Genetically modified (GM) corn in the Philippines : Ecological impacts on agroecosystems, effects on the economic status and farmers' experiences

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General Introduction

Genetically Modified (GM) corn in the Philippines

The Philippines, a country being powered primarily by an agricultural economy, has an expanding population of more than 92 million Filipinos (Anonymous, 2010a). The rapidly increasing population requires agricultural production to become more intensified to answer the ever increasing food demand. In the Philippines, corn (*Zea mays* L.) is second to rice as the most important crop. In spite of the fact that almost 3 million hectares are devoted to the cultivation of this crop annually, production in the past decades showed that it is not enough to meet the local needs due to low yield. In fact, before the introduction of high yielding and pest resistant corn varieties (like *Bacillus thuringiensis*/*Bt* corn) in 2002, corn production was inefficient having an extremely low mean yield of 1.52 mt/ha. in 1996 (Reyes *et al*., 2009).

A cornfield is a complex environment with many factors that can interact to influence the growth of a corn plant (Wright and Rich, 2004). These factors can be biotic and abiotic. Important natural biotic factors are pests such as grubs (*Phyllophaga spp*.), wireworms (*Agriotes lineatus*), seed maggots (*Delia platura*), grasshoppers (*Melanoplus differentialis*), crickets (*Gryllus sp*.), armyworms (*Spodoptera frugiperda*), flea beetles (*Systena spp*.), aphids (*Rhopalosiphum maidis*) and Asian corn borers (*Ostrinia furnacalis* Guenée), diseases (fusarium wilt, leaf blights, anthracnose, leaf spot, stalk & root rots), nematodes, birds, and weeds. Important natural abiotic factors are climate (typhoons, floods, heat and drought), soil types and nutrients. Problems such as pests and diseases force farmers to resort to intensive use of pesticides. However, pesticides can have well known deleterious 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).

The Asian Corn Borer (ACB), *Ostrinia furnacalis*, became the most devastating insect pest and became the major constraint to corn agriculture. A small damage could bring low market value of the corn that affects not only the yield but also affect the quality of the kernel. In other Asian countries like China, ACB is considered the most destructive pest in corn (He *et al.,* 2003; He *et al*., 2006). The Philippines is not exempted by the huge damage brought about by ACB. Records show that ACB could reduce yield by 27% (Logroño, 1998) and the damage could be even worse when corn is planted late (Javier, 2004). The larval stage is the destructive stage of ACB. The larvae are voracious feeders, with powerful mandibles they use for tunnelling in all parts of the corn (Caasi-Lit *et al*., 2009) and finally causing plants to lodge, and reduce the flow of sap and nutrients. They are hard to eradicate using broad spectrum pesticides because of their ability to hide themselves within the stem and cobs.

Aside from insect pests, weed is the second most important corn pest. Weeds compete with available plant nutrients, minerals and water from the soil resulting to poor growth and development of corn plants hence, reduced yield (Figure 1 left). In the Province of Isabela, farmers identified *Racboellia cochinchinensis* (Lour.) locally known as "*Marapagay*" as the most destructive weed pest for corn. This weed is highly prolific and could cause stunted growth of corn plant and reduced yield (Figure 1 center). To mitigate this problem, either manual weeding or soil tillage is applied. However, this is laborious, time consuming and also expensive (due to high cost/labor). Therefore, farmers in general resort to use herbicides. However, herbicides like Gramoxone (paraquat) and Roundup (glyphosate) are non-selective and cause systemic effects that could affect corn plants resulting to wilting or, worst, death when improperly sprayed (Figure 1 right).

Photos taken by the author

Figure 1. Weed covered cornfields and herbicide effect on weeds and corn plants due to improper application of herbicide.

Brief history of GM corn technology

Genetically Modified (GM) corn hybrids are products of modern biotechnology via modification of genes known as genetic engineering. *Bt* corn was first commercialized in US in 1996 and is produced by agribusiness Monsanto Inc. in the United States of America. *Bt* corn is a variant of maize, genetically modified to produce the bacterial *Bt* toxin, which is poisonous to insects. Its known "active ingredient" is derived from a naturally occurring soil borne bacterium, *Bacillus thuringiensis* (*Bt*) that is found worldwide. *Bt* produces a crystalline protein (Cry1Ab- endotoxin) that is toxic to specific groups of insects, for example Lepidopterans. The endotoxin is a stomach poison that must be ingested by the insect, after which the insect dies. The mechanism involves the activation of the *Bt* toxin in the digestive tract of insects where it leads to cessation of feeding and paralysis of the gut, thereby retarding the passage of undigested food (Glare & O'Callaghan, 2000).

As cited in Sanahuja *et al.* (2011), *Bt* was discovered in 1901 by Shigetane Ishiwatari, a Japanese biologist who investigated the cause of the sotto disease and rediscovered in 1911 by Ernst Berliner when he had isolated a bacteria that had killed a Mediterranean flour moth (*Anagasta kuehniella*). In 1956 Fitz-James Hannay and Angus Hannay discovered that *Bt* protein crystal is the reason why moths were killed, which is the start of researches on *Bt* and the *Bt* crystals. By 1977 there were 13 different strains of *Bt*, all still only effective against moths. But also in 1977 the first strain was found that was toxic to flies. The next strain found in 1983 to be toxic to beetles. Today there are thousands of strains and many encode for crystals and over a thousand types of *Bt* that produce over 200 types of protein crystals which are toxic against a wide variety of insects and some other invertebrates.

The Herbicide tolerant (HT) corn is another novel product of genetic engineering which allows farmers to spray broad spectrum herbicides onto their standing corn plant. It has to be noted that HT corn is a corn variety of herbicide-tolerance and not herbicide-resistance, which means that the HT corn develops the capability of withstanding/assimilating the herbicide without being negatively affected or getting killed. Herbicide tolerant (HT) corn was first introduced in 1999 in US (Owen and Zelaya, 2005). HT corn is genetically modified to counteract herbicides' damaging effects, specifically of glyphosate. Glyphosate [N-(phosphonomethyl) glycine] can kill plants by inhibiting the biosynthesis of aromatic compounds via the shikimate pathway (Kishore *et al*., 1992). The HT corn is protected from glyphosate with its genetically built-in EPSP (5-enolpyruvylshikimate-3-phosphate synthase) cDNA isolated from a glyphosate tolerant petunia cell culture line (Padget *et al*., 1995). Its glyphosate tolerant gene was isolated from a common garden Petunia, *Petunia hybrida*, which is flowering plant endemic to South America, primarily Southern Brazil and Argentina, and live in a variety of habitats from grasslands to mountain foothills (Anonymous, 2010b). Further analysis of a *Petunia hybrida* cell culture (MP4-G) tolerant to 1mM glyphosate revealed a 15- to 20-fold increased level of 5-enolpyruvylshikimate-3-phosphate synthase in the herbicide-tolerant strain (Steinrücken *et al*., 1986).

Benefits of GM corn technology

Promoters of agricultural biotechnology claim that GM corn can potentially mitigate the impact of agricultural intensification and *Bt* corn offers the best alternative to traditional insecticides for the control of ACB (Chen *et al*., 2008). Likewise, Monsanto Philippines claims that GM corn offers a golden opportunity for poor farmers to increase their yields thus improving their livelihood and alleviating poverty through: a) protection of crops from insect damage; b) lower pesticide use; c) increase food production and quality; and d) ecological sustainability (http://www.monsanto.com), accessed May 4, 2012). Hence, the driven expectations of high yields, lower pesticide inputs and savings in time management caused an upsurge in GM corn adoption in all major corn-producing countries.

In particular, GM corn cultivation is claimed to provide both pecuniary and non-pecuniary benefits for the farmers. The most common pecuniary benefit is increase yield (Finger *et al*., 2011; Raney, 2006; Qaim & Zilberman, 2003) through reduction of damage in stem by 99% and leaves by 84%. Cultivation of *Bt* and *Bt*HT corn produced an average yield of 2,000 kg ha^{-1} in the Philippines (Thomson *et al*., 2010) and this brought positive yield impact in 1996-2006 compared to conventional corn (Brookes *et al*., 2010a). In addition, Brookes and Barfoot (2010b) listed the most important non-pecuniary benefits with GM corn as follows: (1) ease of management, (2) savings on machinery, (3) lower pesticides use and (4) risk-free to human health. These non-pecuniary benefits were equal to 21% total direct income benefits in 2007 and 25% total cumulative direct farm income in the USA for 1996-2007. Likewise, in the USA, a reduction of 34.6 million kg of pesticides (9.6%) for 1996-2007 (Brookes and Barfoot, 2010a) was a good example of non-pecuniary benefits when using GM corn.

On biodiversity issues, *Bt* corn promise solutions to environmental problems associated with intensive use of pesticides. Although *Bt* corn contains a toxin that is harmful to ACB, the toxin is considered environment-friendly because it is highly specific with few known adverse effects to non-target species (Glare and O'Callaghan, 2000). The foregoing claim invites further verification studies because of the claim that *Bt* toxin is highly specific to ACB yet the same time admitting that non-target species are affected. Many research studies done both in laboratory (Bakonyi *et al*., 2011; Alfageme *et al*., 2010; Sims and Martin, 1997; Escher *et al*., 2000; Saxena and Stotzky, 2000) and fields (Rauschen *et al*., 2009; Bhatti *et al*., 2005a; Bhatti *et al*., 2005b) supported the non-toxic effects of *Bt* Cry1Ab protein to several non-target arthropods and pests. Lots of studies seem to confirm that *Bt* has no negative effects on soil-dwelling invertebrates such as earthworm, woodlouse, pillbug, collembolla and mites, (Clark and Coats, 2006; Escher *et al*., 2000;Clark *et al*., 2006; Griffiths *et al*., 2006). Finally, the meta-analysis of 42 studies on nontarget invertebrates done in temperate countries by Marvier *et al*. (2007) indicates that unsprayed *Bt* corn is more environmental friendly than insecticide sprayed non-*Bt* corn.

Equally, there are many benefits when using herbicide tolerant crops. Broader spectrum of weed control, reduced crop injury, less herbicide carry-over, price reduction for "conventional herbicides", use of herbicides that are more environmental friendly, new modes of action for resistance management, and weed management flexibility and simplicity are among the commonly cited benefits by Knezevic and Cassman (2003). In addition, economic advantage of HT corn was visualised in the developing countries with the farm income gain of $40.8 million in 2007 (Brookes and Barfoot, 2010b) and a savings of $1.2 billion by US farmers similar to cost cutbacks in herbicides, tillage and hand weeding (Gianessi, 2005). Environmentally, HT corn brings several benefits even with glyphosate application. Glyphosate is a chemical yet considered to be a relative risk-free herbicide because it is degradable (Cerdeira and Duke, 2006) and produce limited risk of surface and ground water pollution (Borggaard and Gimsing, 2008). Some studies are claimed to have shown that farmland arthropods were benefited by HT corn (Dewar *et al.,* 2003; Firbank and Forcella, 2000; Freckleton *et al.*, 2004). Such claim needs verification because it is out rightly inconsistent with the general logical assumption that more weeds will harbour more insect species.

Timeline on GM corn in the Philippines

As mentioned above, one promising solution to increase corn production is the development of technologies or corn varieties with novel traits to address the important current problems of corn farmers. In the Philippines, the agricultural sector have been taking steps so that several research agencies and institutions are studying the best possible way of increasing crop yield, allowing crops to thrive in different environmental conditions, developing low-cost and eco-friendly fertilizers and eradication of pests. Furthermore, to address the problem of ACB and weeds, the Philippine Department of Agriculture (DA) allowed GM corn cultivation in the country in 2003.

Table 1 enumerates the timeline of marked historical development of Biotechnology in the Philippines in general and that of *Bt* corn in particular showing how GM corn was gradually incorporated in the farming practices prospers in the corn agricultural landscape and became the leading corn hybrid ever adopted by the farmers in the country. The rapid adoption of *Bt* corn was attributed to the successful multi locational field testings in the Philippines in 2000 which was immediately followed by its commercial release in 2003 along with government approval and endorsement by former Philippine presidents through their policy statements. The important go signal for *Bt* commercialization in the country comes with the government's Department of Agriculture Administrative Order No. 008 series of 2002. Notable in the timeline are the presence of government bodies or institutes that are mandated to promote Biotechnology in general as well as significant legislations such as "The Plant Variety Protection Act" (Republic Act 9168) and government administrative issuances such as the Department of Agriculture Administrative Order No. 8 for the Regulation of Plant and Plant Products produced through modern biotechnology. The history of biotechnology and *Bt* corn technology in the Philippines can be described as in a state of transition with sporadic instances of mistrust and unacceptance of the technology by the public with government institutions ending up coming to the rescue in defense of newly adopted biotechnologies. Such sporadic mistrusts are expected in newly introduced technologies which are often diluted with misconceptions mixed up with valid issues. Towards the end of the last decade majority of corn farmers shifted to GM corn technology and its subsequent varieties and improvements transforming entire corn lands to GM cornfields. It could be said at this point that to date the country, being the 13th GM crop producing country in the world (James, 2011), is at the beginning of the gene revolution and at the end of green revolution.

Table 1. Philippine timeline of marked activities from biotechnology development to GM corn technology introduction and nation-wide large-scale adoption (Ebora *et al*., 2005; Cabanilla 2007; Gonzales *et al*., 2009).

Period	GM Historical Timeline
1960s-70s	Propagation technique using embryo rescue for mutant *makapuno* coconut was developed at University of the Philippines – Los Baños College of Agriculture
70s	Micropropagation and embryo rescue techniques for orchids were also developed
1979	BIOTECH in University of the Philippines – Los Baños, now called the National Institute of Molecular Biology and Biotechnology, was established through a Presidential Decree and became the first biotechnology R&D institute in the Philippines.
1980	Establishment of National Institutes of Biotechnology and Applied Microbiology (BIOTECH)
1987	Scientists from the UPLB, the International Rice Research Institute (IRRI), and Department of Agriculture constituted an ad hoc committee on biosafety and proposed the formulation of a national policy on biosafety to the national government.
1986 to 1992	DOST marked biotechnology as a flagship of high-end technologies, recognizing it as a "strategic tool for achieving sustained economic development".
1990	Former Pres. Corazon C. Aquino established the National Biosafety Committee of the Philippines (NCBP) by Executive Order (EO) 430. The Committee is responsible for regulating the importation, transfer, research and development, and use of genetically modified organisms and potentially harmful exotic species in the country.
1990	Research and Development, Biotechnology high priority in Science and Technology.
1990	Institute of Plant Breeding (IPB) in UP Los Baños and PhilRice able to developed marker technologies that are useful in crop improvement
1992	The Seed Industry Development Act of 1992 mandated IPB to lead in plant biotechnology activities.
1992-1998	During the term of then President Fidel Ramos, Biotechnology remained as a major program of DOST's Science and Technology Program.
1995	The 5-year Crop Biotechnology Program was approved by Pres. Ramos, with first year budget of PhP 65M.
1997	Section 83 of Agriculture and Fisheries and Modernization Act (Republic Act 8435) explicitly allocates 1% of agriculture's Gross Value Added to agricultural research. The Act holds specific provisions for a biotechnology program and a mandated budgetary allocation.
1997-1998	IPB developed facilities and manpower for cloning plant genes and transformation.
1997	Contained testing of *Bt* corn (Mon 810).
1998	Limited, very confined field test of *Bt* corn.
1999	NCBP oversight, Monsanto Philippines conducted first field-testing of *Bt* corn in South Cotabato.
2000	Papaya transgenic plantlets at IPB; PhilRice conducted screen house testing of XA-21 rice, which is resistant to bacterial blight
2000	Former Pres. Joseph Ejercito Estrada issued a National Policy to use biotechnology as a strategy to improve agricultural production, modernize Philippine agriculture and enhance rural development.
2000	Multi locational field tests of *Bt* corn
2000-2001	Public protests were regularly staged by NGO's such as *Kilusan ng Magbubukid sa Pilipinas* (KMP, literally translated as Peasant Movement of the Philippines); MASIPAG (acronym for *Magsasaka at Sayantipiko Para sa Ikauunlad ng Agham Pang agrikultura*), South East Asia Regional Initiatives for Community Empowerment (SEARICE), Greenpeace, and the Philippine Greens.
2001	Former Pres. Gloria Macapagal Arroyo signed policy statement on modern biotechnology for national development.
2001	Department of Agriculture Administrative Order (DA AO) No. 8, 2002 – Regulation of Plant and Plant Products produced through modern biotechnology.
2001	Monsanto Philippines and Pioneer-HiBred conducted multi locational field trial of *Bt* corn.
2002	Administrative Order (AO) 008 Series of 2002, issued by the Department of Agriculture in April 2002, made commercial adoption of crop biotechnology
2002	Bureau of Plant Industry Director approved commercial scale planting of the field-tested *Bt* corn.
2002	Enactment of The Plant Variety Protection Act (Republic Act 9168)
2002	Issuance of Department of Agriculture Administrative Order No. 8 "Rules and Regulations on the Importation and Release Into the Environment of Plants and Plant Products Derived From the Use of Modern Biotechnology" – a science-based biosafety measure that ensures the integrity of human and animal health, and the environment.
2003	Monsanto and Pioneer Hi-Bred reported total gross sales of PhP1.7 billion, or roughly US$30 million.
2003	Non-government organizations (NGOs) led by Greenpeace International held a hunger strike in front of the Department of Agriculture building to stop the commercialization of *Bt* corn
2003	Dr. Terje Traavik, a scientist from the Norwegian Institute of Gene Ecology reported the incident of at least 106 lumad (indigenous people) from Polomolok, South Cotabato sought medical treatment due to infections allegedly caused by 60-day-old *Bt* corn pollen.
2003	About 40% of the *Bt* corn planted in a 0.75 hectare land in Bicol and South Cotabato provinces was damaged by stalk rot resulting to poor harvest of only around 2,000 kg, half of the expected 4,000 kg normal yield.
2003	Approval of NK603 corn for food, feed and processing by BPI.
2004	Dr. Terje Traavik presented the results of the ongoing research at the Biosafety Symposium in Kuala Lumpur, Malaysia and reported that some 39 farmers in Mindanao developed immunity to antibodies because of exposure to *Bt* corn.
2004	Department of Agriculture (DA)'s Bureau of Plant Industry (BPI) issued a statement that it has Made a "thorough review on the safety of *Bt* corn to human and animals. No toxic or Allergenic effect is associated with the approved *Bt* corn variety".
2003 to 2004	Multi location field trials of NK603.
2004	Local government units (such as the Bohol province) expressed opposition to GMOs and declared themselves as GMO free and passed Provincial Ordinance No. 2003-101. Otherwise known as the 'safeguard against GMOs.
2004	Monsanto applied a permit for the commercial propagation of NK603 corn.
2005	Issuance of permit for commercial propagation of NK 603 with trademark Roundup Ready (RR), a glyphosate resistant corn.
2005	Initial deployment of *Bt*HT with 4,580 ha of plantation
2005	Monsanto received the permit for large scale propagation of stacked train *Bt*HT corn hybrids (Mon810 x NK603).
2006	National Biosafety Framework (NBF) under EO 514
2007	Plantation of NK603 zoomed to more than 120,000 ha.
2007	Renewal of propagation permit. The Bureau of Plant Industry (BPI) approved the 5-year extension of the commercial production of *Bt* corn (Mon 810) in the country.
2008	The *Bt* corn production reached 400,000 hectare.
2008	Stacked train corn hybrids, *Bt*HT (Mon810 x NK 603) of plantation reached 241,273 ha.
2011	Philippines was declared as the 13th mega producing country of biotech crop in the world.

Issues on GM corn technology

Despite the known advantages of using GM corn, a wide range of issues and concerns are forwarded by the active antagonist groups of non-government organizations (NGOs). These NGOs are long-term promoters of sustainable agriculture and they question the feasibility of the GM corn promises and point out the many threats that GM corn may pose to biodiversity and to the future of sustainable agriculture. Although, in 2002-2003 some of Catholic clergy became very active during the anti-campaign rallies against *Bt* corn, at present the church seems to be uncertain about its stand on GM corn in the country (Cabanilla, 2007).

Accordingly, *Bt* endotoxin in corn is to be considered as a biopesticide and just like any pesticides it could have diverse effects on human health, pest management, and the environment and food systems. Some of the major issues and concerns raised are as follows:

On environment

1. The ability of the *Bt* corn to produce toxin may be passed on to other plants through cross-pollination, thereby dispersing this ability in places and species where it may be prove harmful (cited by Gonzales *et al*., 2009). E.g., it may transform other organisms into invasive and hard to eliminate species to agro-ecosystems (Shen, 2006).
2. Non-target toxic effects of *Bt* toxin (Altieri, 2000; Andow and Hilbeck, 2004; Dutton *et al*., 2003; Arriola and Ellstrand, 1997; Klinger and Ellstrand, 1994; Linder and Schmitt 1995). For example, Cry1Ab protein from GM crops can affect the soil ecosystem and soil biota like nematodes and fungi, (Meadows *et al*., 1990; Turrini *et al*., 2004). This is attributed to the persistence of *Bt* toxin (25-30% Cry1Ab protein) in the soil for 234 days (Tapp and Stotzky, 1998) and stays on litter for at least 8 months (Zwahlen *et al*., 2003). Likewise, the glyphosate used for HT corn reported to be toxic to some non-target beneficial organisms such as spiders, mites, carabids, coccinellid beetles and earthworms as well as to fish (Pimentel *et al*., 1989).
3. Potential development of secondary pest like in the case of Cotton Mirid bug (*Pseudatomoscelis seriatus* Reuter) outbreak in China (Lu *et al.*, 2010).
4. The simple and significant selection pressure by HT crops and concomitant use of the herbicide could change the vegetation diversity through enhanced weediness (Brown *et al*., 1996; Altieri, 2000; Hammond, 2010). For example, the reported increasing in prominence in some agriecosystems of some weeds like Asiatic dayflower (*Commelina cumminus* L) common lambsquarters (*Chenopodium album* L) and wild buckwheat (*Polygonum convolvulus* L) (Owen and Zelaya, 2005).
5. Potential development of resistance to *Bt* toxin (Altieri, 2000) by the ACB and to glyphosate herbicide by some weeds (Owen and Zelaya, 2005). Resistance to the *Bt* toxin by the ACB will develop once low levels of *Bt* toxins are introduced, thus enabling ACB to survive and become "super bugs" that are resistant to the toxin and breed such resistance into succeeding generations (cited by Gonzales *et al*., 2009). Also, the continuous application of glyphosate may lead to the development of the so-called "glyphosate resistant weeds" alongside of GM cornfields and the fear of the creation of super weed like *Amaranthus palmeri* and horseweed (*Conyza canadensis* (L) Cronq) which are known to be resistant to N-(phosphonomethyl) glycine i.e. as glyphosate (Benaning, 2010; Owen and Zelaya, 2005).

On Socio-Economic issues

The development of *Bt* corn Mon810 cost around $2.6 million (128 million Philippine pesos). This includes the entire process of product development, from concept initiation done in the US in 1985 to implementation of post commercial approval requirements in 2004. The biggest costs were incurred in the conduct of post–commercial application activities followed by 17 multi–location field trials across the country. Project spending was highest in 2002 when field trials and supporting studies were being completed and the product stewardship plan was being developed. It has also been discovered that two–thirds of total cost went into activities conducted in compliance and support to government regulatory requirements (Manalo and Ramon, 2004).

The high cost of investment is reflected on the high price of GM corn seeds available in the market (Zonio, 2004). Besides, farmers cannot recycle the seeds and need to buy new seeds every growing season because farmers may be sued for patent infringement; this creates an economic dependence of farmers on seed producers to corn seeds and agrochemicals. Also, as cited by Gonzales *et al*. (2009), there are no markets for *Bt* corn although this is refuted by the rapid adoption of *Bt* corn.

On human health

As cited in Gonzales *et al*., 2009, the following are the most prominent health related issues being raised against GM crop which are more of perceived concerns:

1. GM crops are hazardous because these carry new proteins that may cause allergies and other reactions and;
2. The development of GM crop may create antibiotic resistant microbes or vectors utilized in genetic engineering of *Bt* genes which may transfer antibiotic resistance genes to other bacteria infecting humans, thus rendering life saving antibiotics useless.

Research objectives

While some resistance was noted during the initial phases of GM corn introduction, particularly during field tests in some areas of the country, overall government approval and support, coupled with massive media information campaigns and stakeholders mobilization, completely shifted to favor eventual adoption. This has made the Philippines the first country in Asia to have a biotechnology crop for food. *Bt* corn was commercially planted beginning 2003 and biotech corn since has a steady massively increasing adoption rate of 5% every single year as farmers and stakeholders experience or perceive improved economic gains.

It is against this backdrop of economic benefits primarily that often environmental concern becomes sidelined in the equation of sustainable practices in agriculture. From the above, it is clear that many issues relating to the environment, biodiversity, economic and social issues warrant further research investigation and validation studies.

The main objective of this research undertaking is to provide a realistic and updated assessment on the impact of GM corn after a decade of continuous cultivation and rapid adoption in the Philippines. This is done from a third party academe-based approach as a way to minimize research results bias. Qualitative and quantitative approaches and procedures were employed to cover the ecological, economic and social domains of this thesis. Specifically, it aimed to:

1. provide a summary and background information in the context of the success and wide-scale adoption of GM corn in the Philippines in the last decade;
2. reinvestigate the efficacy of GM corn containing *Bt* toxin against the Asian corn borer (ACB) as well as its potential effects to a non-ACB pests community;
3. determine the impact of GM corn and its associated changes on agricultural practices on an invertebrate community in the cornfield ecosystem;
4. evaluate the impact of long-term and continuous cultivation of GM corn on the corn agro-ecological system;
5. substantiate claims of agricultural productivity and;
6. assess farmers' perceptions and attitudes about GM corn.

The study has been conducted in the Philippines to address the above objectives. The methods for obtaining answers to the aforementioned objectives are as follows; For the first objective, secondary data (such as books, research articles and digital information materials) from inside and outside the country have been collated and served as reference lines to establish the background information in the success of GM corn in the Philippines. Objective 2 was addressed by actual surveying of 198 GM and non-GM cornfields for the possible occurrence of ACB and non-ACB pests. Percentage infestation specific for corn pests was calculated using the data of characteristic symptoms of pests. The third objective was accomplished by establishing a six hectare experimental field designed to compare the effects on an invertebrate's community present and of the actual agricultural practices associated to GM and non-GM corn. Objective 4 was carried out through careful selections of cornfields that have been continuously cultivated with GM corn for not less than two years. For objectives 3 and 4, collections and monitoring were accomplished using pitfall traps, sticky cards and soil cores to account for different invertebrate dwellers. Finally, for objectives 5 and 6, one to one interviews with the farmers were conducted. Self-structured questionnaires were used to extract local knowledge and primary information of the farmers relative to GM and non-GM corn cultivation. Econometric and Blinder-Oaxaca decomposition methods were employed for objective 4.

Finally, the imperative to conduct environmental and socio-economic impact assessment after long years of continuous GM corn adoption is timely. The study done here to assess the effects of long-term cultivation of GM corn is an example of post evaluation of a technology to ensure that it is sustainably viable. To seek answers for issues surrounding the introduction and nationwide adoption of GM corn in the Philippines, this research undertaking would like to focus on answering the following five major questions as follows:

1. What is the effect of GM corn on ACB and non-ACB pests; and which among these agricultural pests are benefited and vulnerable in a GM and non-GM corn environment?
2. What is the impact of GM corn management systems on invertebrate communities in terms of its species abundance and richness; and is GM corn cultivation more environment-friendly than non-GM corn?
3. What is the impact of the long-term cultivation of GM corn to the abundance and species richness of infield invertebrates in a humid tropical country like the Philippines?
4. Is GM corn economically more viable than non-GM in terms of production output, net income and return on investment among small scale farmers? and;
5. What are the farmers' standpoints and experiences on GM corn?

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