acceptance and adoption by farmers of new technologies is based on experience.

4. Most past studies showed the economic advantages of growing GM corn in terms of increased yields and income. It was seen as an innovation that could help to uplift the economic status of farmers, especially those in areas with high corn-borer infestation and, importantly, those with their own capital resources. For poor farmers, whose crop-investment capital must be borrowed from middlemen at high rates of interest, iso-hybrid non-GM corn continues to be as economically viable as GM corn.

Conclusion

Agricultural intensification is grossly apparent in the one-time grassland-savannah ecosystem of Isabela province. Corn monocropping has become a dominant land use. On one hand, GM-corn technology has demonstrated its ability to increase yields. But on the other, the economic benefits have not necessarily found their way down to small-scale farmers who continue to work within the constrained economic systems and practices of rural Philippines.

In more than two decades of continuous and widespread cultivation, significant environmental change has already taken place, with negative impacts arising from diminishing biodiversity in areas that once supported both flourishing life forms and improvement of soil fertility.

The promise of economic stability and food security remains an elusive goal, especially for poor marginalized farmers who have been lured into adopting the new GM corn technologies. Meanwhile, the problem of biodiversity loss in the context of balanced agro-ecosystems has not been addressed; policy mechanisms are either absent or, at best, weak. The establishment of refuge areas, parcelled from heavily intensified cornfields to serve as sanctuaries for the preservation of biodiversity, should become mandatory.

The following recommendations are made in the context of GM-corn technology.

Recommendations

1. Since weed pests are not such a large problem as Asian corn borer, and considering that not all ‘weeds’ found in cornfields are considered pests, a narrow-spectrum non-Glyphosate herbicide should be developed that will kill only the intended weed pests. At the same time, herbicide-tolerant corn varieties must be developed for targeted outcomes. Farmers must be made aware of which ‘weeds’ are considered pests and which are not, giving them the option of either manual weeding or herbicide spraying that will reduce the impacts from using powerful broad-spectrum chemicals.
2. GM corn can potentially increase farmers’ yields and income to bring them food security. However, the economic viability of GM *Bt* or *Bt*HT corn is only fully realized in areas that are heavily infested with corn borer. In areas of light infestation, farmers should be encouraged to use non-*Bt* toxin remedies, such as

the use of available biocontrol agents (e.g. earwigs), which are environmentally friendly and cost-effective.

3. The high cost of seed is a major factor in poor economic returns to farmers, and it is recommended that the government provide subsidies to lower the cost of GM corn seeds, especially for poor farmers and those in areas of high corn-borer infestation.
4. As large-scale monocropping of GM corn has become highly prevalent in the Philippines, precautionary measures should be considered, such as the establishment of effective refuges in areas of intensive monocropping, to minimize serious implications for biodiversity and the sustainability of corn agro-ecosystems. This can be done by enacting laws and ordinances at national- and local-government levels, with implementing guidelines to be followed by all stakeholders.

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2. In genetically modifying a plant, a gene that produces a trait of interest is identified in a donor organism and is added to the genetic makeup of the plant using molecular technology. In the case of *Bt* corn, the donor organism is a naturally occurring soil bacterium, *Bacillus thuringiensis*, and its genes of interest produce proteins that kill a variety of insect pests, including Lepidoptera larvae, and in particular, European and Asian corn borer. Growers use *Bt* corn as an alternative to spraying insecticides to control pests.