An Overview of Agricultural Pollution in the Philippines

The Crops Sector

2016

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1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000

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ABBREVIATIONS AND ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
AFMA	Agriculture and Fisheries Modernization Act
AS	Ammonium Sulphate
ASEAN	Association of Southeast Asian States
ASN	Ammonium Sulphate Nitrate
ATP	Adenosine Triphosphate
BC	Black Carbon
BNF	Biological Nitrogen Fixation
BPH	Brown Planthopper
BPI	Bureau of Plant Industry
BSWM	Bureau of Soils and Water Management
CTBS	Community Trap Barrier System
DA	Department of Agriculture
DAT	Days After Transplanting
DDT	Dichlorodiphenyltrichloroethane
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DSSAT	Decision Support System for Agrotechnology Transfer
EMB	Environment Management Bureau
FAO	Food and Agriculture organization
FFS	Farmer Field Schools
FPA	Fertilizer and Pesticide Authority
GE	Genetically Engineered
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GIS	Geographic Information System
GM	Genetically Modified
IEC	Information, Education and Communication
IFOAM	International Federation of Organic Agriculture Movements

IPB	Institute of Plant Breeding
IPM	Integrated Pest Management
LCC	Leaf Color Chart
LGU	Local Government Unit
LOQ	Limit of Quantitation
MOET	Minus One Element Technique
MRL	Maximum Residue Level
NCCD	National Committee on Crop Diversification
NDT	Nutrient Diagnostic Technique
NIA-UPRIIS	National Irrigation Administration-Upper Pampanga River Integrated Irrigation System
NMHC	Non-methane Hydrocarbon
NHMC	Non-methane Hydrocarbon
NOAP	National Organic Agriculture Program
NPAL	National Pesticide Analytical Laboratory
NPK	Nitrogen, Phosphorus, Potassium
OC	Organic Carbon
PAH	Polycyclic Aromatic Hydrocarbons
PCA	Philippine Coconut Authority
PNRI	Philippine Nuclear Research Institute
PNSOA	Philippine National Standards for Organic Agriculture
RTV	Rice Tungro Virus
SAFDZ	Strategic Agricultural and Fisheries Development Zone
SALT	Sloping Agricultural Land Technology
SRA	Sugar Regulatory Authority
SS	Suspended Solids
SSNM	Site-Specific Nutrient Management
SVOC	Semi-volatile Organic Compounds
TC	Total Carbon
TESDA	Technical Education and Skills Development Authority
TOT	Training of Trainers
TPM	Total Particulate Matter
TSS	Total Suspended Solids
UNFCCC	United Nations Framework Convention on Climate Change
UPLB	University of the Philippines at Los Baños
VAMRI	Vesicular Arbuscular Mycorrhiza Root Inoculant
VOC	Volatile Organic Compounds

FOREWORD

This report is part of a national overview of agricultural pollution in the Philippines, commissioned by the World Bank. The overview consists of three "chapters" on the crops, livestock, and fisheries sub-sectors, and a summary report. This "chapter" provides a broad national overview of (a) the magnitude, impacts, and drivers of pollution related to the crops sector's development; (b) measures that have been taken by the public sector to manage or mitigate this pollution; and (c) existing knowledge gaps and directions for future research.

This report was prepared on the basis of existing literature, recent analyses, national and international statistics, and interviews. It did not involve new primary research and did not attempt to cover pollution issues that arise beyond the farmgate—such as in processing, transportation, and the manufacturing of agricultural inputs and machinery.

EXECUTIVE SUMMARY

The Philippine archipelago emerged because of the dynamic shifting and collision of four plates: Continental Eurasian plate, Indian-Australian plate, Oceanic Pacific plate, and the Philippine Sea plate. In the past 100 million years, the archipelago was welded together in an island arc punctuated by episodic and extensive magmatic activities. The country's topographic landscape consists of towering mountains with steep slopes, undulating hilly upland areas, and flat lands. The rich volcanic soils, varied topography, seasonality of monsoon rains, abundant rainfall, and warm temperature enabled the suitability of land for planting various crops in the different islands.

Being the staple food, both upland and irrigated rice is widely grown in various provinces all over the country. Yellow corn is largely grown in Isabela and Cagayan in Luzon; and in Bukidnon, North Cotabato and South Cotabato in Mindanao. The major growing areas for white corn are Mindanao and Visayas. Large plantations of banana, pineapple, coffee, rubber, and palm oil are located in Mindanao while large plantations of coconut are found in Quezon and Zamboanga. On the other hand, mango plantations are located in Pangasinan while tobacco is largely grown in the Ilocos Region and Isabela. Large areas are planted with sugarcane in Negros Occidental and Bukidnon. Temperate vegetables are grown largely in the cool high elevation areas of the Benguet Province while tropical vegetables are grown in the expansive areas in Pangasinan, Isabela, and Nueva Ecija in Luzon and in the Visayas Region.

Production of crops has been increasing, both through increases in the area harvested, and by adoption of modern production methods, which have been linked to increased pollution from agriculture.

Production of crops has been increasing, both through increases in area harvested, and by adoption of modern production methods. Farming systems in the Philippines have evolved from low-input agriculture using traditional practices and varieties, to modern high-input systems using modern varieties and methods. The case of rice which underwent a Green Revolution in the 1960s–1980s illustrates this evolution.

Consumption of chemical fertilizers has been trending upward over the past few decades, though consumption has fallen overall since the rise in fertilizer prices in the late 2000s and the implementation of the organic agriculture program.

The implementation of the Green Revolution starting from 1960 marked the beginning of intensive application of inorganic fertilizers in farming systems in the Philippines. From 1961 to 2004, the amount of fertilizer applied in the Philippines increased by 1,000 percent (Figure A-20).

The national consumption of nitrogenous fertilizers increased by 1,658 percent from 35,815 tons in 1961 to 629,808 tons in 2004 with an annual average increase of 10,406 tons/year. However, from 2004 to 2013, there was a general decrease in nitrogenous fertilizer consumption by 54 percent from 629,000 tons to 287,000 tons. The most common forms of inorganic nitrogen fertilizers applied are urea, ammonium sulfate, and complete fertilizer.

The national consumption of phosphate fertilizer in 1961 was 16,006 tons and this consumption increased until 2002 with an annual average increase of 2,482 tons/year. From 1970 to 1985, the national phosphate fertilizer consumption was stable at around 50,000 tons/year. However, during the period from 1985 to 2001, there was a large increase in phosphate fertilizer application from 50,000 tons/year to 148,000 tons/year translating to about an average increase of 6,000 tons/year during this period. In 2002, the national phosphate fertilizer consumption was 227,000 tons, the highest consumption from 1960 until the present time. From 2007, there was in general, a decline in phosphate fertilizer consumption. Phosphate fertilizers commonly applied are mixed fertilizers including ammonium phosphate, di-ammonium phosphate, and complete fertilizer.

The national consumption of potash fertilizer in 1961 was 12,500 tons and this consumption increased up to 174,660 tons in 2009. The average increase of potash application was 1,753 tons/year. From 2001 to 2004, there was a decline in national potash consumption from 125,000 tons to 59,000 tons. The highest potash fertilizer consumption was in 2009, about 174,000 tons. From 2009, national potash consumption continually declined until 2013 when the national consumption was only 39,700 tons. Muriate of potash is the most commonly applied potassium fertilizer.

Generally, there was a continual decline in the national consumption of nitrogen, phosphorus, potassium (NPK) fertilizers in the past decade. This may be attributed to the massive campaign by the Department of Agriculture (DA) for organic farming and the rise in prices of fertilizers.

Fertilizer application in the Philippines varies widely by type of crop and by region/province.

At present, various agricultural crops are widely grown in various provinces and islands all over the country. The rich natural resources of the Philippines including fertile volcanic soils, varied topography, abundant rainfall, and warm tropical temperature with plenty of sunshine made it highly suitable for growing various important economic crops. The top ten major crops grown in the Philippines are widely planted in different provinces and islands. The amount and frequency of timing of fertilizer in these various cropping systems vary. However, available data is quite limited.

Rice is widely grown in various provinces all over the country. The major provinces where large areas of rainfed rice is grown are Abra, Agusan del Norte, and Agusan del Sur. On the other hand, irrigated rice is largely grown in Isabela, Nueva Ecija, Cagayan, and Pangasinan in Northern Luzon. Yellow corn is largely grown in Isabela and Cagayan in Region II; and in Bukidnon, North Cotabato and South Cotabato in Mindanao. The major growing areas for white corn are Maguindanao, Lanao del Norte, and Lanao del Sur in Mindanao; Cebu and Negros Oriental in Visayas.

In 2014, large areas in Lanao del Sur, Bukidnon and Camarines Sur were cultivated with cassava. Large coconut plantations can be seen in Quezon, Zamboanga del Norte, and Davao Oriental. Coffee, on the other hand, is largely grown in Maguindanao, Lanao del Norte, Lanao del Sur, Cebu, Negros Oriental, and

Zamboanga del Sur. Large areas are planted with sugarcane in Negros Occidental and Bukidnon. Temperate vegetables are grown largely in Benguet. Tropical vegetables are grown in many areas in Luzon and Visayas. Large areas in Isabela, Nueva Ecija, Pangasinan and Ilocos Norte have been cultivated with tropical vegetables since 2014. Rubber is largely grown in Zamboanga Sibugay, and North Cotabato. Growing oil palms is becoming popular in the Philippines. These are largely grown in Agusan del Sur, Sultan Kudarat, Palawan, Bohol, and North Cotabato.

Commercial crops tend toward higher rates of fertilizer application. Some of these are grown on large plantations and in general involve intensive agrochemical use.

Large plantations of banana are located in Mindanao including the provinces of Davao del Norte, Davao del Sur, Compostela Valley, Bukidnon, North Cotabato, South Cotabato, and Maguindanao. Pineapple plantations are concentrated in Bukidnon and South Cotabato. On the other hand, large plantation areas of mango are located in Pangasinan while tobacco is largely grown in the Ilocos Region and Isabela. These large plantations employ intensive farming systems to optimize production and produce quality products with minimal pest damage. However, data on the fertilizer and pesticide application in these systems are not available.

In rice farming, nutrient balance analysis suggests releases into the environment of excess nitrogen and phosporous, but not of pottasium.

Nitrogen. To estimate the release of excess nitrogen to the environment, we compute the amount of chemical nitrogen applied, less the amount of nitrogen utilized in rice grain and straw. The factors used are 5.3 kg/ton of nitrogen for straw and 10.9 kg/ton of nitrogen for grain production (De Datta 1981). From 1988 to 2014, the amount of nitrogen applied in the soil in Nueva Ecija (province with the highest yield) is greater than the amounts of nitrogen removed from the soil by harvesting straw and rice grain. There was an increasing trend in the total amount of nitrogen applied from 16,605.70 tons in 1988 to 37,054.62 tons in 2014, with an average 4.74 percent increase. The amount of nitrogen taken up by the crop and that was harvested in the rice grain is about 33 percent of the applied nitrogen in 1988 and 57 percent of applied nitrogen in 2014. Even for the Aklan Province, which has one of the lowest rates of nitrogen fertilizer application and rice production, the amount of nitrogen taken up by the crop and harvested in the rice grain and rice straw is still lower than the amount applied. Typical fertilizer recovery efficiencies in irrigated lowland rice with good crop management and grain yields of 5 to 7 tons/ha is 30–60 percent for nitrogen (Dobermann and Fairhurst 2002).

Phosphorus. A similar technique can be used to estimate excess phosphorus released to the environment due to rice production. In Nueva Ecija, there was an increasing trend in the amounts of phosphorus applied from 4,221.40 tons in 1988 to 13,151.49 tons in 2014 with an annual increase of 8.14 percent in 26 years. Since 1988, the amount of phosphorus applied is much greater than the amounts of phosphorus taken up by the plant and harvested via the rice grain and rice straw.

In Aklan, though the amounts of phosphorus applied were low, the amounts removed by the crop and harvested via the rice grain and straw was still lower than applied phosphorus. Typical fertilizer recovery efficiencies in irrigated lowland rice with good crop management and grain yields of 5 to 7 tons/ha is 10–35 percent for phosphorus (Better Crops International 2002).

Potassium. Unlike nitrogen and phosphorus, the amounts of potassium fertilizer applied (from complete fertilizer) in rice crop in both Nueva Ecija and Aklan Provinces are much lesser than the amounts taken up and accumulated in the rice straw and rice grain. The amount of potassium harvested in the rice grains is almost near the values of the amounts of potassium applied as fertilizer. Typical fertilizer recovery efficiencies in irrigated lowland rice with good crop management and grain yields of 5 to 7 tons/ha is 15–65 percent for potassium (Better Crops International 2002).

The ratio of $N:P_2O_5:K_2O$ fertilizer use in Southeast Asia is about 8:2:1 (Mutert and Fairhurst 2002). This unbalanced fertilizer consumption may deplete the potassium reserves in the soil. Research results have shown negative balances of 40 to 60 kg K/year in intensified rice systems in the Philippines, Thailand, Indonesia, and Vietnam (Sheldrick, Syers, and Lingard 2002; Syers, Sheldrick, and Lingard 2001).

Adverse impacts of intensification of cropping systems are well documented.

Intensification of cropping systems to optimize production of these various major crops involve increased cropping frequency (two to three crops per year for the annual crops), increased cropping intensity (more trees or plants per unit area), increased fertilizer application to boost growth and crop yield, increased pesticide application to control pests and diseases, irrigation systems to augment precipitation, adoption of technologies (new cultivars, hybrid varieties), and farm mechanization.

These efforts may lead to environmental degradation such as depletion of soil nutrients; leaching of excess fertilizers into the environment; pesticide residues in crops, soil, and water resources; volatilization of greenhouse gases (GHG) into the air; soil erosion; and sedimentation and eutrophication in adjacent water bodies. The continuous and intensive use of chemical pesticides can lead to human poisoning, chemical dependency, new pests, pest resurgence and outbreaks, resistance to pests, and water pollution. Moreover, the cultivation of fragile and marginal upland areas can lead to deforestation, accelerated soil erosion, sedimentation of rivers, and biodiversity loss (Department of Environment and Natural Resources — Environment Management Bureau [DENR-EMB] 2002). The forest area has been decreasing over the years. The forest cover was 26 percent in 1970 and it decreased to 18 percent in 2000. This showed that in the last three decades, there has been a fast conversion of forest land for other land uses such as residential, commercial, industrial, and agricultural.

Evidences of soil acidification due to intensive nitrogenous fertilizer application have been reported in intensively cropped soils cultivated with common bean in La Trinidad, Benguet, the Philippines (Gutierrez and Barraquio 2010). Soil acidity can also be attributed to continuous planting of corn and sweet potato which exhausts soil calcium, magnesium, available phosphorus, and organic matter levels (Asio et al. 2009; Siebert 1987).

Contamination of water bodies due to excessive fertilizer nutrients have been detected, though adverse off-site impacts have yet to be firmly established.

Rice cultivation releases agrochemical residues such as nitrates and ammonium into water due to inefficient use of inorganic chemicals and fertilizers. These highly concentrated residues are being carried by water to lakes and rivers through runoff erosion and leaching that often result in contamination of the ground water. The runoff erosion also carries away soil nutrients, soil sediments, and suspended solids (SS) which lead to eutrophication. Eutrophication leads to algal blooms which cause stress, impair the immune system, and damage living organisms, and eventually disrupt aquatic life (NSCB 2000).

Evidences of nitrates in ground water and surface waters were attributed to inefficient nitrogenous fertilizer application in rice-sweet pepper cropping system in Ilocos Norte (Ladha et al. 1998); vegetable-growing areas in Atok, Benguet, and Tirado (Greenpeace Report 2007; Ngidlo et al. 2013); wells in Bulacan (Greenpeace Report 2007); agroecosystems in Laguna. A study conducted by Chang et al. (2009) showed that the Northeastern shore of the Manila Bay is highly eutrophicated due to the higher concentrations of ammonium, phosphate, and silica. The high phosphate concentration in the northern part of the Manila Bay can be attributed to sewage discharge and agricultural activities (EMB 2014).

The Manila Bay watershed covers a total area of 1,972,014 ha and four subwatersheds drain into the Manila Bay. The total NH_4-N loading is 1,245 kg/day and the contributions of the four subwatersheds are: 482 kg/day from Pampanga River Basin, 373 kg/day from Pasig River Basin, 275 kg/day from Bataan subwatershed, and 115 kg/day from Cavite subwatershed.

The total NO_3-N loading is 4,526 kg/day, of which the Pasig River Basin is the major contributor. The total phosphorus loading is 1,877 kg/day, with the Pasig River Basin contributing about 46 percent (861 kg/day) (Samar 2012; BSWM 2013).

In the Manila Bay, it is the rice cropping system that contributes greatly to nitrogen loading into the environment, amounting to 23,706 tons of nitrogen (Samar 2012; BSWM 2013). Nitrogen loading in the environment accounts for 51 percent of the applied nitrogen fertilizer and this shows the low nitrogen use efficiency of rice cropping systems.

The Laguna Lake had high fish production during the early 1970s because of its hypertrophication. The lake has an extremely high nutrient level from the watershed. During this time, around 5,000 tons of nitrogen was entering the lake. This nitrogen came from livestock and poultry (36 percent), domestic sources (26 percent), Pasig River backflow (22 percent), fertilizers (11 percent), and industrial sources (5 percent). In 2000, a waste load model increased the total nitrogen to around 13,800 tons. This came from domestic sources (79 percent), agricultural practices (16.5 percent), industrial wastes (4.5 percent), and other sources (0.5 percent) (Lasco and Espaldon 2005).

The Laguna Lake Development Authority (2003) conducted an inventory of waste loads from the sub-basins into the Laguna Lake including organic matter (biochemical oxygen demand [BOD], chemical oxygen demand [COD]), bacterial pollutants (E. coli), nutrients (NH_4, NO_3, PO_4), micro-pollutants (Copper, Cadmium, Lead, oils) and total suspended solids (TSS). Total load in 1995 was 66,305 tons/year and in 2000 was 74,300 tons/year. Agriculture contributed to 13 percent of the total BOD loading in 1995 (8,620 tons/year) and 11.5 percent of the total BOD loading in 2000 (8,544 tons/year).

Pesticide use is now widespread among even smallholder systems. Pesticide use is highest for the control of insect pest, followed by fungi and weeds.

Pesticide use has been prevalent in various government national food programs since the launching of the Green Revolution in 1965 (Elazegui 1989). Pesticide use is now widespread among even smallholder systems. Pesticide use is highest for the control of insect pest, followed by fungi and weeds. The largest gross application of pesticides among the important crops grown in the Philippines is the rice crop, primarily due to extensive areas planted with rice all over the country (ACIAR 2000). In rice cropping systems in Central Luzon, majority of the farmers (>80 percent) used insecticides once each for both the wet and dry rice cropping seasons during the decade of 1970–1980. Beginning from the 1980s, the frequency of insecticide application increased up to four times during the cropping for both wet and dry seasons (Moya et al. 2015). However, insecticide application in rice crop in the Philippines is the lowest compared with other Asian countries including Thailand, Vietnam, Indonesia, and China (International Rice Research Institute [IRRI] 2015).

Rice farming is the biggest user of pesticides and has been suspected of causing environmental contamination. Herbicide application rates have in fact been rising, that of insecticides has been falling.

In rice-growing areas, application rates of insecticides have been falling, though herbicide application rates have been rising. The increase in herbicide use started after 1974–1975 when farmers started applying herbicide in rice crop during its early growth period. Moreover, the increase was attributed to the decline of farm labor in the area and increase in wage rates (Moya et al. 2015). During the dry season, the use of herbicide was slightly higher because the farmers practiced direct seeding which uses herbicide to control weeds.

Pesticides in vegetable and banana farming are significant sources of environmental pollutants.

The other important crops heavily applied with pesticides are vegetables and banana. The pesticides commonly used in growing temperate vegetables in the provinces of Benguet, Mt. Province, and Ifugao in the Cordilleras belong to the pyrethroid, organophosphates, and carbamate class of pesticides (Ngidlo et al. 2013).

Diamondback moth is the most destructive pest, attacking crucifers such as broccoli, pechay, cabbage, radish, cauliflower, and mustard in Benguet. In 1992, farmers were spraying chemical pesticides 12 to 32 times per season to control the diamondback moth. This intensive use of synthetic insecticides resulted in problems such as resistance to other insecticides, high cost of insecticides, toxic hazards, contamination of soil and water, and reduction of natural enemies and pollinators (Maredia, Dakouo, and Mota-Sanchez 2003).

Fungicides are the most commonly used pesticides in banana plantations in Mindanao. The active ingredients of these fungicides include azoxystrobin, biterthanol, propiconazole, tridemorph, and others.

McCracken and Conway (1987) mentioned that widely used pesticides (carbofuran, endrin, parathion, and monocrotophos) in the country are classified by the World Health Organization (WHO) as extremely hazardous. In Sta. Maria, Pangasinan, around 20 percent of eggplant samples and 42 percent of soil samples from various farms had insecticide residues of 25 commercial brands with varying levels of toxicity from highly toxic, moderately toxic, slightly toxic, and nontoxic (Del Prado-Lu 2015). Banned pesticides and restricted chemicals were frequently sprayed on vegetable crops including cabbage, baguio beans, string beans, tomatoes, pechay, bell pepper, ampalaya, and rice (Saldivar 1996). In Benguet, the Philippines, 44 percent of soil samples were positive for pesticide residues of pyrethroids, organophosphates, and carbamates. A water sample was also found to have a high level of pesticide residue which is toxic to aquatic biota (Lu 2009a).

Prevalent pesticide use has had deleterious on-site impacts, as well as suspected off-site impacts.

Too much use of pesticide can be harmful and result in (a) health diseases; (b) ground and surface water pollution through runoff; (c) food contamination; (d) increased resistance of pest to pesticides, which will then lead to more pest outbreaks; (e) decreased number of helpful insects such as parasites and predators; and (f) decreased number of microorganisms in water and paddy soil which maintain the fertility while decreasing the use of chemical fertilizer. The degree and frequency of these effects are greatly influenced by the type of chemical, its tenacity, and quantities used (Pingali and Roger 1995).

Vegetables commonly bought in public markets and consumed by Filipinos including bitter gourd, eggplant, pechay, and tomato were found to have traces of a combination of pesticide residues ranging from as low as 2 to as many as 10 different pesticides (National Pesticide Analytical Laboratory [NPAL] 2016). Concentrations of cypermethrin residues in bitter gourd, pechay, and tomato exceeding the maximum residue level (MRL) were detected in samples from Cebu, Bohol, Cagayan de Oro, and Nueva Vizcaya. Samples from Cagayan de Oro were also high in concentrations of residues of lambda-cyhalothrin in bitter gourd; and chlorpyrifos and Diazinon in pechay. Though eggplant was also applied with many different pesticides, pesticide residue concentrations were below the MRL.

Majority of the pesticides used by Filipino farmers are highly poisonous to fish and other aquatic organisms (Fabro and Varca 2012). The pollutants from the vegetable and rice farming activities within the Pagsanjan-Lumban catchment affect the fisheries in the area (Varca 2012). Among the pesticides used, the pyrethroids (lambda-cyhalothrin, deltamethrin, and cypermethrin) were identified to be highly toxic under laboratory conditions to the tilapia fingerling and freshwater shrimp. The maximum measured concentration of profenofos (15.4 μg/L) and pyrethroids (3–6 μg/L) in the field samples collected in the Pagsanjan-Lumban catchment were above the 48 h LC_{50} values. Moreover, the sediment-bound contaminants cause changes to the food source of crabs, freshwater shrimp, and fish (Bajet et al. 2012). Poor pesticide management practices may result in the decline of rice-fish cultures and other invertebrates.

Pesticide misuse can cause great health impacts in the farming communities in the Philippines. Numerous researches correlated the extent of direct and indirect pesticide exposure to health hazards such as headache, muscle pain, cough, weakness, eye and chest pain, and eye redness. Farmer-users are especially vulnerable to health effects attributed to pesticides. Loevinsohn's study (1987) showed that the widespread use of pesticides in Central Luzon was followed by a 27 percent increase in death among the farmers from causes other than physical injury. An average of 503 cases of pesticide poisoning had been reported between 1980 and 1988 (of which 15 percent died every year). On the other hand, health hazards prevalent among pregnant women include dermal contamination, fetal abnormalities, spontaneous abortion, and decrease in cholinesterase level (Lu 2009a).

Major sources of GHG emissions from the agriculture sector are methane emissions from irrigated rice and N_2O emissions from synthetic fertilizer application.

In the Philippines Second National Communication (UNFCCC 2001), the agriculture sector ranked second (37,003 Gg CO_2 eq) to the energy sector (69,667 Gg CO_2 eq) in the amount of GHG emissions using 2000 as the base year. GHG emissions from agriculture accounts for 29 percent of the total national GHG emissions.

In 2012, the total GHG emissions from the Philippine agricultural sector increased by 38 percent from the 2000 GHG inventory to 51,256 Gg CO_2eq (FAOSTAT 2013). Methane emissions from rice cultivation constitutes about 64 percent (32,951 Gg) while N_2O emissions from synthetic fertilizer application accounts for 6 percent (2,887 Gg). Burning of crop residues contribute about 1 percent and is composed of 309 Gg CH_4 and 118 Gg N_2O. N_2O emissions from the decomposition of crop residues left in the field contribute about 3 percent (1,767 Gg).

Crop residue burning releases GHG into the atmosphere and results in the decline of soil fertility.

Burning of rice, corn, and sugarcane residues is still widely practiced in the Philippines. This practice is being used to minimize the labor requirement for land preparation of the farms for the next cropping season. Burning of crop residues is also a way to control pests and part of fertilizer management system. The ashes also serve as an immediate source of phosphorus and potassium and to control pests and diseases. However, burning is also a quick way to lose the precious nutrients (particularly nitrogen) from the residues, contributes to GHG emissions (CH_4 and N_2O), and releases toxic gases into the atmosphere. Crop residue burning results in the decline of soil organic matter and contributes to the gradual decline in soil fertility and productivity.

The amount of rice biomass burned increased by 47 percent from 1,748,555 tons in 1961 to 2,579,478 tons in 2012. The amount of corn biomass burned increased by 78 percent from 2,016,270 tons in 1961 to 3,589,460 tons in 1991. From 1961 to 1976, the amount of sugarcane residues burned increased by 147 percent from 150,930 tons in 1961 to 372,190 tons in 1976.

The amount of total N_2O emissions from burning of rice, corn, and sugarcane crop residues in the Philippines range from 0.27 Gg in 1961 to 0.41 Gg in 1990. After 1998, there was a reduction in N_2O emissions to 0.38 Gg in 2012. CH_4 emissions increased by 35.34 percent from 13.44 Gg in 1961 to 18.19 Gg in 1988. After 1998, CH_4 emissions from burning crop residues declined and gradually increased to 20.07 tons in 2012.

The proportion of the rice residue burnt in the open field is highest in the Philippines (95 percent), followed by Thailand (48 percent) and the least was in India (23 percent) (Gadde, Menke, and Wassmann 2009). Crop residue/biomass residue burning emits poisonous gases such as SO_2, CH_4, CO_2, CO, N_2O, NO_x, NO, NO_2, OC, BC, TC, NMHCs, SVOCs, VOCs, O_3 (Gadde et al. 2009; Guoliang et al. 2008; Sahai et al. 2007). Open burning of crop residue/biomass significantly increases the level of particulate matter, gaseous pollutants (SO_2, NO_x, VOCs, PAHs, and so on) in the atmosphere.

Plastic wastes from cropping systems are potential sources of hazardous pollutants.

Plastic bags containing fertilizers and bottles containing pesticides are potential sources of pollutants. Farmers in Ifugao, Mt. Province, and Benguet do not dispose empty pesticide bottles properly (Ngidlo et al. 2013). Empty bottles that are left in the farm are prone to releasing poisonous liquids, which can flow to nearby surface water bodies especially during the rainy season. Sprayers used in spraying pesticides were washed in nearby rivers. These improper methods have negative impacts on soil and water.

In banana plantations in Mindanao, plastic bags coated with pesticides are used to wrap banana fruit bunches to protect them from pests and diseases. These plastic bags contaminated with pesticides are not properly disposed off and some farming households even use them for other domestic purposes. Similarly, plastic mulches used in other cropping systems like strawberries and vegetables are potential agricultural pollutants that need proper disposal. However, no data is available with regard to the volume/quantity of plastic bags used and the amount/type of chemicals used for these purposes.

Solutions that collectively may successfully address the agricultural problems in the Philippines include the creation of the Fertilizer and Pesticide Authority (FPA), organic agriculture, integrated pest management (IPM), farming system technologies, biotechnology, agroforestry, bioenergy, agro-environmental tourism.

There are a number of solutions that address the pollution problems from cropping systems including the creation of the FPA, organic agriculture, IPM, development of bio-pesticides and bio-fertilizers, farming system technologies, ecological engineering, biotechnology, agroforestry, feedstock for bioenergy, and agro-environmental tourism. The FPA was created in 1977 to regulate the processes concerning pesticides such as its formulation, manufacture, distribution, sale, usage, disposal, and so on. Moreover, it is in charge of the following responsibilities: restricting the use of hazardous pesticides, issuing licenses for pesticide users, disseminating information on the safe use of pesticides, and registering new pesticides. The pesticide registration requirements were based according to the international standards by the Food and Agriculture Organization (FAO) and WHO. Before a pesticide is recommended for registration, a Pesticide Technical Advisory Committee will evaluate and review its toxicology, efficacy, and residue data.

IPM began in the Philippines during the early 1940s when farmers planted disease- or pest-resistant crops. Then, they practiced intercropping, crop rotation, and used botanical repellents or biological control agents in controlling pests and insects. In the IPM program, the farmers were trained on the agroecosystem interactions affecting the plant growth and crop management.

The Philippine Organic Agriculture Act (RA 10068, signed on April 6, 2010) created the National Organic Agriculture Program (NOAP) of the DA in an effort to reduce rural poverty by advocating low-input sustainable agricultural techniques that improve land productivity while minimizing adverse impacts to the environment. With this, NOAP targets to attain food security, sustainability, and competitiveness by converting at least 5 percent of the total agricultural area in the country, which is about 483,450 ha of the total area of 9,669,000 ha. The major components of the NOAP include (a) institutional development and strengthening; (b) research and development; (c) production and technology support; (d) extension and capability building; (e) promotion, advocacy, and education; (f) market development; and (g) results-based monitoring and evaluation.

Organic agriculture excludes the use of pesticides, manufactured fertilizers, insecticides, herbicides, fungicides, and even hormones, food additives, genetically modified organisms, and livestock antibiotics. It evolved from the traditional practices in farming communities over the years.

The Philippine Rice Research Institute (PhilRice) is conducting long-term research programs which aim to identify, evaluate, facilitate, and refine the delivery of improved practices in soil, plant, nutrient, and water management. The end goal is to contribute to attain and sustain rice self-sufficiency with the following objectives: (a) identify and propagate approaches for nutrient and crop management with the integration of management of principal insect pests and disease; (b) develop technologies that will improve soil and water conservation practices; (c) develop practices to manage crop residues for healthy soils in rice ecosystems; (d) strengthen the scientific basis for rice-based cropping system technologies; and (e) assess the impact of developed technologies on environmental quality. Finally, PhilRice aims to develop crop management protocol, diagnostic tools, and processes toward sufficiency and sustainability. These include the long-term fertility experiment, long-term experiment on the use of organic fertilizers, the Decision Support System for Agrotechnology Transfer (DSSAT), the field nutrient diagnostic techniques (NDTs), and crop nutrient diagnostic tools.

BIOTECH's research programs include the development of bio-fertilizers and bio-pesticides which are promising alternatives to inorganic fertilizers and chemical pesticides. The bio-fertilizer technologies developed by the institute include BIO-N, the most popular and one of the most effective; Vesicular Arbuscular Mycorrhiza Root Inoculant (VAMRI); Brown Magic; BioGroe; Mykovam; NitroPlus; microbial inoculants for the bioconversion of crop residues and agro-industrial by-products into bio-fertilizers; Cocogro or plant growth hormones from coconut water; and BioCon (Javier and Brown 2009). Bio-fertilizers are very cheap, easy to use, safe, and do not require repeated applications. Bio-pesticides are derived from natural materials including animals, plants, bacteria, and certain minerals.

The farming system technologies developed to improve rice production, their benefits, and some strategies for their implementation have considered major factors for production of rice including (a) seeds, (b) soil and fertilizer management, (c) water management, and (d) pest management. Notable examples of technology intervention included (i) application of optimum fertilizer amounts; (ii) proper management and recycling of crop residues; (iii) use of foliar fertilizers to improve grain filling percentage; (iv) re-introduction of green manures in rice-based farming systems; (v) organic fertilizer application to enhance biological nitrogen fixation (BNF); (vi) integration of bio-fertilizers in rice production systems; (vii) re-introduction of slow release nitrogen fertilizers; (viii) expansion of irrigated areas through installation of shallow tube wells, water harvesting structures, irrigation facility repair, and rehabilitation, among others (Velasco et al. 2012).

Ecological engineering, that is, the provision of habitats for beneficial arthropods, has recently gained considerable attraction as a method to reduce pesticide inputs and enhance biological pest control provided by natural enemies (Gurr et al. 2011). Habitat management through ecological engineering with flower strips can have beneficial and synergistic effects on biological pest control, pollination, and cultural services including landscape aesthetics and recreation (Settele et al. 2015; Westphal et al. 2015).

Biotechnology offers sustainable and practical solutions to numerous problems in rice production, specifically on pest protection. This technology could aid the development of cultivars with higher yields that offer resistance against major pests in the Philippines, research on endophytic fungal isolates from different rice ecosystems in relation to biological control of sheath blight, rice variety site specificity trials like planting low-yielding rice for the sloping uplands, medium-yielding rice for the unfavorable flatlands, and high-yielding rice for the favorable flat uplands, and upland variety resistance to leaf rollers, among others.

Agroforestry is a dynamic, ecologically based, natural resource management system that through the integration of trees into farms, diversifies and sustains smallholder production for increased social, economic, and environmental benefits. Introducing trees within the cropping system can help prevent land degradation, increase biodiversity, and at the same time allow the continued use of the land for agricultural crop production.

The Philippines is implementing various bioenergy policies that focus toward a cleaner and greener environment searching for alternative renewable sources of fuel and energy. It has a large potential for bioenergy production since crops that are used as feedstock are indigenous or locally grown. Further, instead of burning, corn and sugarcane crop residues can be used as biomass feedstocks.

In the Philippines, the active involvement of local communities in agricultural and environmental activities of agritourism and ecotourism programs is trending. Activities such as crop harvesting, fruit and flower picking, food preparation, and environmental protection and conservation schemes such as precision agriculture are increasingly attracting the attention of tourists. Moreover, agritourism has not only become the vehicle to promote environmental aesthetics but has also become a venue for educational tours and community activities showcasing the agricultural landscape.

There are numerous data gaps on fertilizer consumption and pesticide application in other crops.

There are a number of data gaps and research challenges in the country with regard to agripollution. The major data gaps that this study has identified are the lack of available data on the kind and amount of pesticides actually applied in various cropping systems like rice, corn, vegetables, pineapple, banana, tobacco, and other crops grown in the country. There is no national agency that collects and monitors the application of pesticides in various crops.

Similarly, fertilizer consumption data are available only for the two major staple crops: rice and corn. Data on the amount and timing of fertilizer application for all other crops grown in the country are lacking. Clearly, there is a need for the national government to monitor and synthesize the fertilizer consumption and rate of fertilizer application in the other crops grown in various provinces and islands of the country to aid in identifying potential hotspots for excessive fertilizer application that can potentially cause pollution of the land, water, and air resources in these cropping areas.

Moreover, data on fertilizer and pesticide consumption in commercial plantation crops like pineapple and banana are not available despite the common knowledge that massive amounts of pesticides and fertilizers are applied by multinational companies in these systems. The government needs to establish protocol and legislation to collect these data and be able to conduct regular monitoring of farming practices being implemented by these multinational and commercial plantations.

Pesticide residues in tropical and temperate vegetables would likely have a direct impact on human health, thus it is critical to obtain data on the amount, timing, and manner of application of pesticides in these food crops. Close monitoring of pesticide residues in vegetables locally sold in community markets is necessary to ensure food safety of these commodities.

The only water bodies where studies on the impacts of pollution are being monitored are the Manila Bay and Laguna Lake. Studies on the impacts of agricultural pollution on the other major water bodies and river basins is lacking in the country.

Furthermore, pesticide application has adverse impacts on nontarget species and there is a lack of studies that investigate the impact of pesticides on the population and interactions among the various life forms (biodiversity) that make up the food chain in the agricultural systems, particularly the herbivores, pollinators, and predators.

There are huge legislative challenges to address agricultural pollution in the Philippines.

There are still great challenges ahead to address pollution coming from agricultural activities in the Philippines. There are no government programs that directly address the problem of agricultural pollution. The legal mandates that may be related to agricultural pollution are the Environment Code of the Philippines, Clean Water Act, Clean Air Act, and Ecological Solid Waste Management Act. The provisions for controlling agricultural pollution are not being strictly implemented by the national or local government units (LGUs). At the local level, barangay codes should follow the National Clean Air Act and Clean Water Act. Local legislation cannot contradict the national laws. Local laws are always anchored on Republic Acts, Administrative Orders, and Presidential Decrees. The DA and the LGUs must have meaningful, well-coordinated relationship with regard to the implementation of rules and regulations (Serrano 2016, pers comm).

INTRODUCTION

1

The Philippine archipelago emerged because of the dynamic shifting and collision of four plates: Continental Eurasian plate, Indian-Australian plate, Oceanic Pacific plate, and the Philippine Sea plate. In the past 100 million years, the archipelago was welded together in an island arc punctuated by episodic and extensive magmatic activities. The country's topographic landscape consists of towering mountains with steep slopes, undulating hilly upland areas, and flat lands. The rich volcanic soils, varied topography, seasonality of monsoon rains, abundant rainfall, and warm temperature enabled the suitability of land for planting various crops in the different islands. Thus, various crops were easily introduced and cultivated in the country.

Since the early times, rice cultivation has spread in Southeast Asia. Before rice cultivation, the people civilizations were hunter-gatherers. Rice was cultivated in dry fields before in Southeast Asia through slash-and-burn. Then irrigated rice cultivation spread in the region.

Based on historical data, rice cultivation in the Philippines started around 3200 BC when the society became settled in one area and could domesticate rice. The earliest rice, which was found as a mix of wild and cultivated rice today, was excavated in a very fertile plain of Andarayan.

Rice became the staple food in the Philippines under Spanish colonization. During the 1870s, its production decreased relative to its demand. Then, various initiatives, which started from the 1960s Green Revolution, were made to address this issue (Aguilar Jr. 2013).

Rice is usually cultivated in lowland regions. However, in the Philippines, rice is usually cultivated in higher areas which are known as terraces. Special varieties of rice, suited for cooler environments in higher elevations, were developed. Being the staple food, both upland and irrigated rice is widely grown in various provinces all over the country today.

Tobacco was introduced first around the world before it reached the Philippines. Based on historical data, the Spaniards and Portuguese brought tobacco to Europe, East Indies, and Asia during the 1500s. Tobacco was one of the main commodities in their galleon trade. Moreover, the Spaniards cultivated tobacco in their colonized countries. In the Philippines, it was in the last quarter of the 16th century that cigar tobacco seeds were introduced by the Augustinian friars. Then, tobacco monopoly started in the Philippines due to the Spanish government's aim to gain higher revenue (National Tobacco Administration 2008).

The coconut industry in the Philippines started during the Spanish period in 1642. During this period, the Spaniards required 200 coconut trees to be planted by each *indio*. Its further expansion continued in the first two decades of American colonization. Then, the first coconut oil mill was established in Manila which started commercial coconut oil production in 1906 (Dayrit, no date).

It was recorded that in 1572 when Manila was settled by the Spaniards, sugarcane was planted in some provinces in the Philippines. Then, the first shipment of sugarcane to other countries such as the United States was recorded in 1796. Moreover, sugar became the most important export of the Philippines from mid-19th century to mid-1970s (Philippine Tourist Research and Planning Organization 1991).

The abovementioned crops were just some of the main crops introduced in the Philippines by its colonizers. At present, various agricultural crops are widely grown in various provinces all over the country. Ranking of crops grown in the Philippines is based on their contribution to food security, livelihood, and foreign trade (Altoveros and Borromeo 2007). Rice, being a staple food of the Filipino people, is the most important crop to meet food security in all regions of the country. Rice is included in all food preparations three times a day, native delicacies, wine making, and even used as offering in religious rituals and festivals. White corn is consumed as a substitute for rice in certain regions in the country and during lean periods. Corn is also used in preparing traditional delicacies and snacks (Altoveros and Borromeo 2007). On the other hand, yellow corn is grown as animal feed.

Coconut is important primarily for foreign trade and livelihood. It is an important source of cooking oil, beverage, snacks, delicacies, and traditional food (Altoveros and Borromeo 2007). Coconut is also an emerging source of biofuel while its husk is being used to manufacture nets for soil erosion control as well as planting media. Like coconut, the primary importance of sugarcane is for foreign trade. It is a main source of sugar and its by-products including bagasse and molasses are used in paper production and particle boards (Altoveros and Borromeo 2007).

Banana is the most important fruit in the Filipino diet and thus important in meeting food security (Altoveros and Borromeo 2007). For smallholder farmers growing banana in their farming system, it is a constant source of income. Mango is an important fruit for foreign trade. It is also popularly consumed locally as fresh fruit, beverage, dried fruit, and therefore important in meeting food security (Altoveros and Borromeo 2007).

1.1 Areas Planted with Top Ten Major Crops in 2014

The rich natural resources of the Philippines including fertile volcanic soils, varied topography, abundant rainfall, and warm tropical temperature with plenty of sunshine make it highly suitable for growing various important economic crops. The top ten major crops grown in the Philippines are widely planted in different provinces (Figure 1). Rice is widely grown in various provinces all over the country. The major provinces where large areas of rainfed rice are grown are Abra, Agusan del Norte, and Agusan del Sur. On the other hand, irrigated rice is largely grown in Isabela, Nueva Ecija, Cagayan, and Pangasinan in Northern Luzon. Yellow corn is largely grown in Isabela and Cagayan in Region II; and in Bukidnon, North Cotabato, and South Cotabato in Mindanao. Major growing areas for white corn are Maguindanao, Lanao del Norte, and Lanao del Sur in Mindanao; Cebu and Negros Oriental in Visayas.

There are large plantations of banana in Mindanao including the provinces of Davao del Norte, Davao del Sur, Compostela Valley, Bukidnon, North Cotabato, South Cotabato, and Maguindanao. In 2014, large areas in Lanao del Sur, Bukidnon, and Camarines Sur were cultivated with cassava. There are large plantations of coconut in Quezon, Zamboanga del Norte, and Davao Oriental. Coffee, on the other hand is largely grown in Maguindanao, Lanao del Norte, Lanao del Sur, Cebu, Negros Oriental, and Zamboanga del Sur.

Pineapple plantations are concentrated in Bukidnon and South Cotabato (Figure 1). On the other hand, large plantation areas of mango are located in Pangasinan while tobacco is largely grown in the Ilocos Region and Isabela. Large areas are planted with sugarcane in Negros Occidental and Bukidnon.

Temperate vegetables are grown largely in Benguet. Tropical vegetables are grown in many areas in Luzon and Visayas. Large areas in Isabela, Nueva Ecija, Pangasinan and Ilocos Norte have been cultivated with tropical vegetables since 2014 (Figure 1). Rubber is largely grown in Zamboanga Sibugay and North Cotabato. Growing oil palms has become popular recently in the Philippines and it is largely grown in Agusan del Sur, Sultan Kudarat, Palawan, Bohol, and North Cotabato.

Intensification of cropping systems to optimize production of these various major crops involve increased cropping frequency (two to three crops per year for the annual crops), increased cropping intensity (more trees or plants per unit area), increased fertilizer application to boost growth and crop yield, increased pesticide application to control pests and diseases, irrigation systems to augment precipitation, adoption of technologies (new cultivars, hybrid varieties), and farm mechanization. These efforts may lead to environmental degradation such as depletion of soil nutrients; leaching of excess fertilizers into the environment; pesticide residues in crops, soil, and water resources; volatilization of GHG into the air; soil erosion; sedimentation and eutrophication in adjacent water bodies.

1.2 Volume of Production of Top Ten Major Crops in 2014

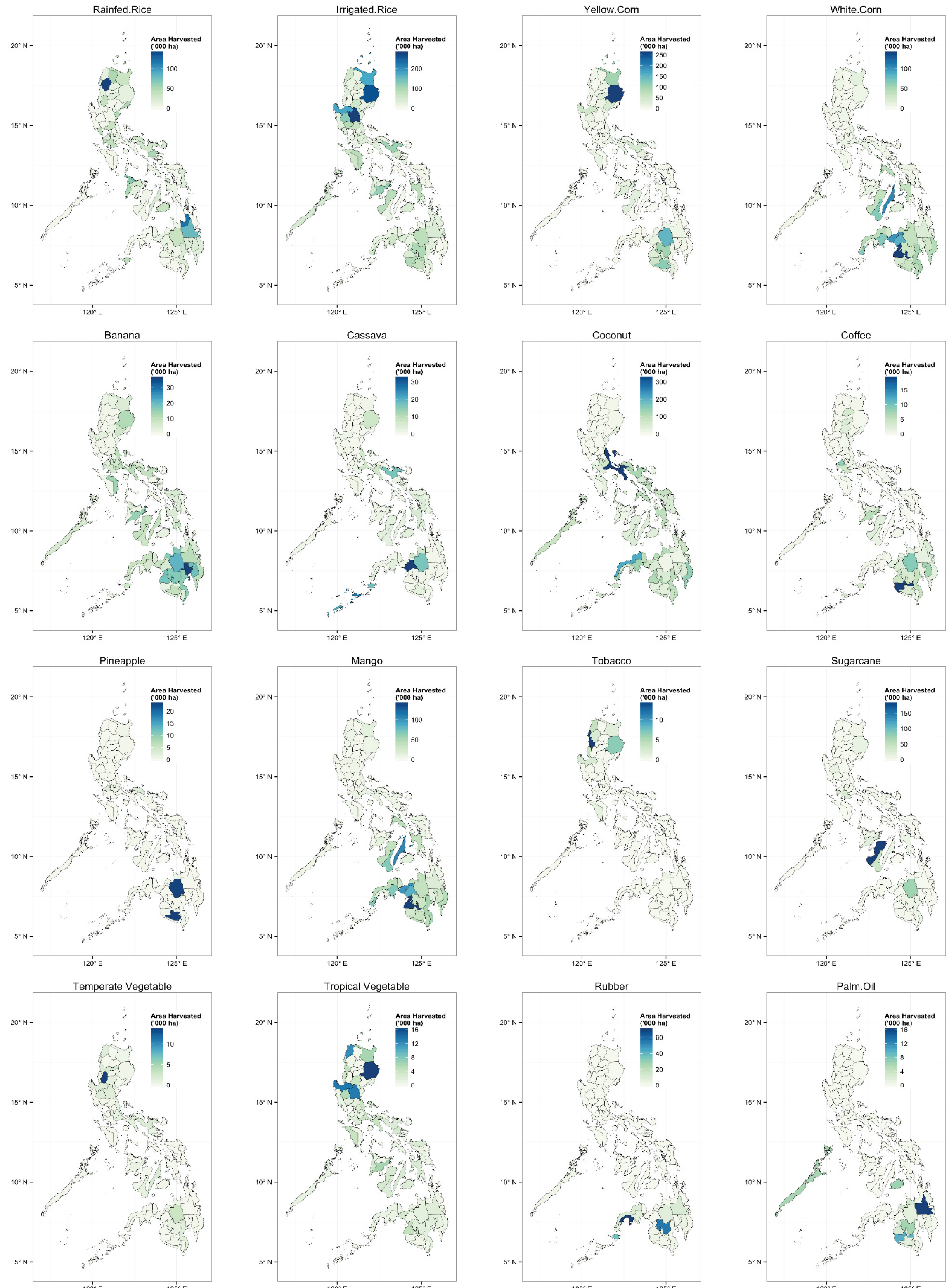
In 2014, Iloilo had the largest volume of rainfed rice production. Other provinces with high production of rainfed rice are Pangasinan and Maguindanao (Figure 2). On the other hand, the highest volume of irrigated rice was produced in Nueva Ecija in 2014. This is followed by Isabela, Cagayan, and Pangasinan. Isabela is the highest producer of yellow corn, followed by Bukidnon, and Cagayan. White corn, on the hand is largely produced in Maguindanao, Lanao del Sur, and Lanao del Norte.

Banana is largely produced in the provinces of Davao del Norte, Bukidnon, North Cotabato, and Davao del Sur in Mindanao Island (Figure 2). In 2014, a large produce of cassava was harvested from the provinces of Lanao del Sur and Bukidnon. The highest coconut-producing province in 2014 was Quezon. Other major producers of coconut are Davao del Sur, Zamboanga del Norte, Davao Oriental and Maguindanao, Misamis Occidental, Lanao del Norte in Mindanao. Palawan is also another major producer of coconut. The major producer of coffee in 2014 was Sultan Kudarat.

The major producer of pineapple in 2014 was Bukidnon, followed by South Cotabato (Figure 2). Pangasinan was the top producer of mango in 2014. Other major producers of mangoes are Zamboanga del Norte and Cebu. The highest producer of tobacco was Ilocos Sur, followed by Isabela. Other major producers of tobacco are the provinces of Pangasinan, La Union, and Ilocos Norte in the Ilocos Region. Sugarcane is largely produced in Negros Occidental. Bukidnon is also another major producer of sugarcane.

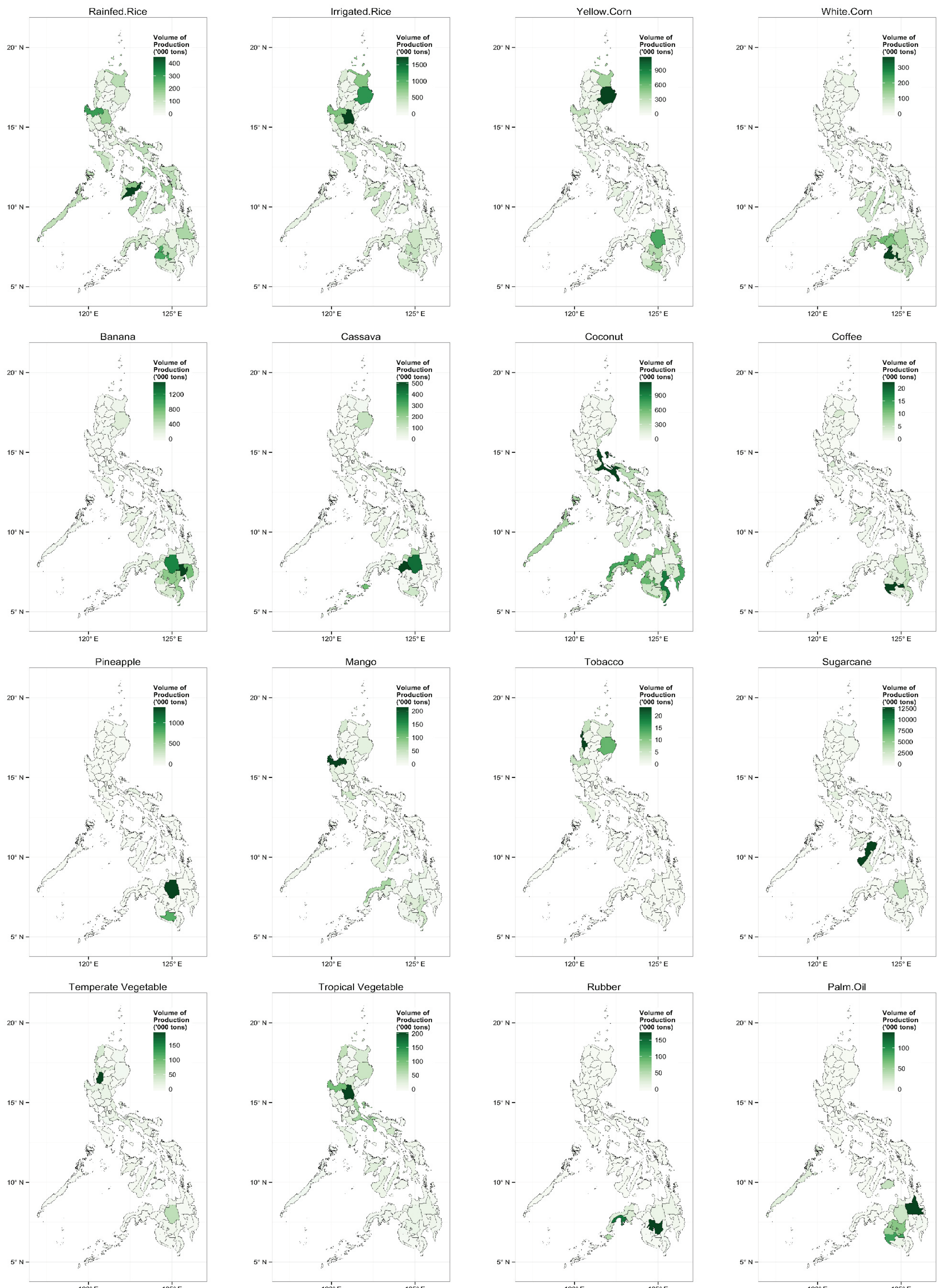
In 2014, the highest producer of temperate vegetables was the Benguet Province in Northern Luzon. In Mindanao, Cotabato is a major producer of temperate vegetables. Tropical vegetables are largely produced in Luzon Island. Nueva Ecija is the top producer of tropical vegetables, followed by Pangasinan. North Cotabato was the highest producer of rubber in 2014, followed by Zamboanga Sibugay. Palm oil is largely harvested in Mindanao Island, where Agusan del Sur is the top producer, followed by Sultan Kudarat. Other major producers of palm oil are North Cotabato and Maguindanao.

Figure 1: Areas where the major crops are grown in the Philippines, 2014



Source: Based on PSA 2015 data.

Figure 2: Volume of production of major crops grown in the Philippines in 2014



Source: Based on PSA 2015 data.

2

INTENSIFICATION AND EXPANSION OF AGRICULTURAL SYSTEMS

2.1 Evolution of Cropping Systems in the Philippines

Historically, the Philippine agricultural systems evolved out of the need to provide for a rapidly growing population. In the past century, the evolution of rice production in the Philippines can be categorized into three periods: pre-Green Revolution, Green Revolution, and post-Green Revolution.

Since the early 1900s, traditional rice varieties were planted once a year and field operations were done manually or using draught animals like carabao or cattle. Irrigation systems were initially developed during the American regime (Figure 3). Transplanting of rice seedlings started to be practiced in the 1920s. Family members, relatives, and local community members share in the labor required in the farming practices like transplanting rice seedlings and harvesting. The natural soil fertility was enough to support the growth of a single crop of rice in a year (Bautista and Javier 2005).

Before the Green Revolution, rice production management involved changes in yield with relative proportions of irrigated, rainfed, and upland areas, changes in seasonal harvesting pattern and the varieties planted (Gonzalo 1950). With new and improved seed varieties; irrigation canals and the expansion of irrigated areas by building big dams and concrete canals; rice yield in the Philippines has consistently increased from the 1900s to 1950s.

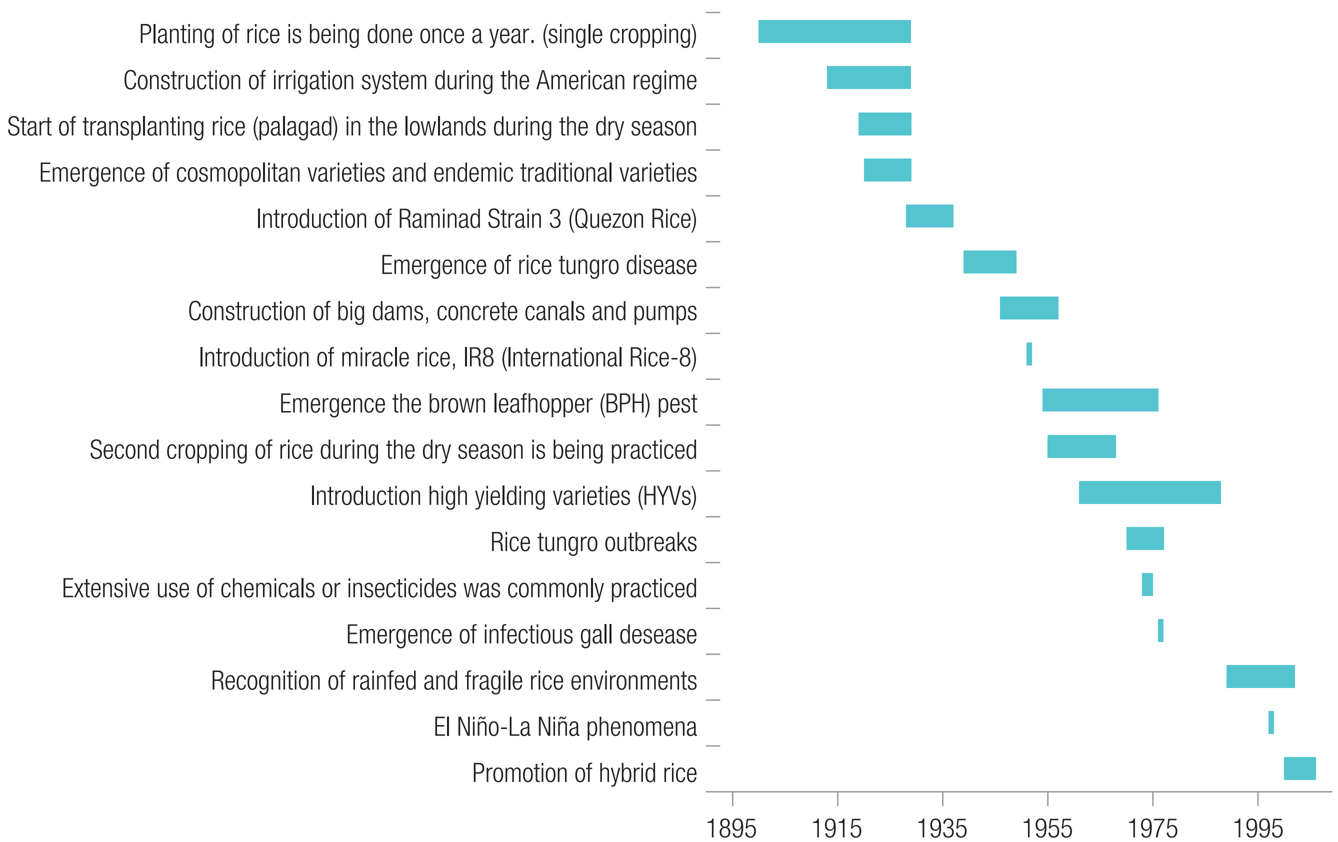
Cosmopolitan and endemic rice varieties emerged during the decade 1920–1930. Quezon rice variety was introduced in the 1930s while miracle rice was introduced in 1950. Massive construction of big dams and concrete canals was done between 1948 and 1956. This enabled the practice of planting a second crop of rice during the dry season from 1955 to 1970 (Bautista and Javier 2005).

Rice production practices and technologies promoted the increase of yield and at the same time lower production costs. Moreover, these techniques are ever-changing in the Philippines because of technologies and government programs aiming to solve the dynamic challenges and needs of the Filipinos. Among the most important concerns is the growth of population in need of staple food and the cost-reduction methods to benefit rice farmers. Fortunately, major improvements in yield and cost reduction of growing rice have been achieved over time.

Schools such as the University of the Philippines College of Agriculture, Central Luzon Agricultural School, and other provincial schools were established to support agriculture in the country during the early years. Agricultural (rural) high schools were established to promote agricultural knowledge and capabilities. These institutions were further aided by agencies promoting agricultural development by irrigation system provision, fertilizer administration, land settlements, and water and soil conservation. However, the progress of the Philippine rice industry during these times was relatively slow in comparison with other rice-producing countries such as Japan, China, and Korea because of the Philippine government's lack of support and facilities for rice research and organizations (Serrano 1952).

During the Green Revolution period from 1966 to 1988, modern high-yielding rice varieties that are short-statured, non-photosensitive, and early maturing were developed and irrigation infrastructure were constructed that revolutionized the rice farming system. These high-yielding varieties (HYVs) require high fertilizer and pesticide inputs and irrigation water which enabled two croppings a year. The main objective of

Figure 3: Evolution of rice farming systems in the Philippines



Source: Bautista and Javier 2005.

farming production during this period was to attain high yield and double the crop potential of these modern varieties (Bautista and Javier 2005). The IRRI spearheaded the researches on new rice variety development, fertilizer management, pest management, harvesting, threshing, drying, and milling. Farming practices evolved including fertilizer management, chemical control of pests and diseases, mechanized threshing, and drying of palay, although the farmers were selective in the new technologies that they adopted. Further, the newly passed Land Reform Law during this period transformed rice farmers from mere tillers to managers of their own farm land (Bautista and Javier 2005).

It was seen that the period between 1965 and 1980 gained more from the impact of the development and adoption of new technologies than from any change in the production technology. With the advent of the Green Revolution and the lack of and increasing cost of labor, research and development of mechanization technologies was vigorously initiated and mechanized farming became dominant in the rice field.

Rice production during the Green Revolution is considered as most progressive because of the massive improvement in crop productivity and significant changes in rice production techniques and management. IRRI led major changes in rice planting from the development and introduction of modern HYVs, intensive use of chemicals and machines to sustain high yields, and double cropping system (Bautista and Javier 2005).

In response to the challenges of increasing crop production while sustaining the natural resources, the country started to adopt multiple cropping systems in the late 1960s and prioritized multiple cropping programs for rainfed rice in the early 1970s. From rice-based cropping systems, it eventually expanded toward corn-, coconut-, and sugarcane-based systems. In 1971, upland farming systems were developed including the sloping agricultural land technology (SALT) system. Since, upland areas constitute 60 percent of the Philippines' land areas, the adoption of SALT allows farmers to strip-crop annual crops and grow perennial crops in sloping and hilly areas, primarily for domestic consumption and income generation. Moreover, SALT can prevent soil erosion and can help in addressing the decrease in soil productivity of upland areas (Philippine Country Report 1995).

Cropping systems for irrigated rice areas are generally in a rice-rice sequence. In the mid-1970s, these systems evolved to include fish or duck raising, mungbean (*Vigna radiata*), peanut (*Arachis hypogaea*), and soybean (*Glycine max*) planting after two rice croppings. Meanwhile, cropping for rainfed rice systems usually involved planting of garlic (*Allium sativum*), onion (*Allium cepa*), and tomato using zero to minimum tillage (Philippine Country Report 1995).

For coconut cropping systems, usually in flat lands, they are cultivated and grown with various crops such as rice, corn, sweet potato, pineapple, banana, lanzones, rambutan, papaya, peanut, mungbean, abaca, taro (*Colocasia esculenta*), arrowroot (*Maranta arundinacea*), daisy (*Gerbera* sp.), sorghum (*Sorghum bicolor*), coffee (*Coffea* spp.), cacao (*Theobroma cacao*), black pepper (*Piper nigrum*), vanilla (*Vanilla planifolia*), and many others. Cattle and small ruminants are also raised in vast coconut areas with available pasture grass and legumes (Philippine Country Report 1995).

In sugarcane cropping systems, legumes such as mungbean and cowpea are intercropped during the first three months. Livestock are also raised if space is available. However, when the price of sugarcane shoots up, farmers revert back to monoculture for greater returns.

The Philippines experienced more rapid development of sustainable farming systems after the 1970s. Intensification and expansion of cropping systems yielded higher production, increased farmer income, and maximized the use of natural resources such as land, capital, labor, and irrigation facilities. Moreover, despite the developments and growth in the rural areas, environmental degradation was held at a minimum.

The post-Green Revolution period started from 1989 to the present time. During this period, Filipino farmers were concerned in sustaining productivity while minimizing costs by adopting efficient, inexpensive, and promising technologies for higher income.

Integrated pest, nutrient, and water managements systems were further improved. High-quality seeds and hybrid seeds were introduced by the government. Direct seeding and application of herbicides were practiced with the aim of decreasing labor costs. Sustainability and protection of rainfed and fragile environments were recognized (Bautista and Javier 2005).

In the late 1980s to the early 1990s, crop diversification was identified as a strategy to strengthen the agriculture sector. This technique, which was written in the Medium-Term Philippines Development Plan (1987–1992), aimed to support food security, open more employment opportunities, increase farm incomes, and reduce dependence on traditional export commodities with declining demand in the world market (Adriano and Cabezon 1989).

Moreover, a National Committee on Crop Diversification (NCCD) was established in 1992 in the DA. NCCD is inter-agency in nature, with a function of planning and implementing a crop diversification program. It has prepared four commodity-based plans for rice, corn, coconut, and sugarcane. These plans were used for the DA's Medium-Term Development Plan in the early 1900s (Pecson 1993).

Other economic policies supporting crop diversification were drafted by the Philippine government such as pricing policies, tax and tariff policies; and subsidies were imposed. The government reduced the price support for rice in consideration of farmers shifting to alternative cash crops. The government also wants to reduce its direct intervention function in marketing rice by relying on the private sector to trade (domestic and international) and hold stocks (Adriano and Cabezon 1989).

2.1.1 *Organic Agriculture*

Organic agriculture uses socially, environmentally, and economically sound food production with wide-range goals of economic viability, social humaneness, and ecological soundness (Maghirang and Villareal 2000). The philosophy of organic food production systems maintains certain principles such as biodiversity, ecological balance, sustainability, natural plant fertilization, natural pest management, and soil integrity. Organic farming excludes or strictly limits the use of manufactured fertilizers, pesticides, herbicides, insecticides, and fungicides, plant growth regulators such as hormones, livestock antibiotics, food additives, and genetically modified organisms (Maghirang and Villareal 2000). The local markets for organic products has already expanded to regular markets which can normally be found in supermarkets and special food outlets. Since organic products are getting popular in the country today, more outlets and markets are starting to sell it (Maghirang and Villareal 2000).

The development of organic agriculture in the country was influenced by the following national policies and regulations:

- **Philippine Agenda 21 (PA 21)** also known as the National Agenda for Sustainable Development which aims at "a better quality of life for all, through the development of a just, moral, creative, spiritual, economically vibrant, caring, diverse yet cohesive society characterized by appropriate productivity, participatory and democratic processes, and a living in harmony within the limits of the carrying capacity of nature and the integrity of creation."
- **Agriculture and Fisheries Modernization Act (AFMA)** secures the agriculture and fisheries sector development accordingly to the "principles of poverty alleviation and social security; food security; rational use of resources; global competitiveness; sustainable development; people empowerment; and protection from unfair competition." It also aimed to lessen the use of harmful agrochemicals.
- **Executive Order 481 (EO 481)** promotes organic farming in rural farming communities. It will also "forge effective networking and collaboration with the stakeholders involved in the production, handling, processing and marketing of organic agriculture products; guarantee food and

environmental safety by means of an ecological approach to farming; and ensure the integrity of organic products through the approved organic certification procedures and organic production, handling and processing standards."

- **Philippine National Standards for Organic Agriculture (PNSOA)** provides uniform method to the requirements of conversion to organic agriculture, processing, labelling, livestock, crop production, special products, and consumer information.
- **Department of Agriculture Administrative Order No. 25 Series of 2005** creates the rules and regulations used by the DA related to the Good and Agricultural Practices certification of individual farmers. The certification is important to increase "increase the market access of horticultural products both in the local and foreign markets; to empower farmers to respond to the demands of consumers that specific criteria to achieve food safety and quality be met; to facilitate farmer adoption of sustainable agricultural practices; to uplift GAP-FV farmers profile as member of the nationally recognized list of vegetable farmers who are setting the benchmark for the production of safe and quality fruits and vegetables; and to enable consumers exercise the option of buying quality fruits and vegetable from traceable and certified sources."
- **Organic Agriculture Act of 2010 (Republic Act No. 10068)** develops, promotes and implements organic agriculture practices which can "enrich the fertility of the soil; increase farm productivity; reduce pollution and destruction of the environment; prevent the depletion of natural resources; further protect the health of farmers, consumers and the general public, and save the program for the promotion of community-based organic agricultural systems which include, among others, farmers produced purely organic fertilizers such as compost, pesticides and other farm inputs, together with a nationwide educational and promotional campaign for the use and processing, as well as the adoption of organic agricultural system as a viable alternative shall be undertaken."
- **The Philippine Organic Agriculture Act (RA 10068, signed on April 6, 2010)** created the NOAP of the DA in an effort to reduce rural poverty by advocating low-input sustainable agricultural techniques that improve land productivity while minimizing adverse impacts to the environment. With this, NOAP targets to attain food security, sustainability, and competitiveness by converting at least 5 percent of the total agricultural area in the country, which is about 483,450 ha of the total area of 9,669,000 ha. The major components of the NOAP include (a) institutional development and strengthening, (b) research and development, (c) production and technology support, (d) extension and capability building, (e) promotion, advocacy and education, (f) market development, and (g) results-based monitoring and evaluation.

2.1.2 *AFMA*

The AFMA of 1997 focuses on "poverty alleviation and social equity; food security; rational use of resources; global competitiveness; sustainable development; people empowerment; and protection from unfair competition;" which includes incentives for trade and fiscal enterprises in agriculture and fisheries (DA 2015). Republic Act 8435 otherwise know as AFMA is the codified mandate on which the vision and goals of agricultural modernization was anchored. AFMA establishes the mechanisms and strategies for the more efficient use of available resources. It also emphasizes the primacy of private enterprises in agricultural modernization and growth. With AFMA, it is mandated that public investments in support of productive enterprises should be concentrated in the selected Strategic Agricultural and Fisheries Development Zones (SAFDZs). The law also sets forth the identification of 'centers of excellence' that will be the focus of support for world-class agricultural education and research. It also outlines the priorities in public investments—principally communal irrigation, operated and sustained through collaboration between irrigator's associations and LGUs. Another efficiency-boosting strategy enshrined in the law is the empowerment of the civil society groups and the LGUs to provide area-specific extension services.

AFMA places production technology at the heart of the government's drive toward revitalized agricultural and rural growth. Hence, AFMA requires maximized investments in research and development to capitalize on the benefits of the latest and more productive advances in productive technologies. As defined in the law, the Technical Education and Skills Development Authority (TESDA) is specifically mandated to provide agri-fishery skills training programs for farmers and fisherfolks.

In sum, AFMA is the overall framework by which the Philippines shall achieve sustainable food security and a modernized agriculture through revitalized productivity, more efficient deployment of resources and genuine partnerships between the government and the private sector.

2.1.3 *Productivity and Areas Grown to Different Rice Systems in the Philippines*

In 2002, the total area planted with rice in the Philippines was 3,759,000 ha. Irrigated rice covered 2,334,000 ha, comprising about 62 percent of the total rice area (IRRI Rice Facts 2002), while lowland rice covered 1,304,000 ha (35 percent) and upland rice covered 120,000 ha making up a mere 3 percent of the total area planted with rice (Table 1). Irrigated and rainfed lowland rice account for 97 percent of the rice production.

Irrigated rice has the highest productivity among the three different rice systems where more than one crop of rice is grown per year (Table 1). Rice grown in upland systems has the lowest yield with one crop per year since inorganic fertilizer is not applied in this system and when soil productivity becomes low, the land is left to fallow to rejuvenate soil fertility for a number of years, ranging from 4 to 20 years.

2.1.4 *Areas Harvested for Irrigated Rice in the Past 24 Years*

Being the staple food of the Filipinos, irrigated rice is widely grown all over the country (Figure 4). Regions II and III in the island of Luzon are the major growing areas of irrigated rice. The provinces of Isabela in Region II and Nueva Ecija in Region III have the largest irrigated rice fields: 262,236 ha and 280,756 ha, respectively. Both provinces also have high rates of increase in areas harvested for irrigated rice fields from 1990 to 2014: 37.7 percent and 42.3 percent, respectively.

2.1.5 *Upland Rice Harvested Areas in the Past 24 Years*

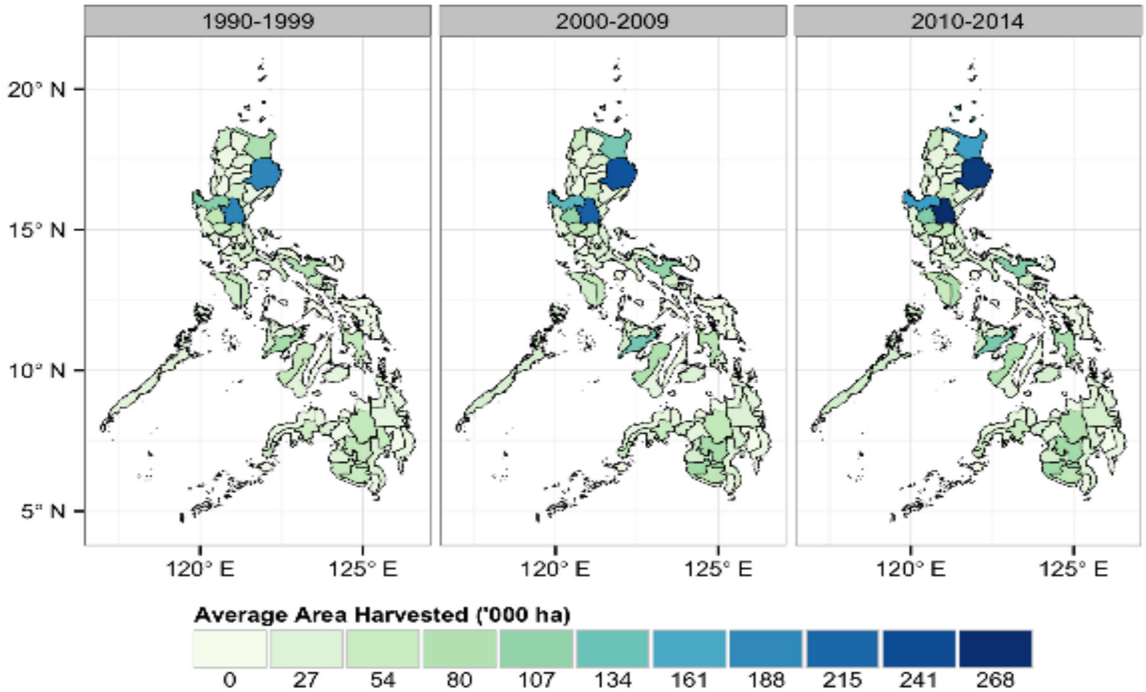
Upland rice is also widely grown in sloping and hilly areas all over the country (Figure 6). About half of the agricultural areas planted with rainfed rice is in upland areas situated on rolling and hilly terrain (National

Table 1: A comparison of the productivity of four different rice systems

System	Area (ha, thousands) (% of total)	Yield, ton/ha	Crops/year	Fallow period, year	Productivity, ton/ha/year
Irrigated rice	2,334 (62)	5.0	2.5	1	12.5
Rainfed rice	1,304 (35)	2.5	1.0	0	2.5
Upland rice*	120 (3)	1.0	1.0	8	0.12

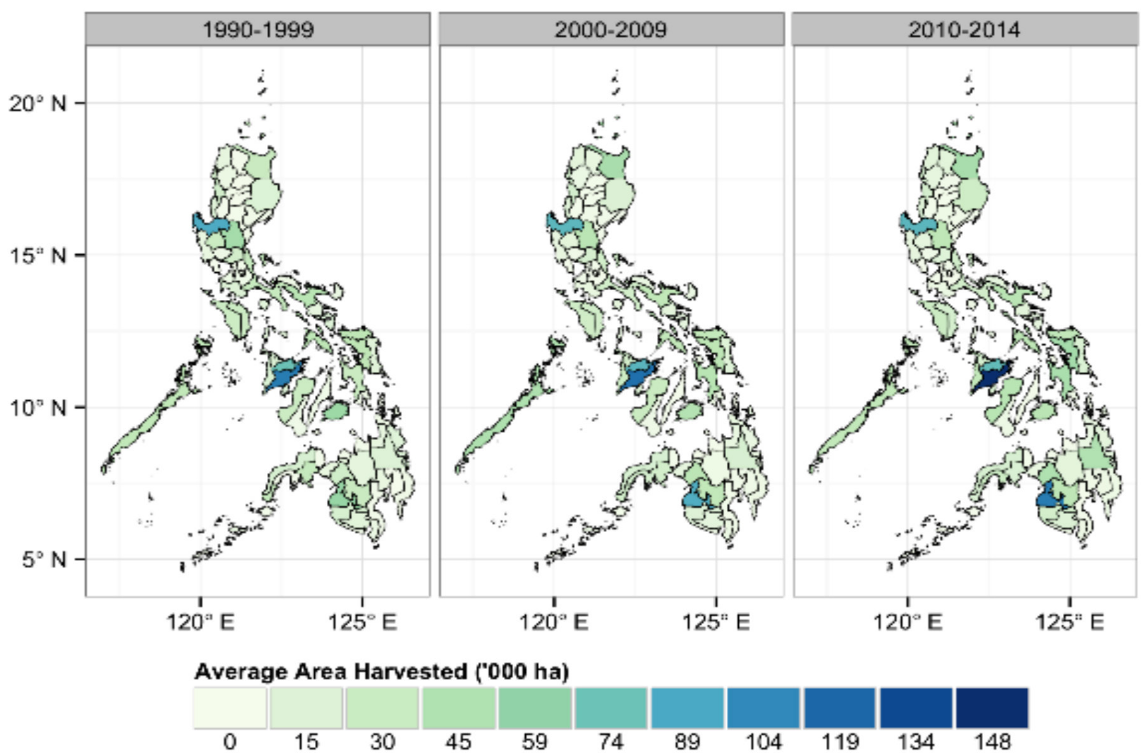
Source: Mutert and Fairhurst 2002; IRRI Rice Facts 2002.
Note: *Grown in slash-and-burn, usually on sloping land.

Figure 4: Areas harvested for irrigated rice from 1990 to 2014



Source: Based on PSA 2015 data.

Figure 5: Areas harvested for upland rice in the Philippines, 1990–2014



Source: Based on PSA 2015 data.

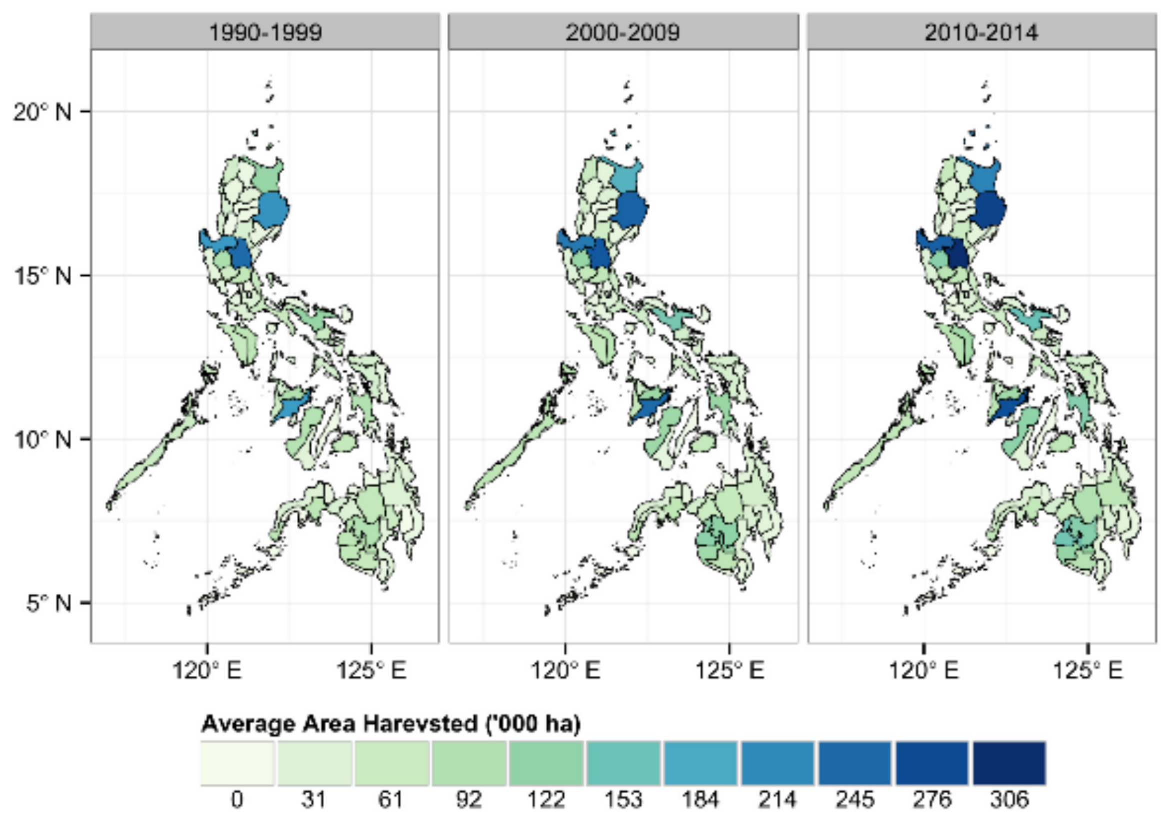
Statistics Office [NSO] 1991). A major upland rice-growing area is the province of Iloilo on the island of Panay in the Visayas. The island also exhibited the fastest rate of increase (51 percent) in areas where upland rice was harvested, from 96,970 ha in 1990 to 146,697 ha in 2014. Another province in Panay Island with vast areas where upland rice was harvested is the province of Capiz (Figure 5).

In Luzon Island, the province of Pangasinan has the largest area (80,530 ha in 2014) harvested for upland rice in the past 24 years. On the other hand, in Mindanao Island, large areas were harvested for upland rice and there was also an increase in the harvested area for upland rice in the past 24 years. In 1990, 43,170 ha were harvested for upland rice in Maguindanao and it increased by 176 percent to 119,027 ha in 2014 (Figure 5).

2.1.6 *Total Harvested Area for Rice in the Country*

The combined total area harvested for irrigated and upland rice in the country increased in the past 24 years. Rice is widely grown all over the country (Figure 6). Major growing areas are the provinces of Isabela with a 40 percent increase from 204,280 ha to 286,319 ha and Cagayan with an increase of 141 percent from 94,370 ha to 227,493 ha in Region II; Pangasinan with an increase of 34 percent from 194,210 ha to 260,632 ha in Region I; Nueva Ecija with an increase of 33 percent from 240,210 ha to 318,284 ha in Region III; Iloilo with an increase of 75 percent from 150,680 ha to 264,269 ha in Region VI. In Mindanao Island, areas planted with rice in Region XII has increased in the past 25 years by 107 percent from 167,780 ha to 346,906 ha (Figure 6).

Figure 6: Areas harvested for rice in the Philippines, 1990–2014



Source: Based on PSA 2015 data.

Nueva Ecija is the largest rice-producing province in the country, contributing about 10 percent of the total rice production in the Philippines in 2014 (Table 2). The province of Isabela ranks second contributing 6.7 percent of the total rice production. Pangasinan, Cagayan, and Tarlac Provinces rank third, fourth, and sixth, respectively. All these provinces are located in the Luzon Island and together contribute about 31 percent of the country's total rice production.

Table 2: Top ten rice-producing provinces in 2014

Province	Volume (tons)	% Contribution
Nueva Ecija	1,930,996	10.19
Isabela	1,277,623	6.74
Pangasinan	1,113,725	5.88
Cagayan	895,580	4.73
Iloilo	846,636	4.47
Tarlac	638,906	3.37
Camarines Sur	583,797	3.08
North Cotabato	530,029	2.80
Leyte	502,146	2.65
Negros Occidental	478,782	2.53

Source: PSA 2015.

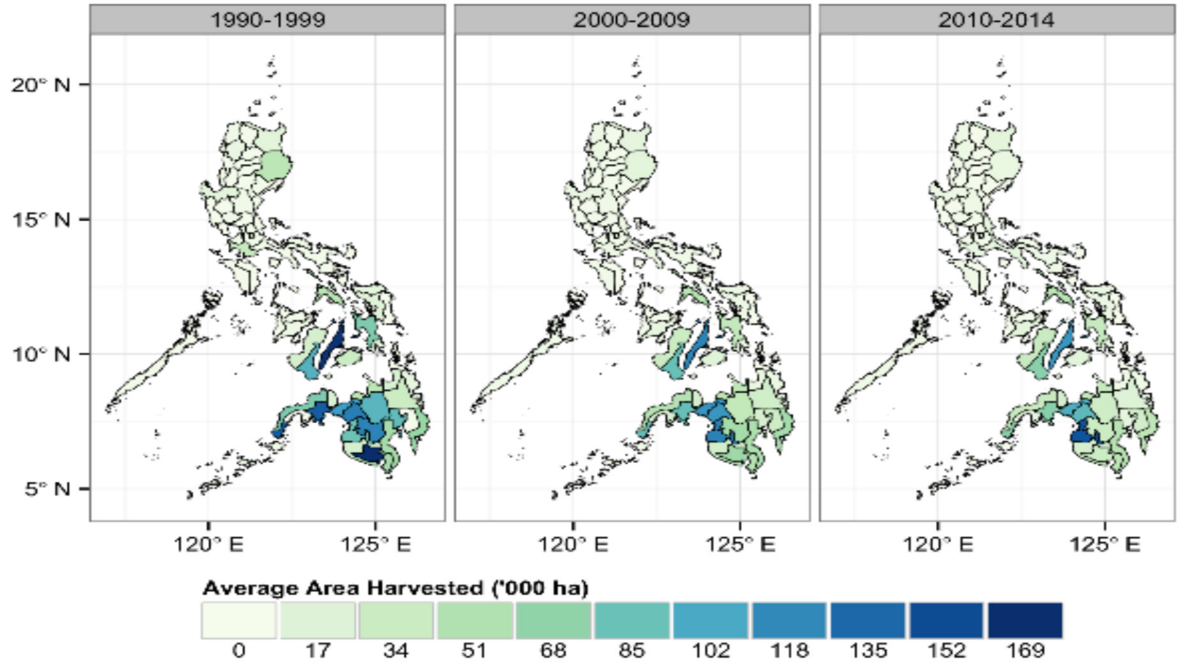
2.1.7 *Corn Farming System and Production*

Corn agro-ecozone is found in the sloping, rolling, to hilly uplands in Isabela, Camarines Sur, Bukidnon, South Cotabato, and Cotabato. With sufficient rainfall and favorable weather conditions, two to three croppings of corn can be grown in these areas. The third cropping can be corn, legumes, tobacco, and other vegetables (Gerpacio 2004).

2.1.8 *Areas Harvested for White Corn in the Past 24 Years*

White corn is mainly grown in Mindanao and Visayas Islands (Figure 7). In the decade of 1990–1999, large areas were harvested for white corn in Regions IX, XII, and Autonomous Region of Muslim Mindanao

Figure 7: Areas harvested for white corn in the past 24 years



Source: Based on PSA 2015 data.

(ARMM). In the past 24 years, the areas harvested for white corn gradually declined. Areas harvested for white corn in North Cotabato decreased by 42.5 percent from 227,300 ha to 130,699 ha. Similarly, areas harvested for white corn in South Cotabato decreased by 69 percent from 483,580 ha to 148,367 ha. In the 1990s, the island of Cebu had 350,570 ha and decreased down to 106,694 ha in 2014.

On the other hand, areas harvested for white corn in Bukidnon and Maguindanao increased. In Bukidnon areas harvested for white corn increased by 4.15 percent from 180,200 ha to 187,999 ha while in Maguindanao, it increased by 13.35 percent from 149,060 ha to 172,032 ha.

2.1.9 *Areas Harvested for Yellow Corn in the Past 24 Years*

Yellow corn is widely grown in upland areas in the country and the areas cultivated with yellow corn has increased in the past 24 years (Figure 8). The province of Isabela is the largest yellow-corn-growing area and the area increased rapidly in the past 24 years with a total area of 263,014 ha, constituting 10.07 percent of the total area cultivated with yellow corn in the entire country.

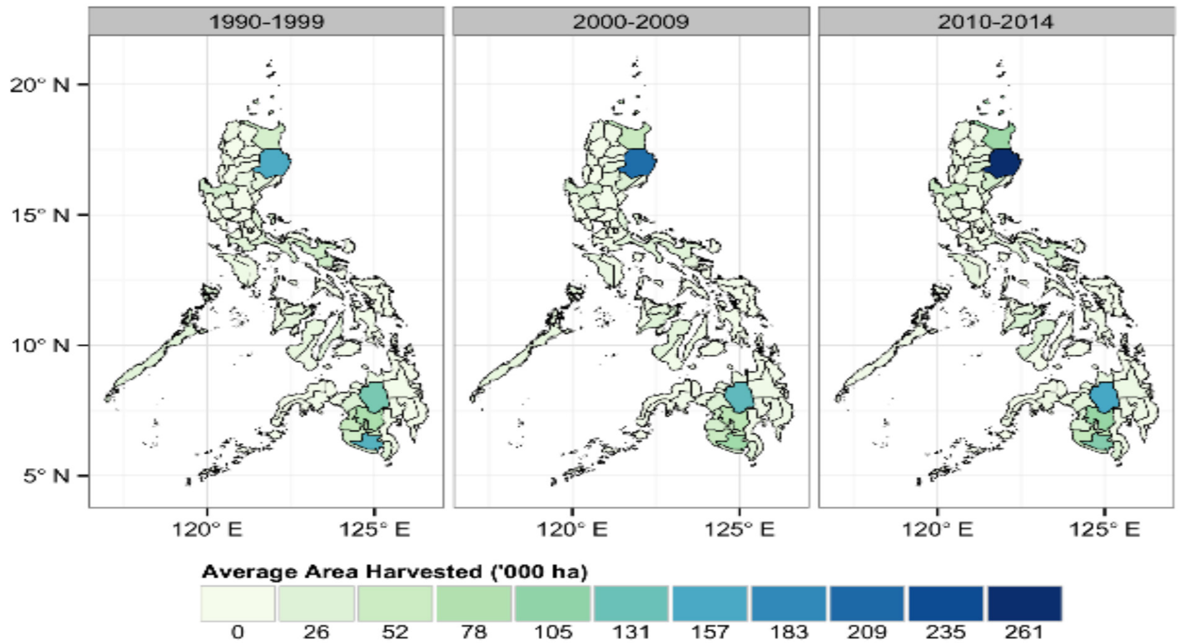
In Southern Philippines, yellow corn is largely harvested in the provinces of Bukidnon (150,130 ha), North Cotabato (130,699 ha), and South Cotabato (116,005 ha) (Figure 8).

2.1.10 *Areas Currently Harvested for White and Yellow Corn in 2014*

Yellow and white corn are planted in the Philippines. White corn is mainly for human consumption while yellow corn is mainly for animal feeds. Major yellow-corn-growing areas are the provinces of Isabela and Cagayan in Region II. In Isabela, area harvested for corn increased by 28.75 percent from 187,390 ha in 1990 to 263,014 ha in 2014 (Figure 9). Similarly, the land area harvested for corn in Cagayan increased by 73.13 percent from 26,500 ha in 1990 to 98,634 ha in 2014.

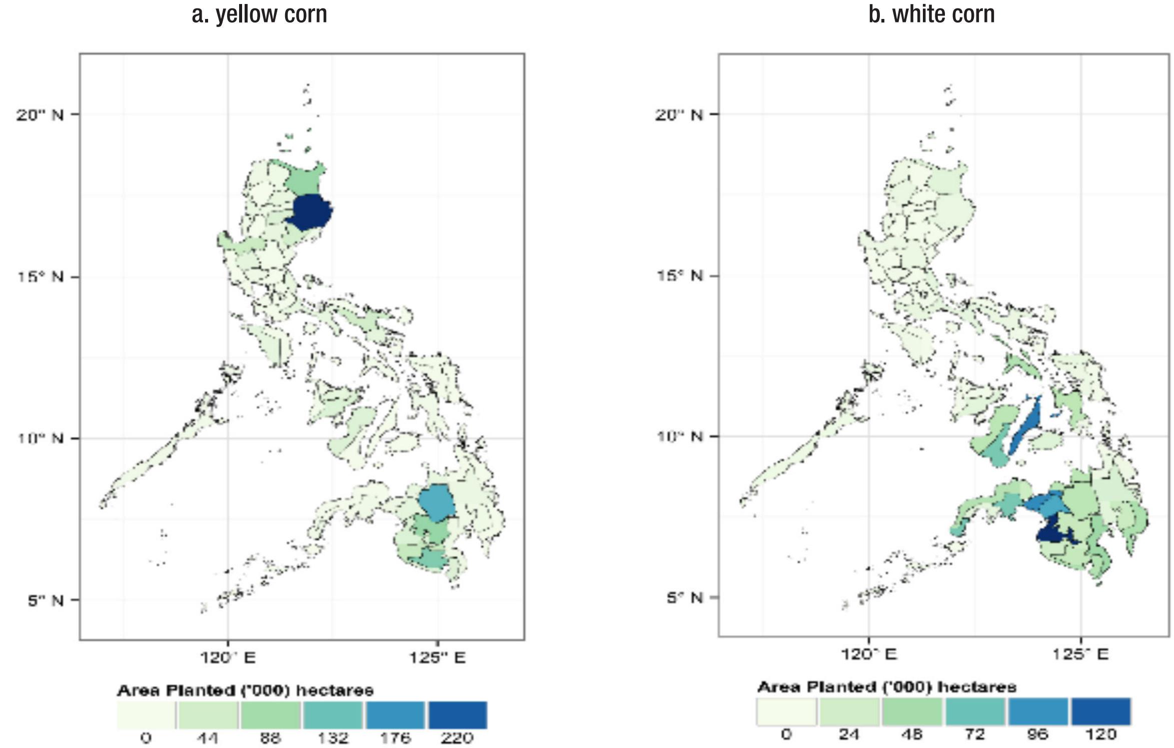
In Mindanao, areas harvested for corn also increased in the past 24 years. In Region X, corn was widely harvested in the province of Bukidnon where the harvested area increased by 40 percent from 76,630 ha to

Figure 8: Areas harvested for yellow corn in the past 24 years



Source: Based on PSA 2015 data.

Figure 9: Areas where (a) yellow corn and (b) white corn were harvested in 2014



Source: Based on PSA 2015 data.

150,130 ha. In Region XII, corn is widely harvested in the provinces of North Cotabato (7 percent from 93,250 ha to 99,763 ha) and South Cotabato (decrease of 36 percent from 183,700 ha to 116,005 ha) (Figure 9).

2.1.11 *2014 Corn Production*

The province of Isabela was the largest corn-producing province in 2014, contributing about 15 percent of the total corn production in the country (Table 3). This was closely followed by the province of Bukidnon with 805,845 tons of corn production, contributing about 10.4 percent of the country's total corn production (Table 3).

2.1.12 *Areas Harvested for Sugarcane in the Past 25 Years*

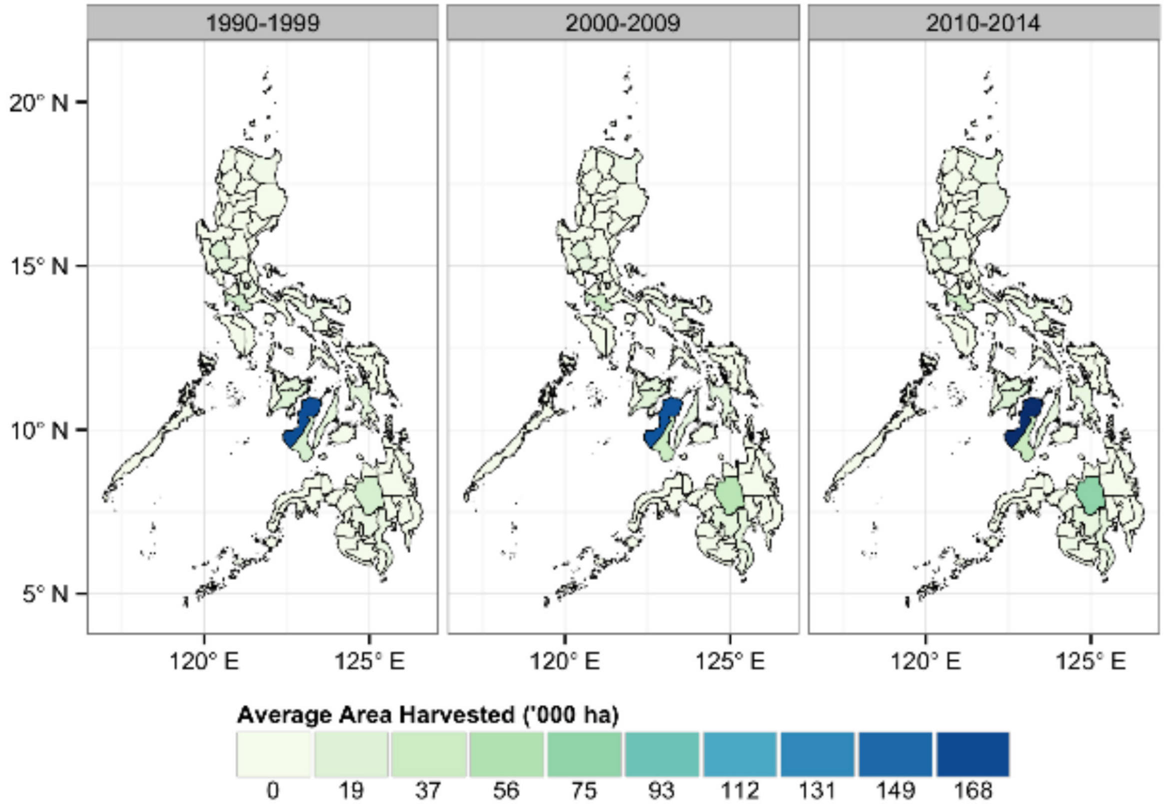
The major sugarcane-growing area in the Philippines is Negros Occidental and the area has increased by 54 percent from 121,249 ha to 186,788 ha in the past 24 years (Figure 10). The areas cultivated with sugarcane in Bukidnon also increased in the past 24 years by 380 percent from 14,990 ha to 72,000 ha, though the total

Table 3: Top ten corn-producing provinces in 2014

Province	Volume (tons)	% Contribution
Isabela	1,175,322	15.18
Bukidnon	805,845	10.41
South Cotabato	500,738	6.47
Maguindanao	464,984	6.00
Cagayan	431,235	5.57
North Cotabato	414,630	5.35
Pangasinan	309,684	4.00
Sultan Kudarat	253,241	3.27
Lanao del Sur	232,513	3.00
Lanao del Norte	220,483	2.85

Source: PSA 2015.

Figure 10: Areas where sugarcane was harvested in the past 24 years



Source: Based on PSA 2015 data.

area cultivated with sugarcane is much less compared with Negros Occidental. In Mindanao, areas harvested for sugarcane have rapidly increased in the recent years.

Negros Occidental has the highest production of sugarcane (Table 4) comprising about 50 percent of the total volume of sugarcane production in the country in 2014. Among the top ten provinces with the largest sugarcane production, Bukidnon ranks second, contributing about 14 percent of the total production in the country.

2.1.13 *Areas Harvested for Coconut in the Past 25 Years*

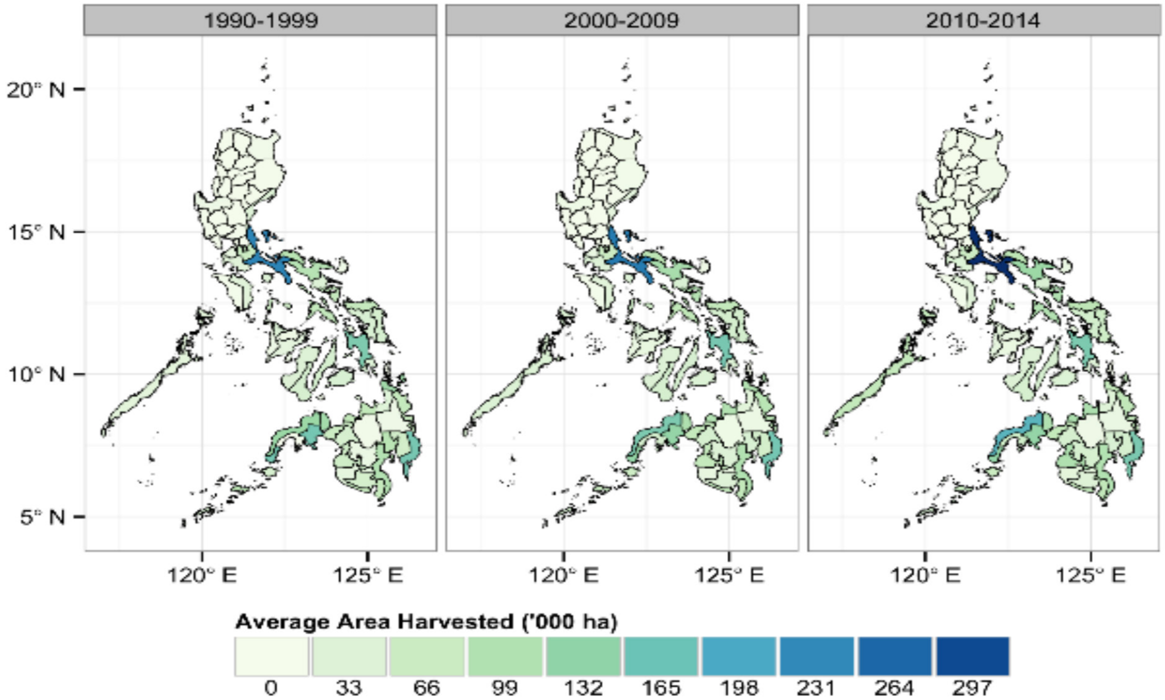
Coconut is widely grown in upland and coastal areas in the southern part of Luzon, Visayas, and Mindanao (Figure 11). The major corn-growing area is the province of Quezon in Region IV with an increase of 43.73 percent from 235,662 ha in 1990 to 338,723 ha in 2014. Another province that has increased areas harvested for coconut is Zamboanga del Norte in Mindanao Island with an increase of 71.65 percent from

Table 4: Top ten sugarcane-producing provinces in 2014

Province	Volume (tons)	% Contribution
Negros Occidental	12,716,403	50.80
Bukidnon	3,440,881	13.75
Negros Oriental	1,875,244	7.49
Batangas	1,512,903	6.04
Iloilo	1,270,718	5.08
Tarlac	725,957	2.90
Capiz	482,210	1.93
Cebu	397,247	1.59
Isabela	392,331	1.57
North Cotabato	389,770	1.56

Source: PSA 2015.

Figure 11: Coconut harvested areas in the Philippines in the past 25 years



Source: Based on PSA 2015 data.

121,683 ha to 208,870 ha in a span of 24 years. Large areas in Davao Oriental and Leyte Island are also planted with coconut.

The province of Quezon had the largest volume of coconut production in 2014 (1,177,893 tons), contributing about 8 percent of the total production in the country (Table 5). Davao del Sur ranks second in coconut production contributing about 6.5 percent of the country's total production. All the other eight provincial top coconut producers in the country are from the island of Mindanao. Together, these nine provinces contribute about 39 percent of the country's total coconut production.

2.1.14 *Harvested Areas for Banana in the Past 24 Years*

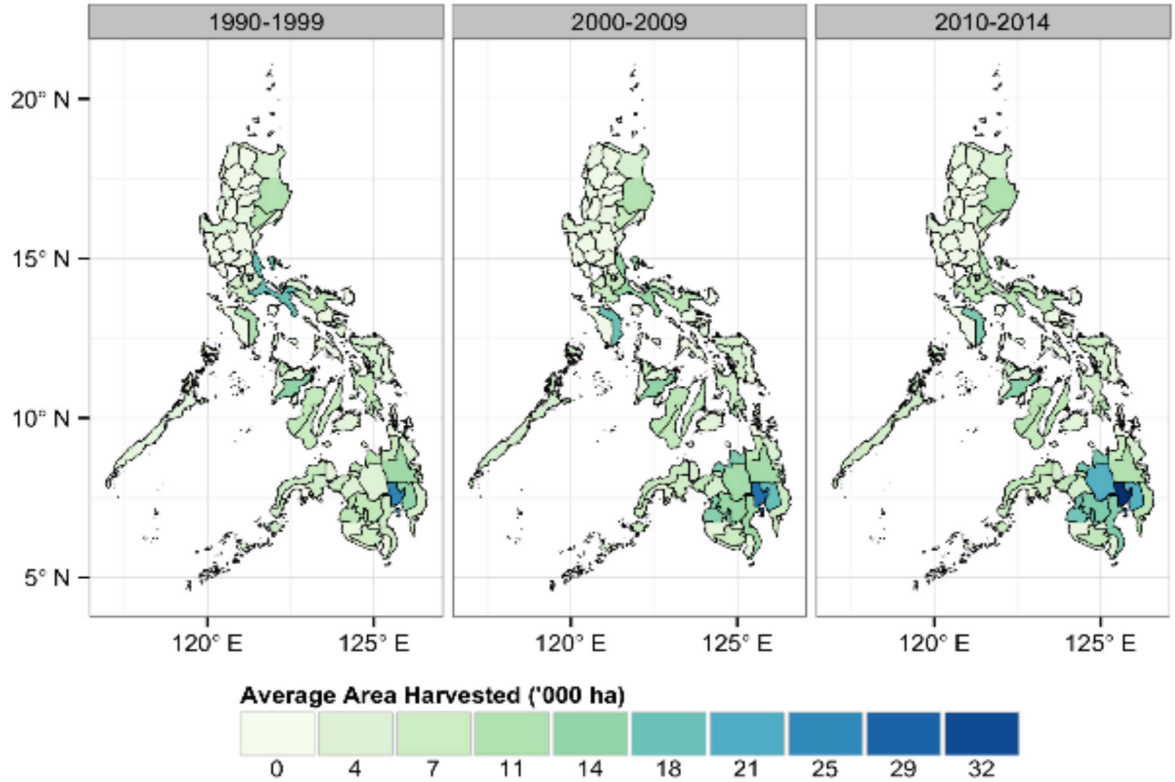
Various varieties of banana are being grown all over the country (Figure 12). There are cooking varieties like saba, and sweet varieties like latundan and lakatan. They maybe small patches of banana farms or planted in backyard. The major growing areas for multinational banana plantations are in Mindanao particularly the provinces of Davao del Norte (36,153 ha), Bukidnon (20,789 ha), Compostela Valley (18,962 ha), Maguindanao (18,077 ha), Misamis Oriental (16,702 ha), North Cotabato (16,663 ha), and Davao del Sur (15,384 ha).

Table 5: Top ten coconut-producing provinces in 2014

Province	Volume (tons)	% Contribution
Quezon	1,177,893	8.16
Davao del Sur	938,557	6.50
Zamboanga del Norte	736,199	5.10
Davao Oriental	724,773	5.02
Maguindanao	621,104	4.30
Lanao del Norte	586,380	4.06
Misamis Occidental	572,602	3.97
Misamis Oriental	520,454	3.61
Zamboanga del Sur	506,452	3.51
Sarangani	452,979	3.14

Source: PSA 2015.

Figure 12: Areas harvested for banana in the past 24 years



Source: Based on PSA 2015 data.

The past two decades have seen the rapid expansion of banana plantations in Davao del Norte with an increase of 74.9 percent from 20,671 ha to 36,153 ha; Compostela Valley with an increase of 33.96 percent from 14,154 ha to 18,962 ha; Bukidnon with an increase of 622 percent from 2,881 ha to 20,789 ha; Maguindanao with an increase of 132 percent from 7,800 ha to 18,077 ha and North Cotabato with an increase of 47.34 percent from 11,309 ha to 16,663 ha. In the province of Quezon, areas harvested for banana declined by 43.70 percent from 18,140 ha to 10,213 ha in the past two decades.

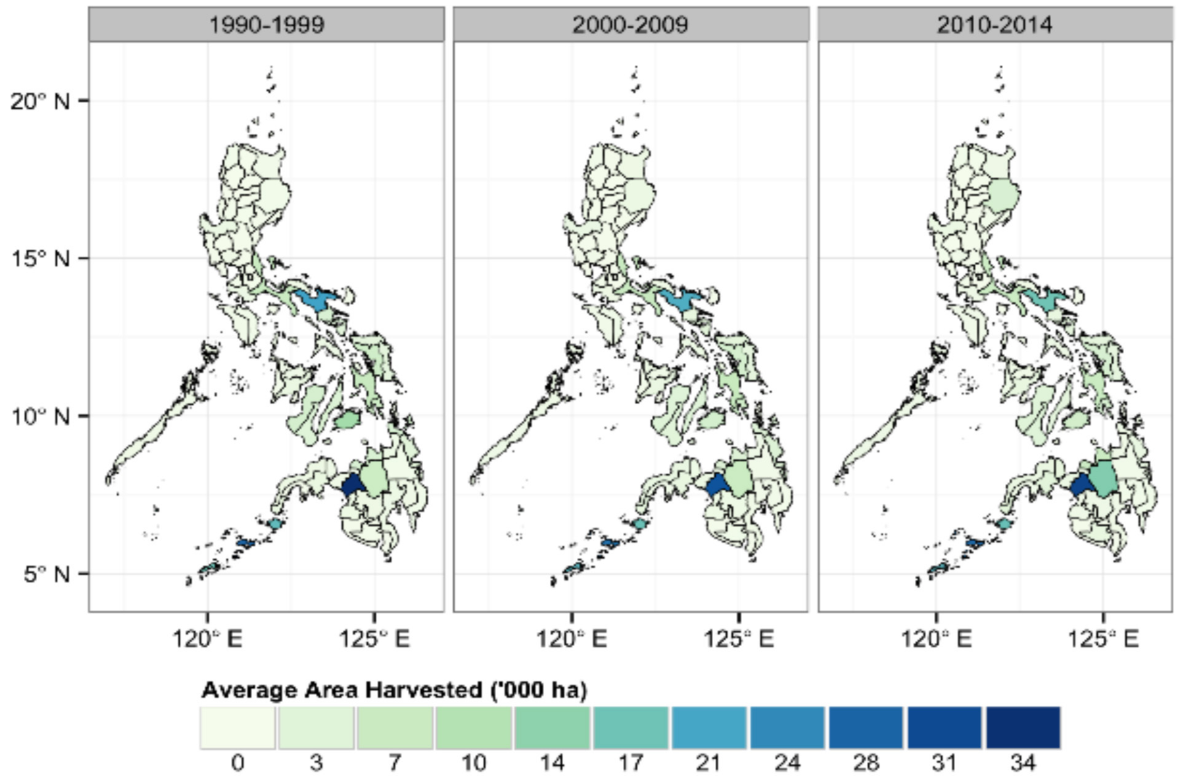
The highest ranking province in banana production is Davao del Norte (1,591,008 tons) making up about 18.4 percent of the country's total banana production (Table 6). Bukidnon ranks second contributing about 14 percent of the total national production. All the top nine banana-producing provinces are located in Mindanao Island, together making up 69 percent of the total national banana production. The other 30 percent is harvested from the rest of the country.

Table 6: Top ten banana-producing provinces in 2014

Province	Volume (tons)	% Contribution
Davao del Norte	1,591,008	18.42
Bukidnon	1,199,550	13.89
Compostela Valley	777,984	9.01
North Cotabato	664,230	7.69
Davao del Sur	593,672	6.87
Maguindanao	336,244	3.89
Lanao del Norte	281,360	3.26
South Cotabato	277,206	3.21
Misamis Oriental	219,968	2.55
Isabela	214,635	2.48

Source: PSA 2015.

Figure 13: Areas cultivated with cassava in the past 24 years



Source: Based on PSA 2015 data.

2.1.15 *Harvested Areas for Cassava in the Past 25 Years*

Cassava is widely grown in Lanao del Sur since the early 1990s (Figure 13). The area cultivated with cassava in this province increased by 3.82 percent from 32,267 ha in 1990 to 33,500 ha in 2014. In the neighboring province of Bukidnon, areas cultivated with cassava increased by 361 percent from 3,589 ha to 16,550 ha in the past 25 years. Another province where cassava is grown in large areas is Camarines Sur in Region V, though the area planted decreased by 20.22 percent from 20,889 ha in 1990 to 16,665 ha in 2014.

Lanao del Sur was the largest producer of cassava in 2014 with 518,095 tons, comprising 20 percent of the national total cassava production. The second largest cassava producer is Bukidnon contributing 17.5 percent of total national production. Cassava is largely produced in the island of Mindanao with seven provinces of the top ten largest producing provinces (Table 7).

2.1.16 *Areas Harvested for Coffee in the Past 25 Years*

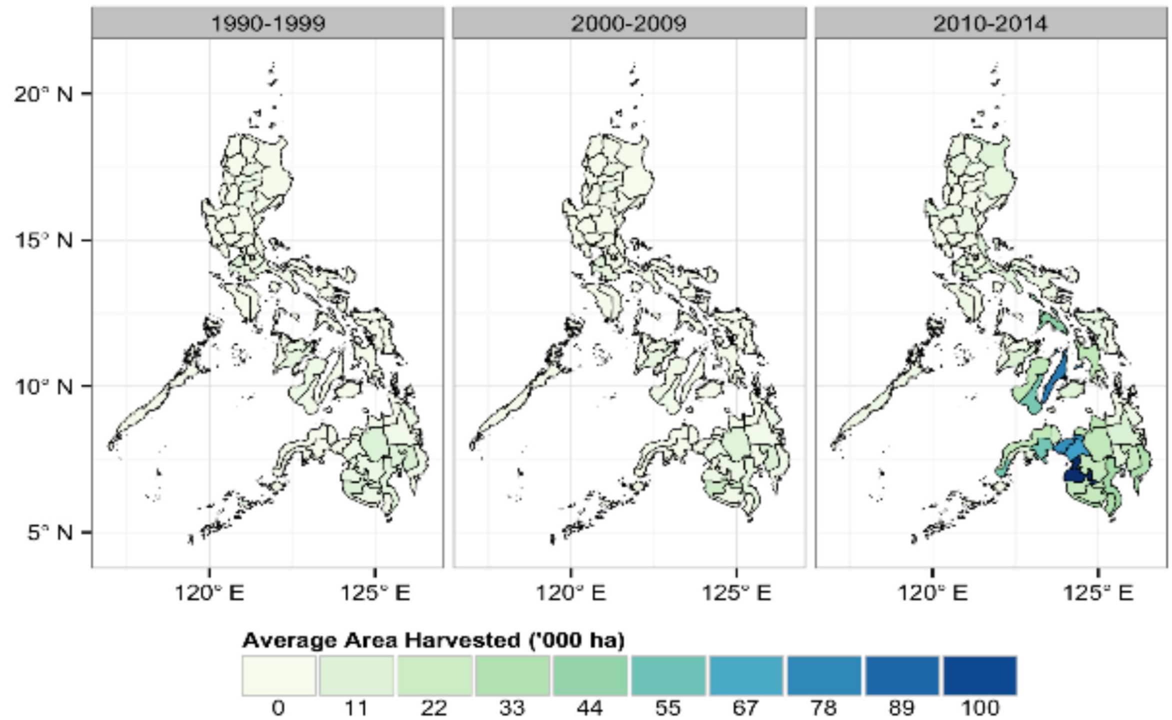
It was only in the recent 5 years that coffee is being widely grown in the Mindanao Island. Maguindanao

Table 7: Top ten cassava-producing provinces in 2014

Province	Volume (tons)	% Contribution
Lanao del Sur	518,096	20.42
Bukidnon	445,000	17.54
Basilan	259,920	10.25
Sulu	168,200	6.63
Misamis Oriental	151,596	5.98
Isabela	121,291	4.78
South Cotabato	106,580	4.20
Tawi-tawi	94,802	3.74
Camarines Sur	76,518	3.02
Bohol	39,716	1.57

Source: PSA 2015.

Figure 14: Areas harvested for coffee in the past 24 years



Source: Based on PSA 2015 data.

province has the largest area planted with coffee (143, 262 ha), followed by Cebu (106, 505 ha), Lanao del Norte (99, 397 ha), Lanao del Sur (85,382 ha), and Cebu (98 ha) (Figure 14). The area harvested for coffee in Sultan Kudarat is 24, 600 ha.

Coffee is mainly grown in the island of Mindanao. Of the top ten coffee-producing provinces in the country, seven provinces are located in Mindanao Island. Together, these seven provinces produce a total of 44,930 tons, comprising about 62 percent of the total coffee production in the country. The province of Sultan Kudarat is the major coffee-growing province in the country, producing about 22,613 tons of coffee in 2014, contributing 31 percent of the total coffee production in the country. Maguindanao produce only 3,348 tons in 2014 despite wide areas planted with coffee. This may be due to the young age of coffee plants in the province. In Luzon Island, the province of Cavite is producing 3,514 tons of coffee, about 4.83 percent and the province of Kalinga producing 3,470 tons (Table 8).

2.1.17 *Areas Harvested for Tobacco in the Past 24 Years*

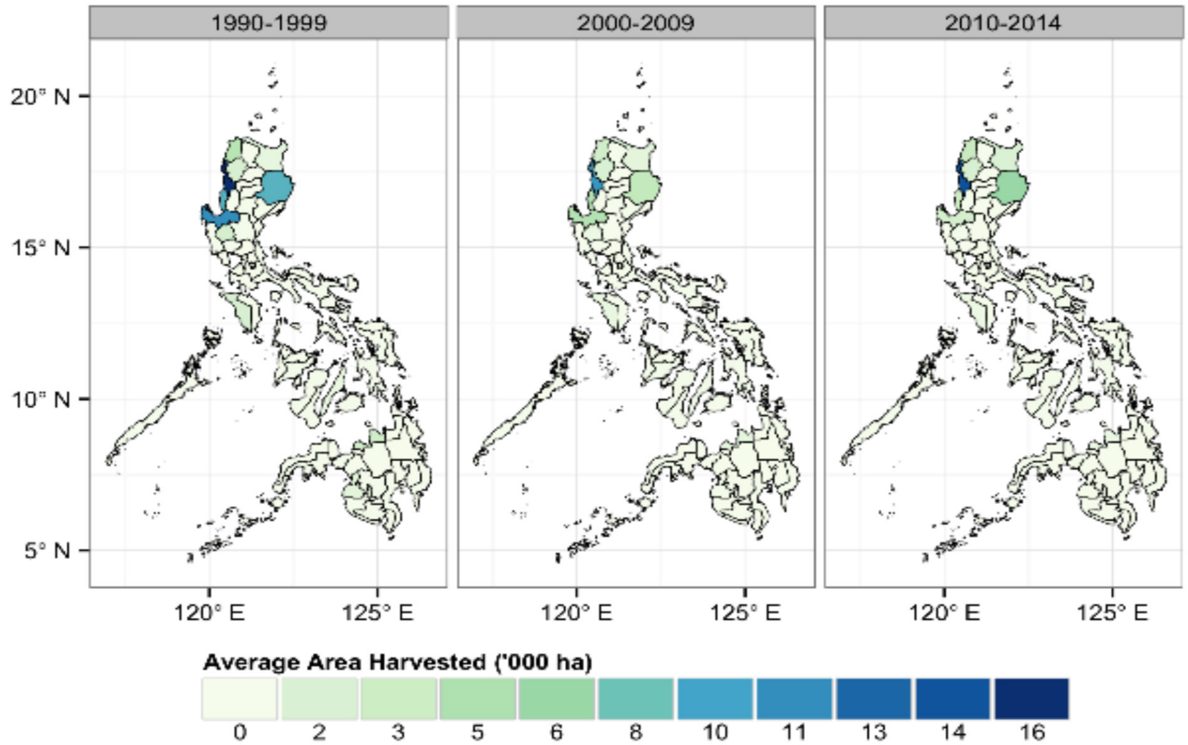
Through the years, tobacco was mainly grown in Northern Luzon. In the 1990s, many areas in Region I (Ilocos Sur, la Union and Pangasinan) and Region

Table 8: Top ten coffee-producing provinces in 2014

Province	Volume (tons)	% Contribution
Sultan Kudarat	22,613	31.06
Davao del Sur	5,083	6.98
Sulu	4,831	6.64
Bukidnon	4,224	5.80
Cavite	3,514	4.83
Kalinga	3,470	4.77
Maguindanao	3,349	4.60
North Cotabato	2,858	3.93
Iloilo	2,723	3.74
South Cotabato	1,973	2.71

Source: PSA 2015.

Figure 15: Areas harvested for tobacco in the past 24 years



Source: Based on PSA 2015 data.

II (Isabela) were cultivated with tobacco (Figure 15). The areas harvested for tobacco in most of these provinces declined through the years. In Ilocos Sur, the planted area decreased by 14 percent from 17,199 ha to 14,751 ha while in La Union the harvested areas decreased by 84.57 percent from 19,976 ha to 3,082 ha and in Pangasinan the harvested area decreased by 84.79 percent from 14,194 to 2,159 ha. The area harvested for tobacco greatly decreased (30.3 percent) in the province of Isabela from 9,282 ha in 1999 to 6,465 ha in 2014.

Ilocos Sur is the top producer of tobacco (23,270 tons) making up about 38 percent of the total national production in 2014 (Table 9). Isabela ranks second with 12,536 tons contributing about 20 percent of total production. The top six tobacco-producing provinces are from Northern Luzon making up about 91 percent of total production. An emerging tobacco-growing area in the recent years is Misamis Oriental in Northern Mindanao.

2.1.18 *Areas Harvested for Pineapple in the Past 24 Years*

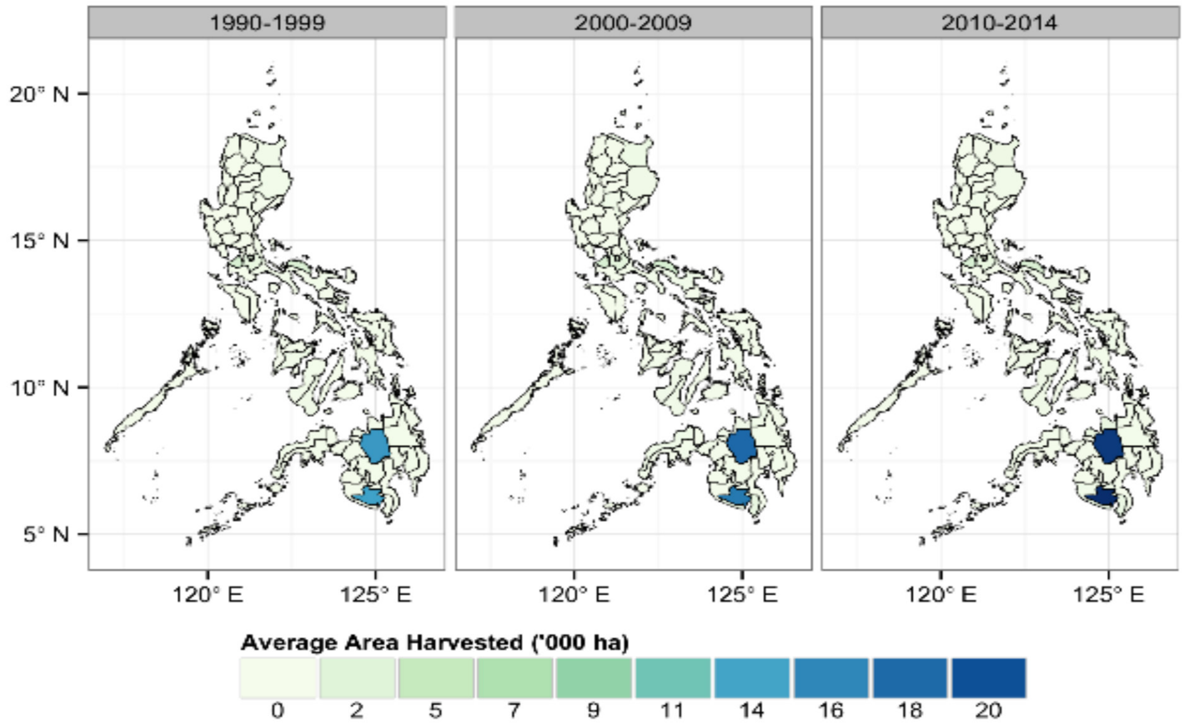
Pineapple is largely grown in the provinces of Bukidnon (23,000 ha) and South Cotabato (23,346 ha) in

Table 9: Top ten tobacco-producing provinces in 2014

Province	Volume (tons)	% Contribution
Ilocos Sur	23,270	37.89
Isabela	12,537	20.41
La Union	5,701	9.28
Ilocos Norte	5,691	9.27
Pangasinan	5,411	8.81
Cagayan	3,401	5.54
Occidental Mindoro	2,700	4.40
Abra	1,250	2.04
Misamis Oriental	1,005	1.64
Iloilo	250	0.41

Source: PSA 2015.

Figure 16: Areas harvested for pineapple, 1990–2014



Source: Based on PSA 2015 data.

Mindanao Island (Figure 16). Large pineapple plantations of Del Monte and Dole companies are located in these provinces. The areas harvested for pineapple increased in both provinces (66 percent in Bukidnon and 61 percent in South Cotabato) in the past 24 years.

Table 10: Top ten provinces with the largest production of pineapple (2014)

Province	Volume (tons)	% Contribution
Bukidnon	1,355,200	54.66
South Cotabato	769,286	31.03
Camarines Norte	118,492	4.78
Cavite	71,601	2.89
Misamis Oriental	36,475	1.47
Sarangani	28,794	1.16
Cagayan	15,816	0.64
Laguna	12,669	0.51
Iloilo	12,161	0.49
Isabela	9,371	0.38

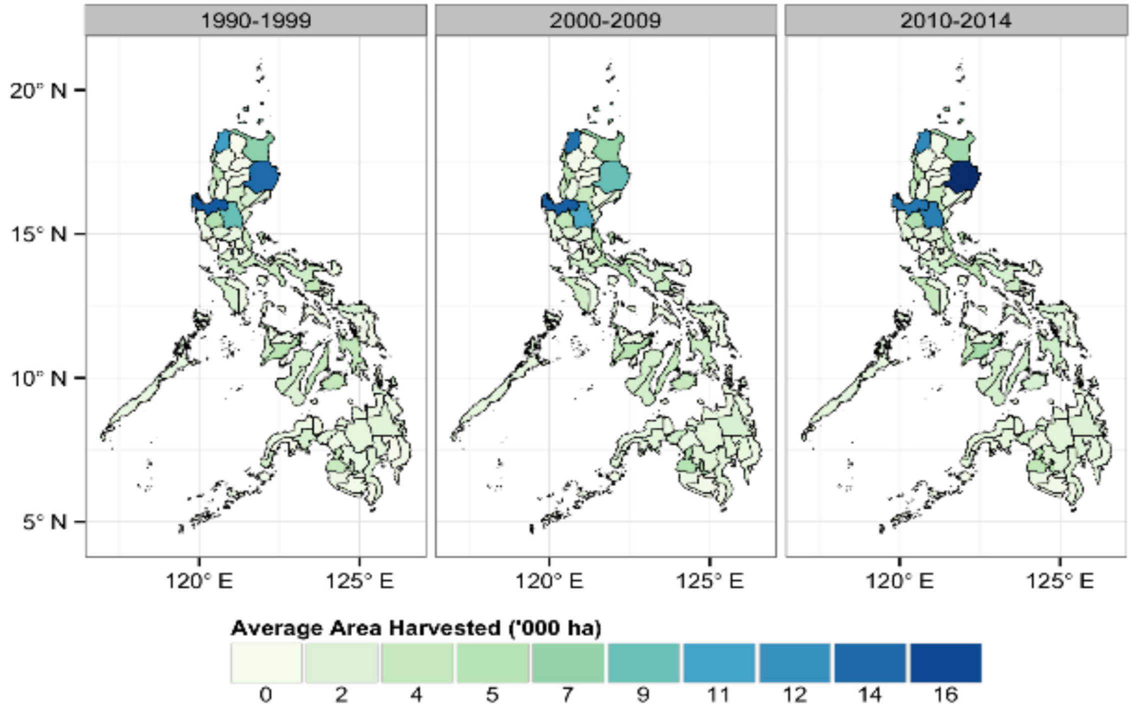
Source: PSA 2015.

2.1.19 *Areas Harvested for Tropical Vegetables in the Past 24 Years*

The various tropical vegetables grown in the Philippines include mungbean, yardlong bean, cowpea, tomatoes, eggplant, squash, garlic, and onion. They are planted all over the country with the largest harvested areas located in Regions I, II, and III in Northern and Central Luzon (Figure 17). Isabela has the largest harvested area (16,730 ha) and highest rate of increase in the past 24 years (9 percent).

Nueva Ecija is the top producer of tropical vegetables in the country, producing 207,608 tons in 2014, contributing about 19.6 percent of the total national tropical vegetable production (Table 11). Pangasinan ranks second contributing about 9.3 percent of total

Figure 17: Areas harvested for tropical vegetables in the Philippines in the past 24 years



Source: Based on PSA 2015 data.

national tropical vegetable production. All the top ten tropical-vegetable-producing provinces are located in the Luzon Island (Table 11).

2.1.20 *Areas Harvested for Temperate Vegetables in the Past 24 Years*

Temperate vegetables grow well in high elevation areas where the temperature is relatively cooler than the low elevation areas in the country. Vast areas of mountainous terrain (13,646 ha) in the province of Benguet in the Cordilleras Mountain range are being cultivated with temperate vegetables including carrot, potato, cabbage, Chinese cabbage, broccoli, lettuce, beans, and cauliflower (Figure 18). The area harvested for temperate vegetables in Benguet increased by 8.71 percent from 12,458 ha in 1990 to 13,646 ha in 2014.

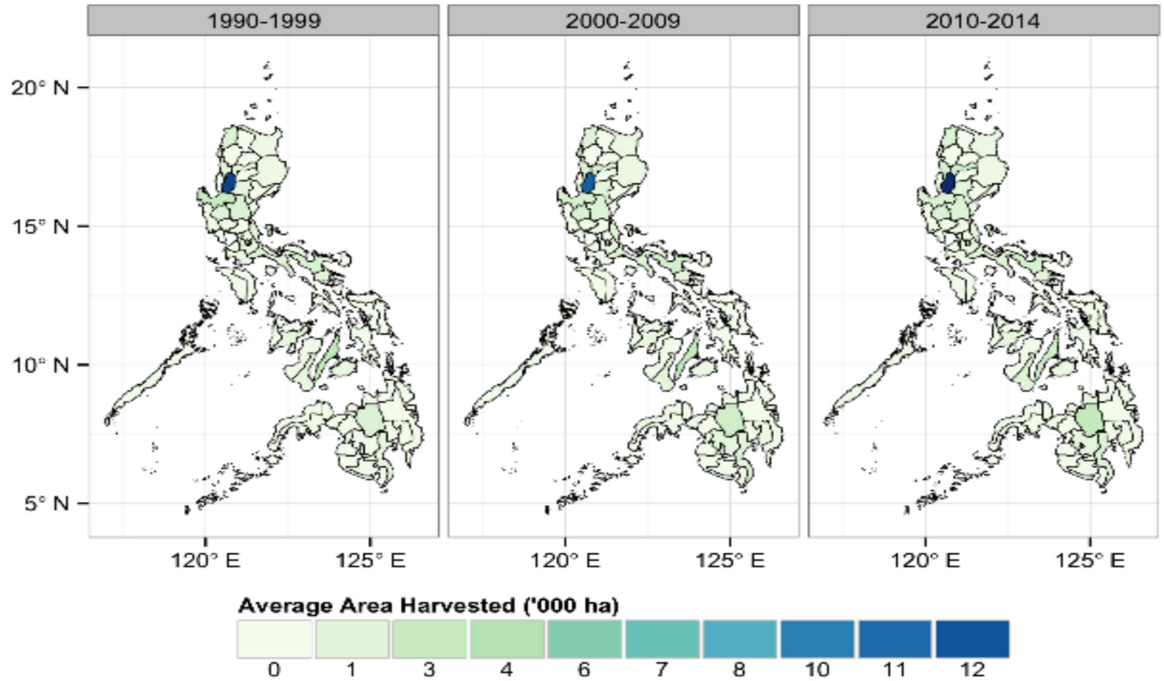
Benguet Province is the number one producer of temperate vegetables, with 197,845 tons of vegetable produced in 2014 that contribute 37 percent of total national production (Table 12). The highlands of Bukidnon have cool temperature favorable for temperate vegetable production. It produced 51,345 tons of vegetables comprising about 10 percent of national

Table 11: Top ten tropical-vegetable-producing provinces in 2014

Province	Volume (tons)	% Contribution
Nueva Ecija	207,608	19.61
Pangasinan	98,605	9.31
Quezon	71,980	6.80
Ilocos Norte	53,328	5.04
Isabela	45,242	4.27
Albay	40,656	3.84
Nueva Vizcaya	34,620	3.27
Cagayan	32,742	3.09
Ilocos Sur	29,425	2.78
Bulacan	27,964	2.64

Source: PSA 2015.

Figure 18: Areas harvested for temperate vegetables in the past 24 years



Source: Based on PSA 2015 data.

temperate vegetable production. Eight of the ten top provinces producing temperate vegetables are in Northern Luzon: Ilocos Norte, Ilocos Sur and Pangasinan from Region I; Nueva Vizcaya from Region II; Benguet and Mountain Province from Cordillera Administrative Region (CAR) and Nueva Ecija from Region III (Table 12).

Table 12: Top ten temperate-vegetable-producing provinces in 2014

Province	Volume (tons)	% Contribution
Benguet	197,845	37.66
Bukidnon	51,345	9.77
Ilocos Norte	31,143	5.93
Ilocos Sur	31,124	5.92
Mountain Province	21,831	4.16
Pangasinan	18,626	3.55
Quezon	14,826	2.82
Cebu	14,693	2.80
Nueva Ecija	13,079	2.49
Nueva Vizcaya	9,902	1.88

Source: PSA 2015

FARMING PRACTICES AND SOURCES OF POLLUTION

3

3.1 Fertilizer Use

3.1.1 *Trends in Fertilizer Consumption*

The implementation of the Green Revolution starting from 1960 marked the beginning of the application of inorganic fertilizers in farming systems in the Philippines. From 1961 to 2004, the amount of fertilizer applied in the Philippines increased by 1000 percent (Figure 19).

The national consumption of nitrogenous fertilizers increased continuously from 35,815 tons in 1961 to 629,808 tons in 2004 with an annual average increase of 10,406 tons/year. However, from 2004 to 2013, there was a general decrease in nitrogenous fertilizer consumption by 54 percent from 629,000 tons to 287,000 tons.

Nitrogen is taken up from the soil solution by plant roots in ammonium (NH_4^+) and nitrate (NO_3^-) forms. In the plant, ammonium and nitrate form part of amino acids making up proteins and chlorophyll molecules. Nitrogen constitutes 1–4 percent of plant dry matter. It is involved in all major metabolic processes of plant growth, development, and vegetative production (IFA 2000).

The most common forms of inorganic nitrogen fertilizers applied are urea, ammonium sulfate, and complete fertilizer. Urea fertilizer is the world's major source of nitrogen due to its high concentration (46 percent nitrogen) and reasonable price per unit of nitrogent (IFA 2000). Ammonium sulfate contains 21 percent nitrogen (in the form of ammonia) and 23 percent sulphur, another essential nutrient required by plants. On the other hand, ammonium sulfate nitrate contains

26 percent nitrogen (about two-thirds in the form of ammonia and one-third in the form of nitrate) and 13 to 15 percent sulphur (IFA 2000).

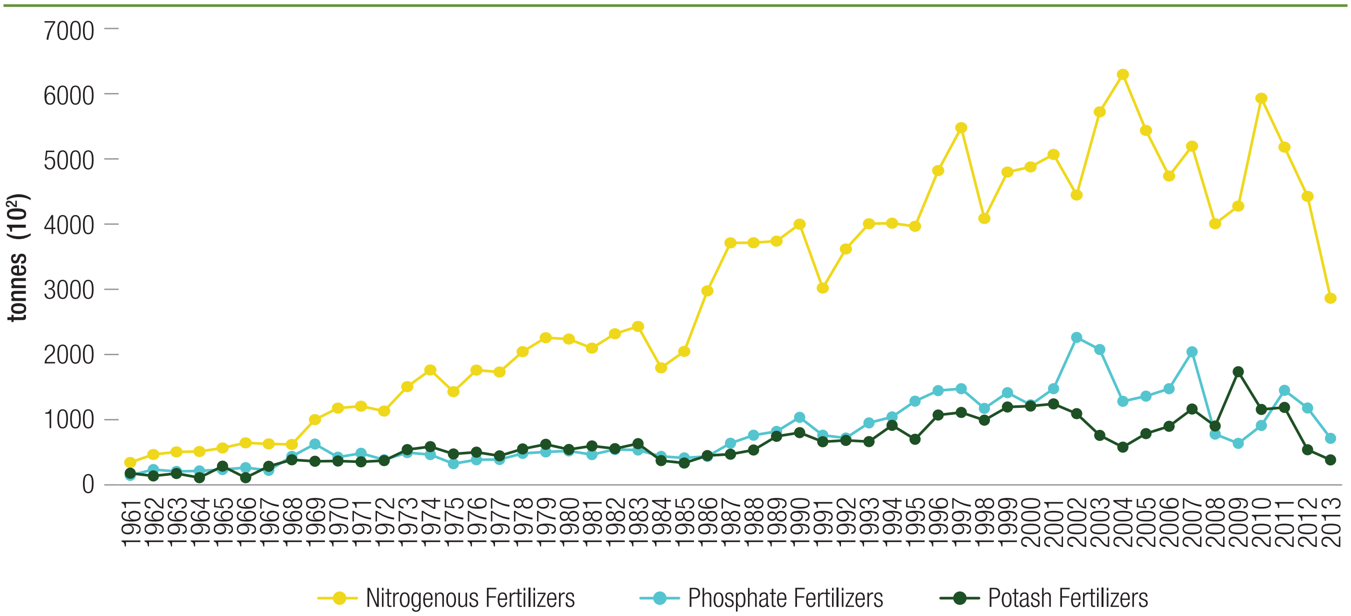
Phosphorus is another macronutrient required by plants in large quantities and it makes up about 0.1 to 0.4 percent of the plant dry matter. Phosphorus is a major component of adenosine triphosphate (ATP), the energy currency of the cell, thus it is very important in all metabolic processes in the plant like photosynthesis and respiration. Phosphorus is deficient in most agricultural soils (IFA 2000).

The national consumption of phosphate fertilizer in 1961 was 16,006 tons and this consumption increased until 2002 with an annual average increase of 2,482 tons/year. From 1970 to 1985, the national phosphate fertilizer consumption was stable at around 50,000 tons/year (Figure 19). From 1985 to 2001, there was a large increase in phosphorus fertilizer application from 50,000 tons/year to 148,000 tons/year translating to about an average increase of 6,000 tons/year during this period. In 2002, the national phosphate fertilizer consumption was 227,000 tons, the highest consumption from 1960 until the present time. From 2007, there was in general, a decline in phosphate fertilizer consumption. Phosphate fertilizers commonly applied are mixed fertilizers including ammonium phosphate, di-ammonium phosphate, and complete fertilizer.

Potassium is a macronutrient required by plants in large quantities and it makes up between 1 and 4 percent of the plant dry matter. Pottasium is essential in carbohydrate and protein metabolism, and water regime of plants. Pottasium increases the plants' tolerance to diseases, drought, frost, and salinity (IFA 2000).

The national consumption of potash fertilizer in 1961 was 12,500 tons and this consumption increased up to 174,660 tons in 2009 (Figure 20). The average increase of potash application was 1,753 tons/year. From 2001 to 2004, there was a decline in national potash consumption from 125,000 tons to 59,000 tons. The highest potash fertilizer consumption was in 2009, about 174,000 tons. From 2009, national potash consumption continually declined until 2013 when the national consumption was only 39,700 tons. Muriate of potash is the most commonly applied potassium fertilizer.

Figure 19: National consumption of NPK fertilizers in the Philippines from 1961 to 2013



Source: FAO 2014.

Table 13: Extent and rate of fertilizer application in the Philippines, by type of nutrient, 2001

Application, extent of area harvested (% total)		Fertilization rate (kg/ha)		
		Nitrogen	Phosphorus	Potassium
Rice	85	51	15	11
Sugarcane	80	85	55	30
Maize	80	58	16	10
Palm oil	80	75	25	70
Potato	80	85	55	45
Tobacco	80	75	20	55
Cocoa	50	85	45	45
Fruits	50	75	35	40
Vegetables	50	0.1	0	0
Coffee	40	0	0	0
Rubber	40	25	15	80
Coconut	30	20	15	10
Other crops	30	25	15	10
Groundnut	20	40	30	20
Soya	20	20	30	10

Source: FAO FertiStat 2001.

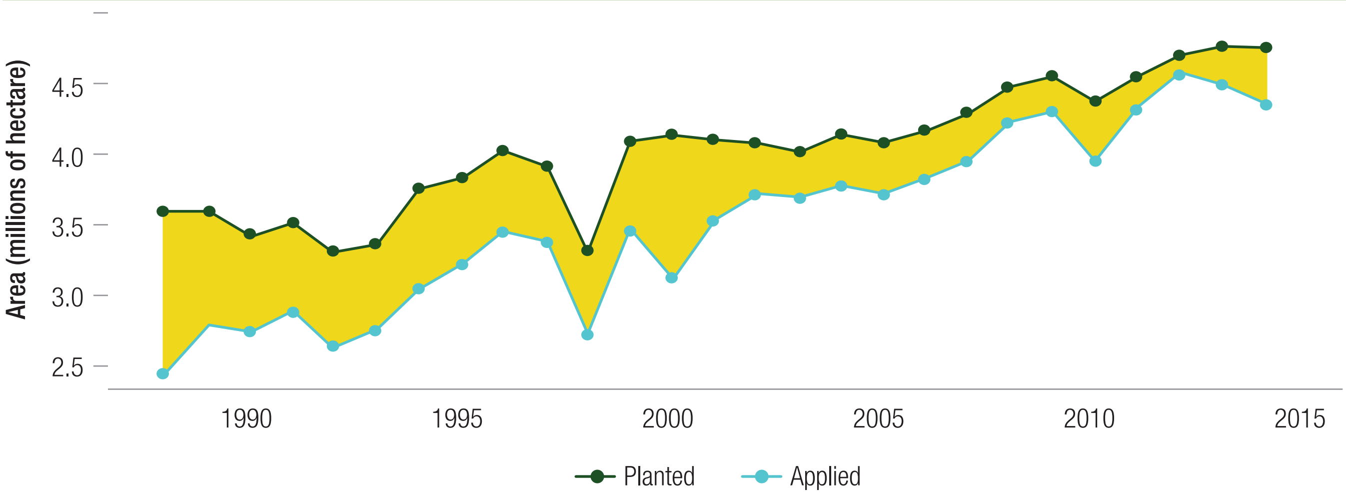
Generally, there has been a continual decline in the national consumption of NPK fertilizers in the past decade. This may be attributed to the rising fertilizer costs and massive campaign by the DA for organic farming.

Disaggregated into crop fertilizer consumption, the national data on the amount of fertilizer applied and rate of fertilizer application is available for rice and corn only. Such data for other crops grown in the country are lacking. The only data available on the extent and rate of fertilizer application for various crops in the Philippines is an outdated one that was published by FAO in 2001 (Table 13). Clearly, there is a need for the national government to monitor and synthesize the fertilizer consumption and rate of fertilizer application in the other crops grown in various provinces and islands of the country to help identify potential hotspots for excessive fertilizer application that can cause pollution of the land, water, and air resources in these cropping areas.

3.1.2 *Area Planted with Rice and Applied with Fertilizer*

From 1988 to 2014, the total area planted with rice in the Philippines increased from 3,570,790 ha to 4,909,686 ha (Figure 20). The area applied with fertilizer also increased from 2,422,160 ha in 1988 to 4,572,108 ha in 2012. Further, the proportion of area fertilized increased from 67.8 percent of area planted in 1988 to 96.4 percent in 2012. In the last couple of

Figure 20: Area cultivated with rice and area applied with fertilizers in the Philippines



Source: PSA 2015.

years, there was a decline in the proportion of planted area that has been fertilized. In 2014, only 88.6 percent of the planted area was applied with fertilizer.

3.1.3 *Evolution of Soil and Nutrient Management in Rice in the Philippines*

The traditional farming practice for lowland rice is to grow them in heavy clay soils that drain easily while upland rice is grown in loamy soils. These soils must not necessarily contain high levels of nitrogen as high nitrogen levels promote more of vegetative growth than reproductive growth thus the rice plants have high biomass (rice straw) but little grain yield. Tall varieties grown in soils with high levels of nitrogen were susceptible to lodging when exposed to strong winds particularly during the rainy season (Camus 1921).

Since the early years of the 1900s, the plains of Central Luzon (Region III) were the best rice-producing areas in the country, with the province of Nueva Ecija as the number one rice-producing province (Bautista and Javier 2005). Rice was planted only once a year to allow for the soil to regain its natural fertility level during the fallow period. During these early years, the nutrient consumption of a hectare of rice was estimated at 13 kg nitrogen, 19 kg phosphorus, and 57 kg potassium (Kelly and Thompson 1910). The country's total rice production in 1910 was 43.6 million kg.

Several researches were conducted to study the effect of organic and inorganic fertilizers on rice growth. As early as 1912, Villegas found out that adding sodium nitrate to cogon and bamboo soil extracts enhanced rice growth. In 1916, Balangue reported that adding lime in old soils, and various combinations of organic and inorganic fertilizers such as horse manure, horse manure + ashes, and 100 kg double superphosphate can increase rice growth. In 1918, Goco found out that various combinations of organic and inorganic fertilizers including ammonium sulfate-potassium chloride-double superphosphate or horse manure + ash + double superphosphate can promote rice growth at later stages of development. In 1920, Trelease and Pulino reported increments in rice yield after addition of inorganic fertilizers specifically, 9.6 times increase after addition of ammonium sulfate, 6.5 times increase after addition of ammonium nitrate, 3 times increase with calcium nitrate, and 3.2 times increase with sodium nitrate. In 1926, Vibar found out that a natural mixture of KCl, MgCl, and NaCl (KainitTM) was more damaging when applied singly or in combination with other fertilizers to rice crop (Bautista and Javier 2005).

Rice straw biomass is a rich source of carbon and nitrogen, thus when it is added in paddy soils, microbial population increases immobilizing nitrates in the microbial biomass and releasing organic acids during the rice straw decomposition process (Fairhurst et al. 2007; Muray 1921; Villegas-Pangga, Blair, and Lefroy 2000; Walksman 1924). This phenomenon causes temporary 'loss' of nitrogen that otherwise should have been available for rice plants. Thus, it was observed that addition of rice straw and rice straw ash caused damages to rice seedlings (Bautista and Javier 2005). This maybe one of the reasons why farmers preferred to burn the rice straw and apply the ash to paddy fields.

Rice straw management (application on the soil surface or incorporation into the soil) affected differently the abundance of aquatic and soil fauna groups (Schmidt et al. 2015). Incorporation of straw in the paddy soil resulted in increased abundance of nematodes while scattering of rice straw on the soil surface favored aquatic invertebrates including small plant-, detritus- and bacterial-feeding or omnivorous invertebrates (Cladocera or larvae of Culicidae and Brachycera) and their predators (Naucoridae, Anisoptera larvae, and so on) (Schmidt et al. 2015). Rice straw on the paddy soil surface attracts small aquatic invertebrates as it provides energy source and shelter from predators (Moore et al. 2004). These invertebrates promote decomposition of rice straw thereby contributing to soil fertility. Increased aquatic invertebrates in turn attract predatory insects (Hagen et al. 2012).

The price of palay shot up in the 1930s and it motivated farmers to increase their rice production. Many of them opted to apply inorganic fertilizers to boost the rice yield. In 1933, the commonly used inorganic fertilizers were ammonium sulfate, HozTM(1A-6–2), CoronaTM (10–6-2), Corona ArrozTM (9–9-4), NitrophoskaTM (15–15–18), ammonium phosphate (20–20–0), or the Nin-Plus-UltraTM (17–20–0) (Calma, Galvez and Velasco 1952). Other fertilizers that are still being used today since the 1930s are Superphosphate (0–18–0) or SolophosTM and sulfate of potash (0–0-50) which was later improved (0–0-60) (Muriate of PotashTM) .

Calma et al. (1952) published that from 1933 to 1941 several fertilizer rates and types were tried and they improved the rice yield of two rice varieties (Elon-elon and Ramil) by 91 percent to as high as 100 cavans/ha. This increased rice yield stimulated farmers to apply inorganic and organic fertilizers including guano, copra cake, dried lye or algae, compost + nitrogen (Aquino and Subido 1952 as cited in Bautista and Javier 2005).

In the 1950s, new rice varieties were introduced with higher yields if fertilized with inorganic fertilizers (28.3 cavans/ha) compared with the yield of 25.1 cavans/ha from unfertilized fields (Galang 1952). With this development, application of inorganic fertilizers became a common practice in the 1950s.

3.1.4 *The Green Revolution (1965–1990)*

The Asian Green Revolution spanned 2.5 decades from 1965 to 1990. The main objective of the Green Revolution was to increase food production to meet the demand of the increasing population. A component of the Green Revolution was soil and nutrient management package, the Philippine Masagana 99. Incorporating the research findings of the IRRI that basal application of fertilizer during the last harrowing and puddling prior to transplanting is more efficient than broadcasting fertilizer, the Masagana 99 technology package on fertilizer management included the following: see table 14.

3.1.5 *Water Management During the Green Revolution*

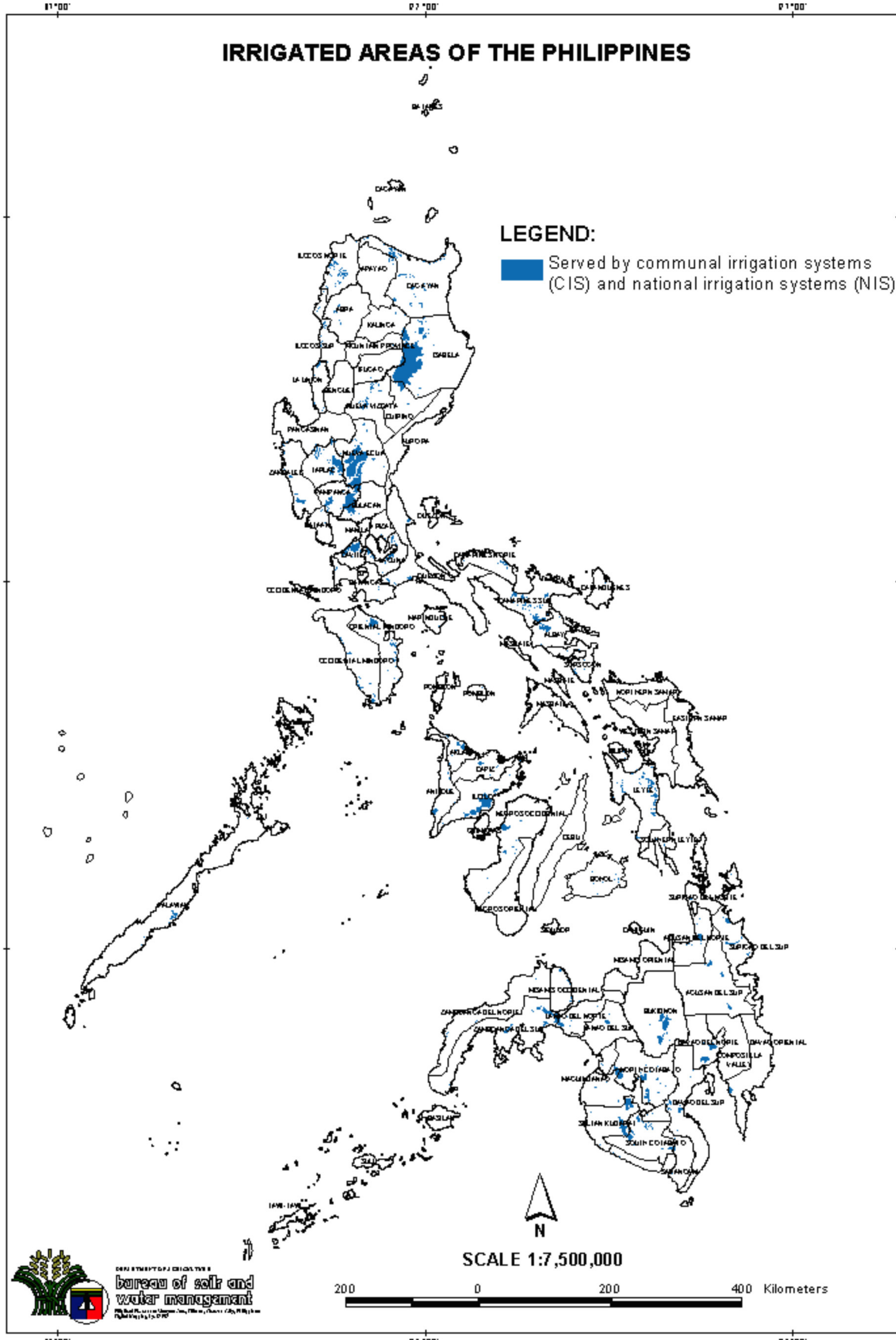
Water management is another important component for the success of the Green Revolution. Irrigation infrastructure developments include the construction of the Pantabangan Dam or Angat Irrigation Project in the late 1960s, the rehabilitation of old irrigation canals, and the establishment of the National Irrigation Administration-Upper Pampanga River Integrated Irrigation System in the late 1970s (Figure 21). Continuous availability of water throughout the year together with the introduction of non-photoperiod sensitive HYVs enabled farmers to plant two crops of rice within a year in Central Luzon. The combined impact of the 40 percent increase in irrigated area, increased use of fertilizer, and improved cultivation practices resulted in increased rice yields during this period (Mears et al. 1974).

Table 14: The Masagana 99 packaged technology on fertilizer rate and management

Dry season	Wet season
4 bags 14–14–14 2 bags urea 10–15 kg $ZnSO_4$ (73–28–28 kg NPK/ha)	4 bags 14–14–14 1 bag urea 10–15 kg $ZnSO_4$ (51–28–28 kg NPK/ha)
3 bags 16–20–0 1 bag 21–0-0 2 bags urea 1 bag 0–0-60 10–15 kg $ZnSO_4$ (80–30–30 kg NPK/ha)	3 bags 16–20–0 3 bags 21–0-0 1 bag urea 1 bag 0–0-60 10–15 kg $ZnSO_4$ (57–30–30 kg NPK/ha)
1.5 bags 18–46–0 2 bags 21–0-0 2 bags urea 1 bag 0–0-60 10–15 kg $ZnSO_4$ (80–35–30 kg NPK/ha)	1.5 bags 18–46–0 2 bags 21–0-0 1 bags urea 1 bag 0–0-60 10–15 kg $ZnSO_4$ (57–35–30 kg NPK/ha)

Source: Bautista and Javier 2005.
Note:
a. Application method: Two-thirds nitrogen and all phosphorus and pottasium were incorporated during the final harrowing.
b. One-third nitrogen 5–7 days before panicle initiation.
c. Apply $ZnSO_4$ into the soil, in the seedbed or in the paddy field, foliar spray or dipping seedlings in ZnO.
d. In the upland, no fertilizer application was done. It is suggested that 90 kg N/ha can be applied at 10, 35, and at 65 days after seeding.
e. Organic fertilizer is also recommended.

Figure 21: Map of irrigated areas in the Philippines



Source: BSWM 1994.

3.1.6 *Modern Soil and Nutrient Management (1990 to Present)*

Intensive rice monoculture, that is, planting two to three crops of rice within a year, was practiced when irrigation facilities were developed and continuous supply of water was made available to the farms. The downside of intensive cultivation is the rapid depletion of the soil fertility level and degradation of the paddy resource base. Rice yields declined in the 1980s despite the introduction of HYVs and increased fertilizer application rates (IRRI 1998). This posed new research challenges to the IRRI and PhilRice to increase nutrient use efficiency. They found out that improving the supply of nitrogen with plant demand through dynamic adjustment of nitrogen fertilizer rates and timing of split application may partially improve rice productivity. Application of more balanced NPK nutrition with higher potassium application was also tested.

To increase nutrient use efficiency, several monitoring and diagnostic tools were developed and tested including leaf color chart (LCC), Minus One Element Technique (MOET) and site-specific nutrient management (SSNM). In 2003, IRRI standardized the LCC that can be used to determine when the plant requires nitrogen supplement by monitoring and comparing the shade of green color of the leaf with the colors in the chart. The LCC-based fertilizer application (timing of fertilizer application is based on the color of the leaf) is proven to attain higher yield at a lower fertilizer rate (Moya et al. 2015). Data from farmers' fields showed that a given target yield can be attained with a significantly lower fertilizer rate (Sebastian, Alviola, and Franciso 2000).

In the same year, PhilRice tested the MOET kit which is composed of seven sachets that contain formulation of essential nutrients minus one element. The kit is set up 45 days before transplanting where rice plants were grown in seven different formulations and the rice plants were observed for the development of nutrient deficiency symptoms to identify the missing element in the paddy soil. The SSNM technique was developed by IRRI in partnership with several rice research institutions in Asia in the mid-1990s. SSNM considers the heterogeneity of the paddy field and it is used to determine the amount of NPK that needs to be applied in specific locations in the paddy field.

3.1.7 *Trends of NPK Fertilizer Application and Rice Yields*

With the Green Revolution from the mid 1960s to late 1980s, yield of rice increased primarily due to introduction of HYVs coupled with commercial fertilizer application, irrigation, and pesticide application.

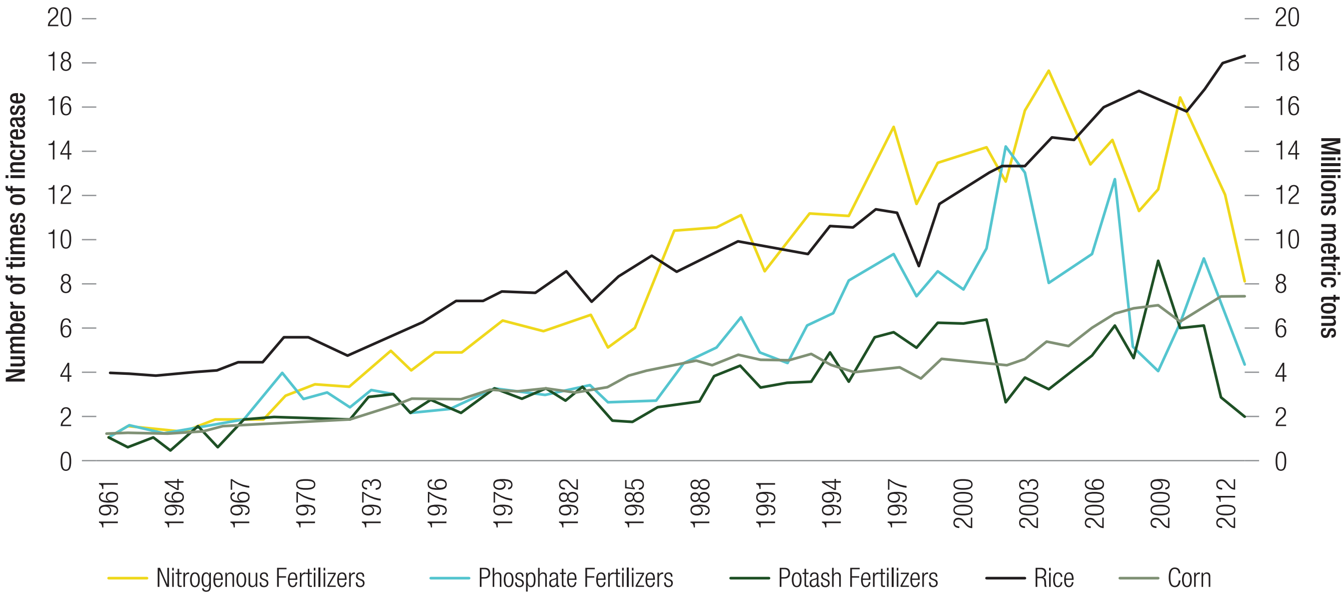
The national consumption of NPK fertilizer increased from 1961 to 2004 (Figure 22). This was also accompanied by an increasing trend in national rice production from 3.91 million tons in 1961 to 18.44 tons in 2013. The amount of nitrogenous fertilizers consumed increased by 1,658 percent from 35,815 tons in 1961 to 629,808 tons in 2004. Likewise, phosphorus fertilizer consumption increased by 708 percent from 16,006 tons in 1961 to 129,401 tons in 2004. During this period, rice productivity increased by 270 percent.

3.1.8 *Trends of Fertilizer Application by Type in Various Rice-Growing Provinces from 1990 to 2014*

Since the 1990s, urea is the most widely applied nitrogenous fertilizer in rice fields in Northern and Central Luzon and in Davao Oriental (Figure 23). The amount of urea fertilizer applied increased in the past 2.5 decades in these areas, particularly in Apayao (from 117 kg/ha in 1990 to 167 kg/ha in 2014) and Ilocos Norte (from 110 kg/ha in 1990 to 209 kg/ha in 2014) in Region I; Isabela (from 133 kg/ha in 1990 to 144 kg/ha in 2014) and Cagayan (from 77 kg/ha in 1990 to 84 kg/ha in 2014) in Region II; and Davao Oriental (from 135 kg/ha in 1990 to 159 kg/ha in 2013) in Region XI.

Complete fertilizer (14–14–14) is the second most applied fertilizer in rice-growing areas in the country. It is a source of nitrogen, phosphorus, and potassium. During the decade of 1990–1999, the provinces

Figure 22: Trends in NPK fertilizer consumption and crop production from 1960 to 2014



Source: Based on PSA 2015.
Note: The fertilizer levels are read on the y-axis to the left, and rice and corn levels are read on the y-axis to the right.

of Nueva Ecija (113 kg/ha) and Zambales (148 kg/ha) (Region III) and Ilocos Norte (110 kg/ha) (Region I) applied high quantities of complete fertilizer (Figure 24). In the succeeding period (2000–2014), the amount of complete fertilizer applied continually increased in these provinces with applications amounting to 149 kg/ha in Nueva Ecija, 142 kg/ha in Zambales, 147 and kg/ha in Ilocos Norte. Other provinces in Regions I, II, and III in Northern Luzon also had increasing trends in complete fertilizer application. Likewise, the provinces of Palawan (111 kg/ha), Bohol (172 kg/ha), and Davao Oriental (155 kg/ha) had increased amounts of complete fertilizer applied in the recent years.

Other sources of nitrogen are ammonium phosphate and ammonium sulfate fertilizers. Both fertilizer types are widely applied in most rice-growing areas all over the country, though at a much lower rate, an average value of 27 kg/ha for ammonium phosphate and 22 kg/ha for ammonium sulfate from 1990 to 2014 (Figure 23). Since 2000, there was an increase in the amount of ammonium sulfate fertilizer applied in the provinces of Bukidnon (from 39 kg/ha in 1990 to 81 kg/ha in 2014), La Union (from 35 kg/ha in 1990 to 116 kg/ha in 2014), and Misamis Occidental (from 43 kg/ha in 1990 to 86 kg/ha in 2014).

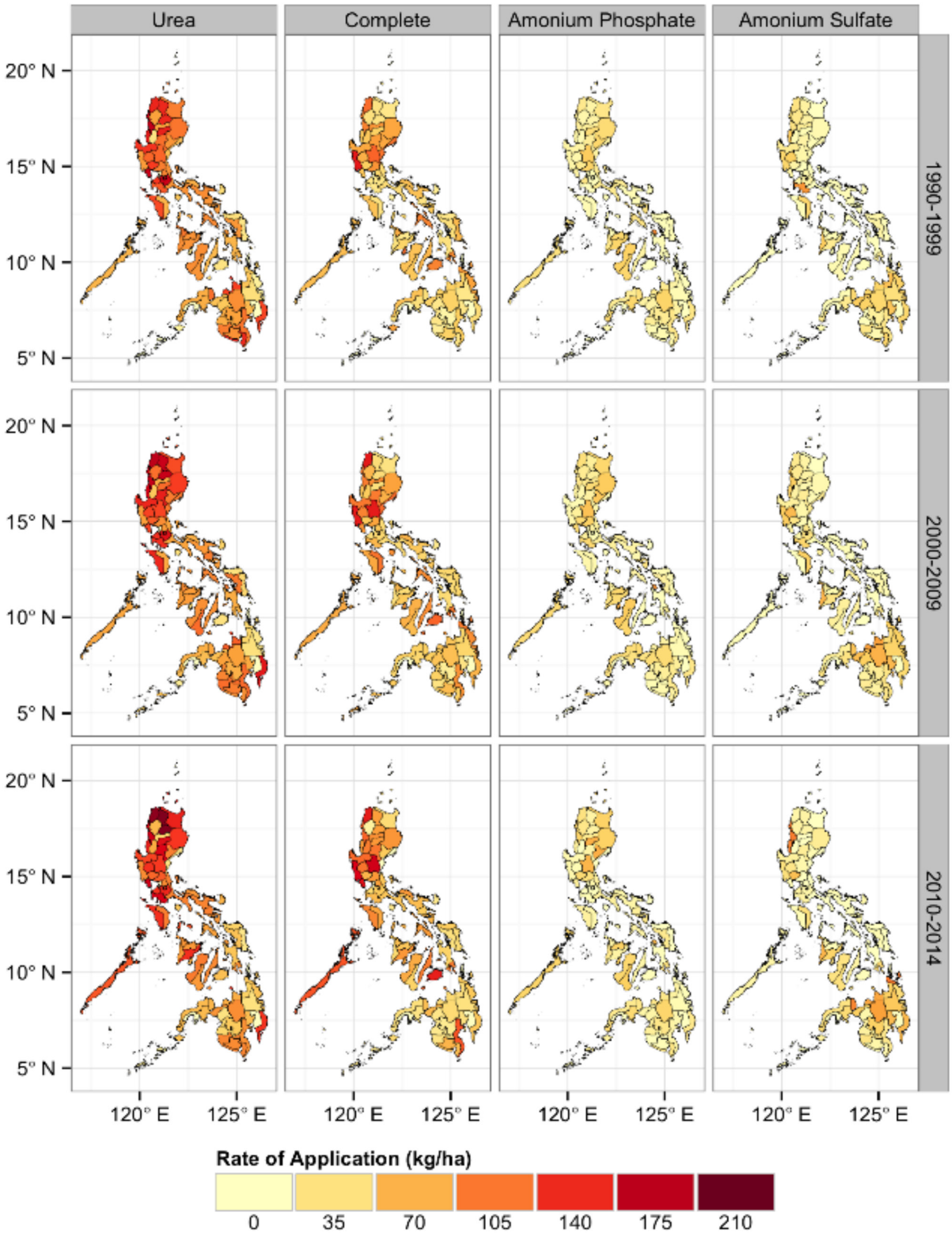
3.1.9 *Fertilizer Application in Irrigated and Nonirrigated Rice Systems During the 2011 Wet and 2012 Dry Cropping Systems in Various Regions in the Country*[1]

Nitrogen Fertilizer Application

In a survey of 2,500 farmers all over the country, the Socioeconomic Division of PhilRice reported that the national average rate of nitrogen fertilizer application in irrigated rice during the 2011 wet season (July–December 2011) cropping is 78 kg N/ha and 81 kg N/ha during the 2012 dry cropping season (January–June 2012). This rate is higher than the application rate in nonirrigated areas, with values of 53 kg N/ha during the wet season and 42 kg N/ha during the dry season. In both rice farming systems, nitrogen fertilizer application is higher in irrigated areas and during the wet season.

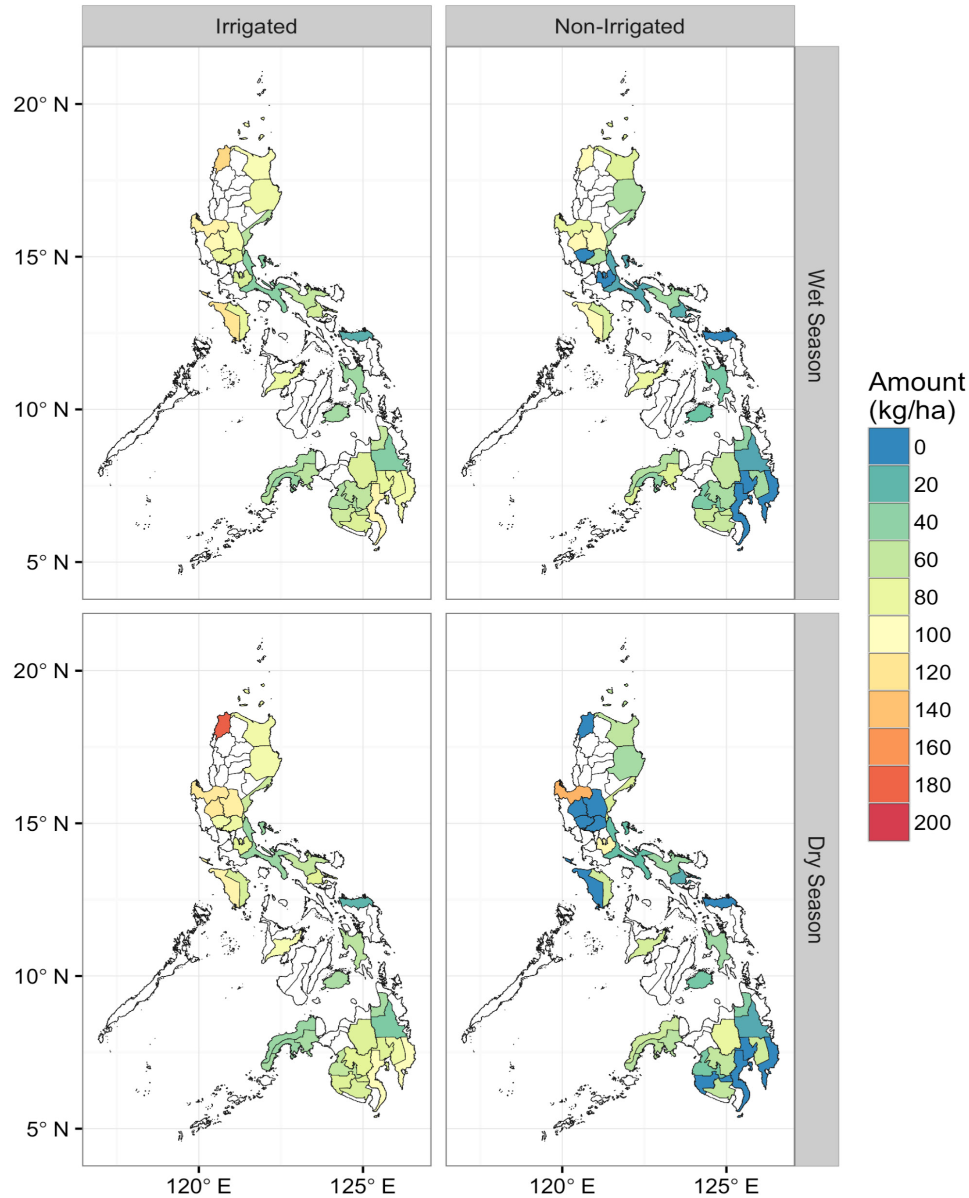
1 based on PhilRice 2016 data.

Figure 23: Trends of four major types nitrogenous fertilizer application in rice crop from 1990 to 2014



Source: Based on PSA 2015 data.

Figure 24: Rate of nitrogen fertilizer application (kg N/ha) during the wet (July–December 2011) and dry (January–June 2012) cropping seasons in the various provinces in the Philippines



Source: Based on PhilRice 2016 data.

The rate of nitrogen fertilizer application varied greatly among the different provinces in the country (Figure 24). In irrigated rice, the rate of fertilizer application during the wet season, ranged from as low as 17 kg N/ha (Samar) in the various provinces in Visayas and Mindanao to as high as 129 kg N/ha (Ilocos Norte) in Northern Luzon, Mindoro, and Southern Mindanao. In nonirrigated rice, a few provinces (Samar, Davao del Norte, Davao del Sur, Davao Oriental) did not apply fertilizer during both wet and dry seasons. Tarlac Province had the highest rate of nitrogen fertilizer application both during the wet (104 kg N/ha) and dry (117.5 kg N/ha) cropping seasons (Figure 24).

Phosphorus Fertilizer Application

From the same survey of 2,500 farmers all the country, PhilRice reported that the national average rate of phosphorus fertilizer application in irrigated rice during the 2011 wet season (July–December 2011) cropping is 6.8 kg P/ha and 7.7 kg P/ha during the 2012 dry cropping season (January–June 2012). This rate is higher than the application rate in nonirrigated areas, with values of 4.9 kg P/ha during the wet season and 4.2 kg P/ha during the dry season.

The rate of phosphorus fertilizer application varied greatly among the different provinces in the country (Figure 25). In irrigated rice, the rate of phosphorus fertilizer application during the wet season, ranged from as low as 0.23 kg P/ha (Samar) to as high as 12.9 kg P/ha (Ilocos Norte). During the dry season, the rate of phosphorus fertilizer application in irrigated rice is from 1.25 kg P/ha (Northern Samar) to as high as 20.9 kg P/ha (Ilocos Norte). To summarize, among all the provinces in the country, Ilocos Norte has the highest rate of phosphorus application in both wet and dry seasons in irrigated rice.

In nonirrigated areas, a few provinces (Pampanga, Laguna, Northern Samar, Davao del Norte, Davao del Sur, Davao Oriental) did not apply phosphorus fertilizer during both wet and dry seasons (Figure 25). During the dry season in nonirrigated areas, rice farmers in many provinces including Ilocos Norte, Samar, Bulacan, Nueva Ecija, Pampanga, Tarlac, Occidental Mindoro, Northern Samar, Daval del Norte, Davao del Sur, Davao Oriental, Sultan Kudarat, and Maguindanao did not apply phosphorus fertilizer. Among those that applied phosphorus fertilizer during the dry season in nonirrigated areas, the range of application was from 0.5 kg P/ha (North Cotabato) to 14.3 kg P/ha (Aurora). During the wet season, the range of phosphorus fertilizer application was from 0.68 kg P/ha (Oriental Mindoro) to 12.6 kg P/ha in Ilocos Norte.

Potassium Fertilizer Application

From the same survey of 2,500 farmers all over the country, PhilRice reported that the national average rate of potassium fertilizer application in irrigated rice during the 2011 wet season (July–December 2011) cropping was 10.5 kg K/ha and 11.3 kg K/ha during the 2012 dry cropping season (January–June 2012). This rate was higher than the application rate in nonirrigated areas, with values of 6 kg K/ha during the wet season and 5.3 kg K/ha during the dry season.

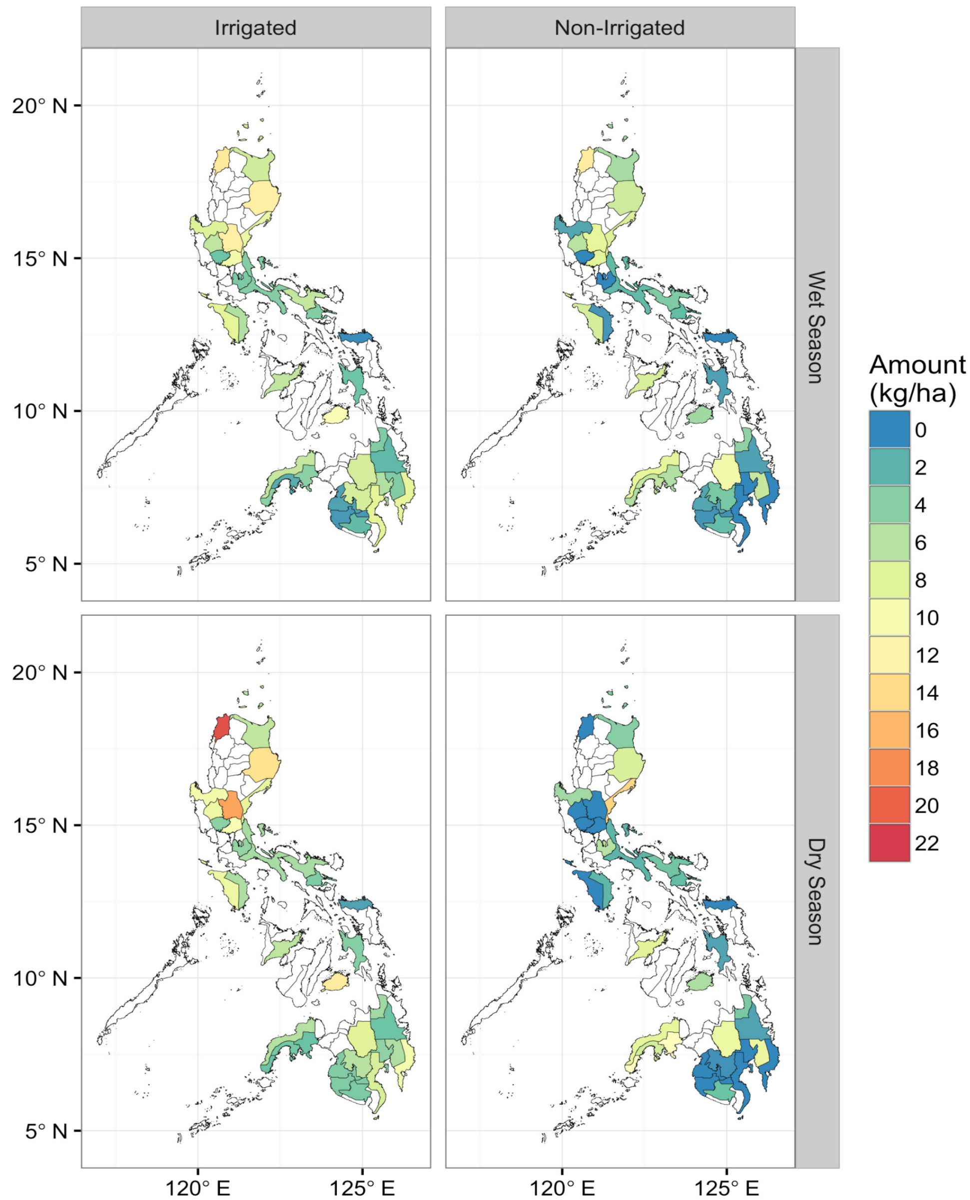
The rate of potassium fertilizer application varied greatly among the different provinces in the country (Figure 26). In irrigated rice, the rate of potassium fertilizer application during the wet season, ranged from as low as 0.43 kg K/ha (Northern Samar) to as high as 19.9 kg K/ha (Ilocos Norte). During the dry season, the rate of potassium fertilizer application in irrigated rice was from 2.37 kg K/ha (Northern Samar) to as high as 28.4 kg K/ha (Ilocos Norte). To summarize, among all the provinces in the country, Ilocos Norte has the highest rate of potassium application in both wet and dry seasons in irrigated rice. Potassium application was higher during the dry season than the wet season.

In nonirrigated areas, a few provinces (Davao del Norte, Davao del Sur, Davao Oriental, and Pampanga) did not apply potassium fertilizer during both wet and dry seasons (Figure 26). During the dry season in nonirrigated areas, rice farmers in many more provinces including Sultan Kudarat, Maguindanao, Bulacan, Nueva Ecija, Tarlac did not apply potassium fertilizer. Among those that applied potassium fertilizer during the dry season in nonirrigated areas, the range of application is from 0.01 kg K/ha (North Cotabato) to 27 kg K/ha (Aurora). During the wet season, the range of potassium fertilizer application was from 0.09 kg K/ha (Cagayan) to 24.02 kg K/ha in Ilocos Norte.

3.1.10 Fertilizer Application in Irrigated Rice during Wet and Dry Cropping Seasons in Central Luzon

The IRRI conducted a loop survey of rice farmers in a span of 45 years from 1966 to 2012 in Central Luzon. The amount of nitrogen fertilizer applied to irrigated rice crop increased dramatically from around 10 kg/

Figure 25: The rate of phosphorus fertilizer application (kg N/ha) during the wet (July–December 2011) and dry (January–June 2012) cropping seasons in the various provinces in the Philippines

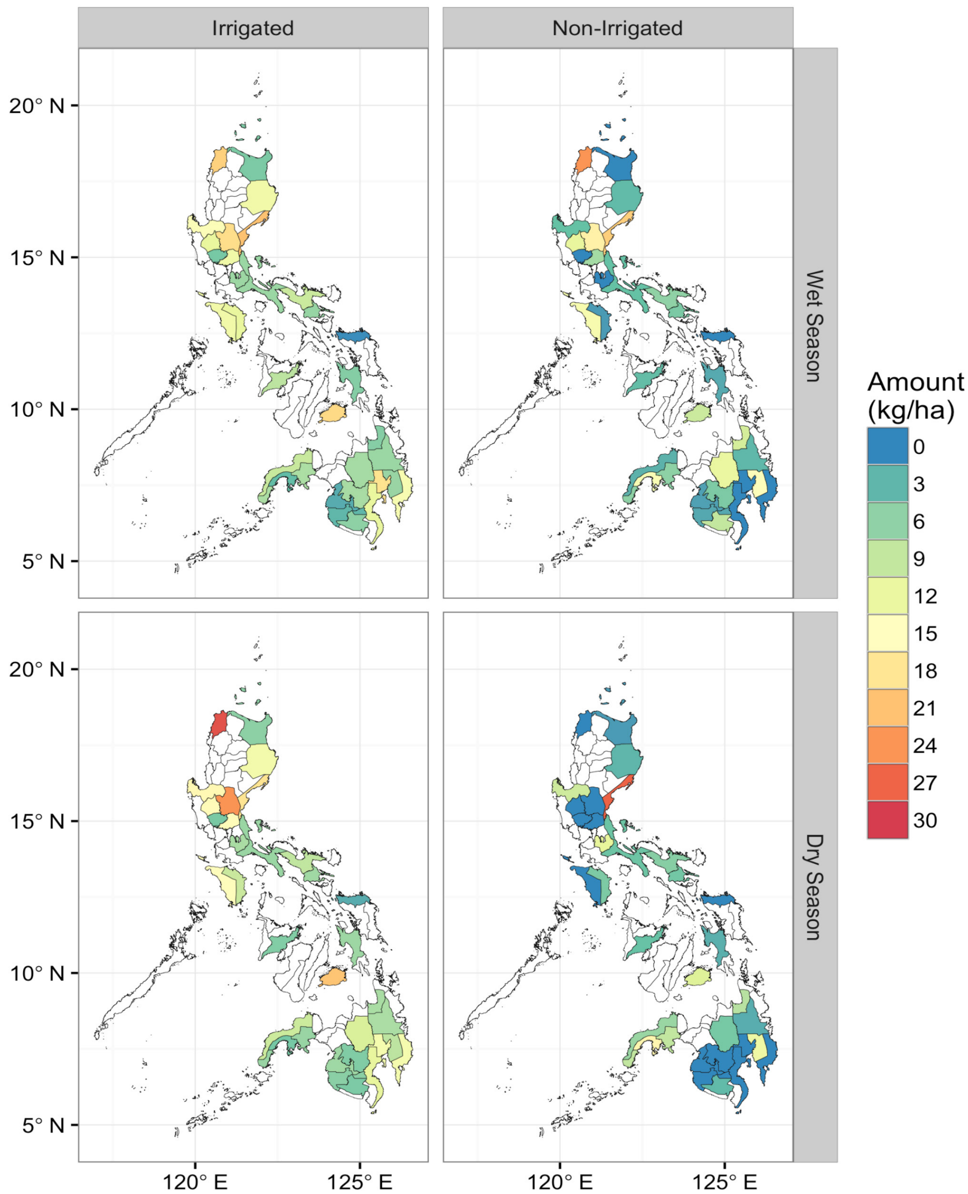


Source: Based on PhilRice 2016 data.

ha in 1966 to almost 120 kg/ha in 2011 (Figure 27). Farmers applied even higher amounts of nitrogen fertilizer during the dry season rice cropping than dry season cropping (Figures A-27 and A-28) (Moya et al. 2015). The higher rates of application in the 2000s approach the recommended level of 100 kg/ha (Sebastian, Alviola, and Francisco 2000). The increase in nitrogen fertilizer rate application in the 1970s is due to the shift in planting of rice varieties from traditional to HYVs which are more responsive to applied fertilizers (Moya et al. 2015).

The amounts of phosphorus and potassium application were much lower compared with nitrogen fertilizer application. Phosphorus application ranged from around 4 kg/ha in 1966 to 15 kg/ha in 2011. Likewise,

Figure 26: Rate of potassium fertilizer application (kg K/ha) during the wet (July–December 2011) and dry (January–June 2012) cropping seasons in the various provinces in the Philippines



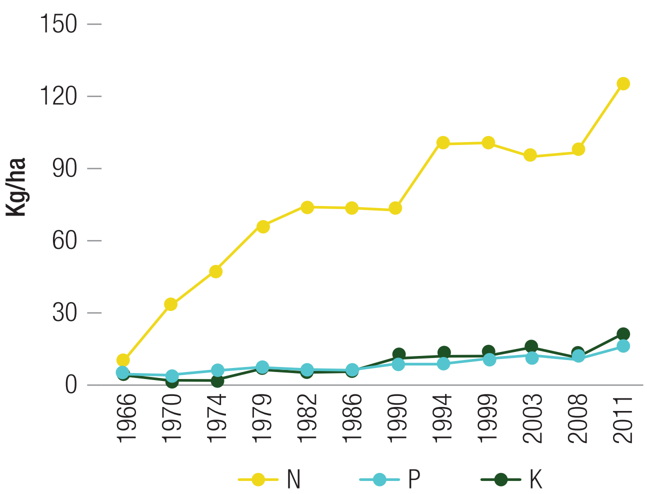
Source: Based on PhilRice 2016 data.

potassium fertilizer application was also low, ranging from as low as 3 kg/ha in 1974 to as high as 19 kg/ha in 2011 (Moya et al. 2015).

Comparing the amounts of nitrogen applied in wet season rice cropping systems between irrigated and rainfed rice, much higher amounts of nitrogen fertilizer are applied in irrigated rice in the order of 18 kg/ha (Figure 29) (Moya et al. 2015). This reflects the complementarity between fertilization and irrigation.

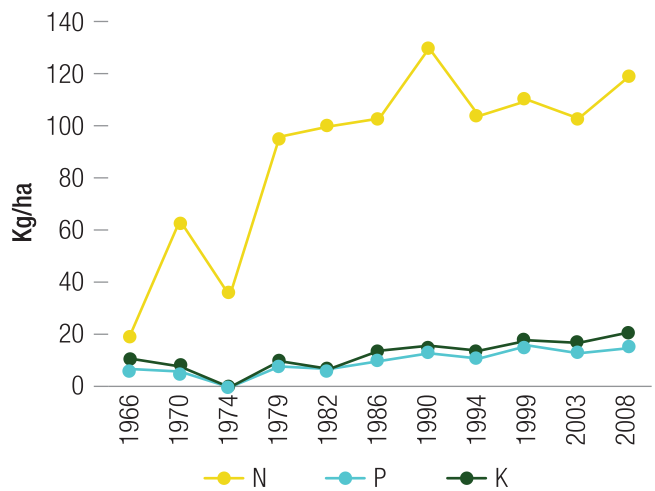
With regard to timing of fertilizer application, the majority of the rice farmers in Central Luzon apply fertilizer 16–45 days after transplanting (DAT) and at 1–15 DAT since 1966 for both wet and dry rice cropping seasons (Figure 30).

Figure 27: Trends in fertilizer use per hectare, wet season, Central



Source: Moya et al. 2015.

Figure 28: Trends in fertilizer use per hectare, dry season, Central



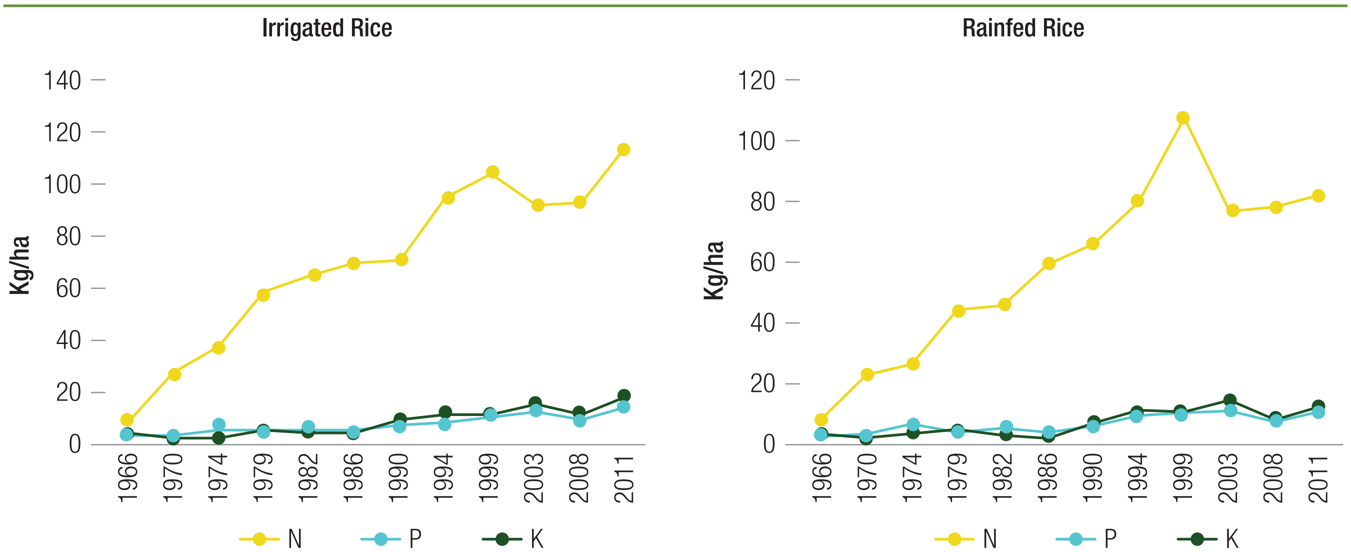
Source: Moya et al. 2015.

Farmers have varied practices of frequency of applying fertilizers in rice crop between seasons. During the dry season, the majority of the farmers apply fertilizer twice during the cropping season since 1966. On the other hand, during the wet season cropping, there is an increasing trend in splitting the application of fertilizer up to more than three times during the cropping season since the 1990s (Moya et al. 2015) . This is to reduce losses of the applied fertilizer by the rain events during the wet season.

3.1.11 *Fertilizer Application on Corn Cropping Systems*

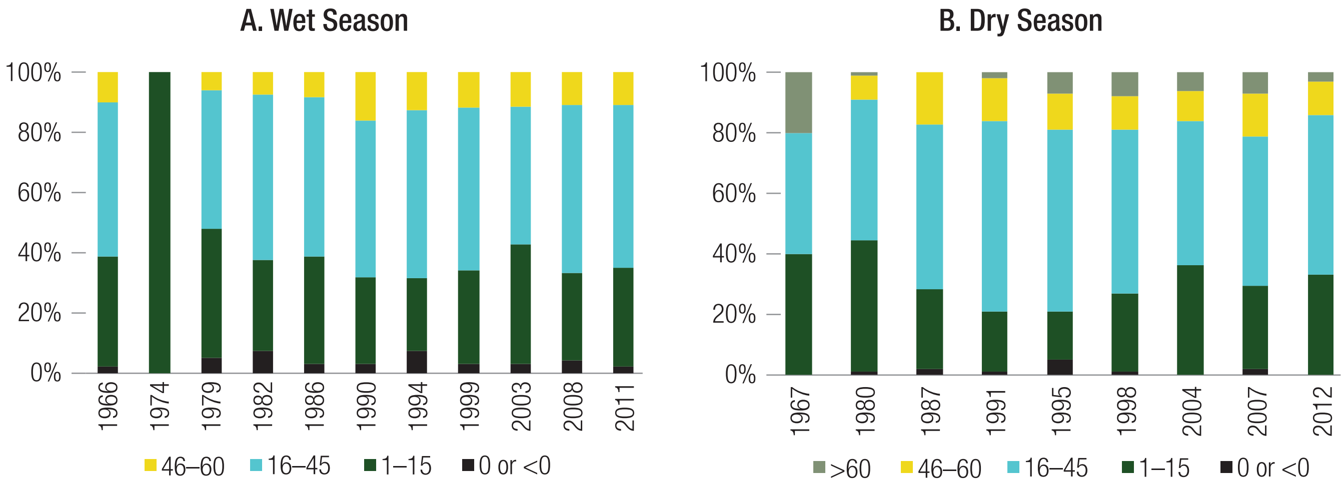
The total area cultivated with corn in the Philippines decreased from 3,803,760 ha in 1988 to 2,985,962 ha

Figure 29: Comparative fertilizer use (kg/ha), wet season, irrigated and rainfed farms



Source: Moya et al. 2015.

Figure 30: Timing of fertilizer application in (a) wet season and (b) dry season of the surveyed farmers



Source: Moya et al. 2015.

in 2014 (Figure 32). Way back in 1988, only a small percentage (17.38 percent) of area cultivated with corn was fertilized (661,180 ha) (Figure 32). Starting the following year, in 1999, the proportion of areas cultivated with corn that was fertilized increased to 2,156,400 ha, about 57.7 percent. Fertilizer application in corn-growing areas was continuously sustained through the years since then. In the years from 2011 to 2013, almost all areas cultivated with corn were fertilized (100 percent). However, in 2014, there was a sudden decrease in the areas fertilized by 20 percent from 2,563,306 ha down to 2,049,744 ha while the areas cultivated with corn jumped by 16.4 percent from 2,563,306 ha in 2013 to 2,985,962 ha in 2014.

3.1.12 *Trends in NPK Fertilizer Application to Corn from 1960 to 2013*

With the implementation of the Green Revolution in the mid-1960s that primarily aimed to boost crop

Figure 31: Frequency of fertilizer application in (a) wet season and (b) dry season of the surveyed farmers

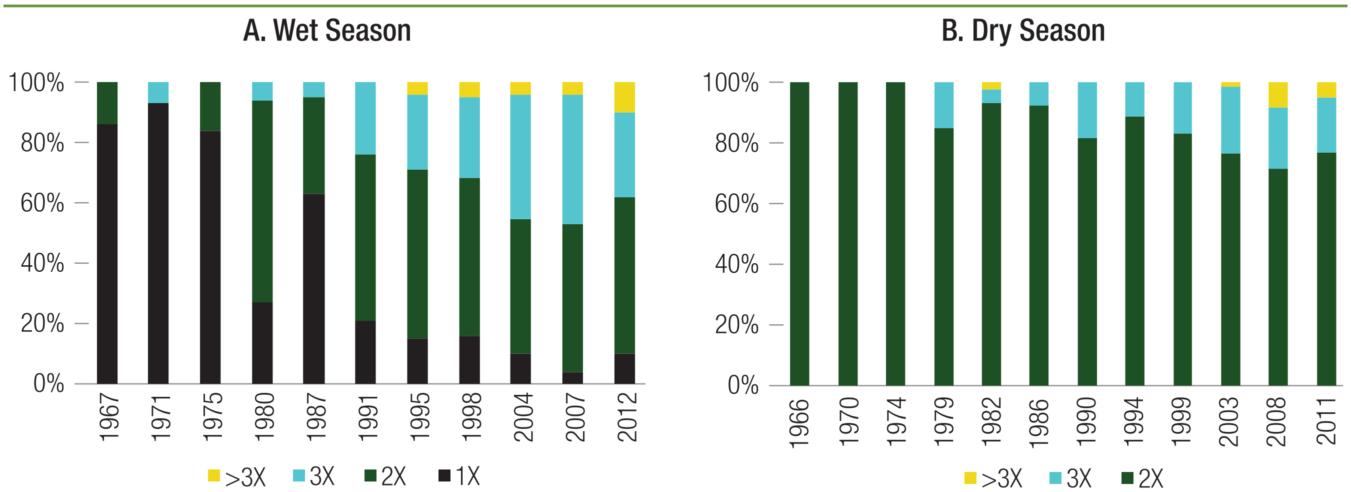
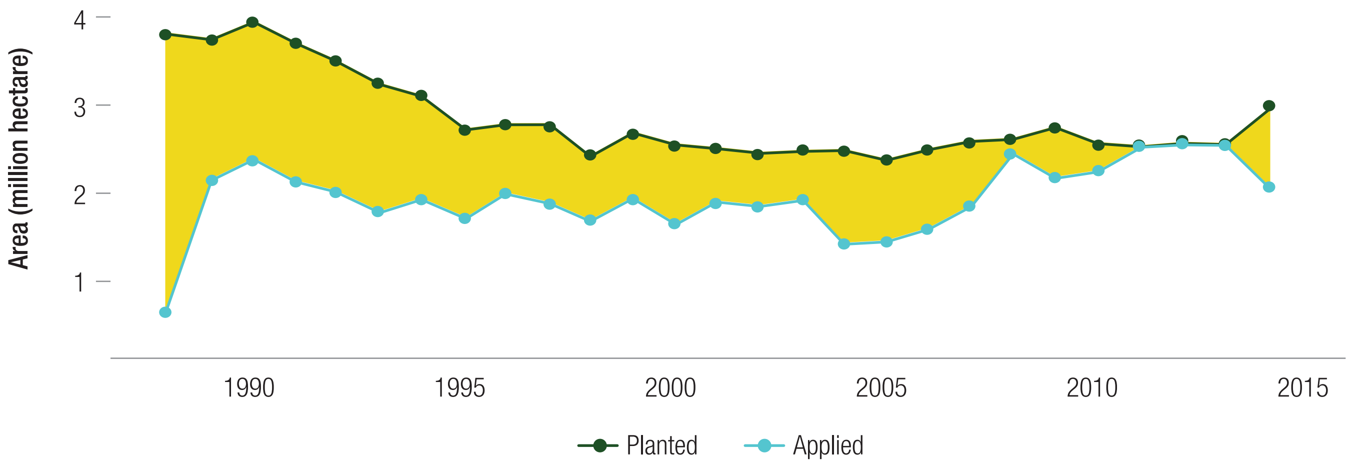


Figure 32: Area cultivated with corn and applied with fertilizers from 1988 to 2014



Source: Based on PSA 2015.

production to meet the increasing food demand for the increasing population, fertilizer application in corn started to increase. The national volume of corn production generally increased by 483 percent from 1,266,270 tons in 1961 to 7,377,076 tons in 2013. To attain this increase in yield, commercial fertilizer application increased through the years. Nitrogenous fertilizers applied increased by 1,658 percent from 35,815 tons in 1961 to 629,808 tons in 2004. From 2004 to 2007, the amount of nitrogenous fertilizer applied declined by 17 percent to 519,960 tons in 2007. High amounts of nitrogenous fertilizer were applied (593,226 tons) in 2010, but since then, the amount of nitrogenous fertilizer continually declined by 51.6 percent to 287,291 tons in 2013.

Similarly, phosphate fertilizers applied increased by 1,182 percent from 16,006 tons in 1961 to 205,168 tons in 2007. Among the three nutrient fertilizers, it was the phosphate fertilizer application that remained low (about 50,000 tons/year) from 1960 to 1985. It was during the period from 1985 to 2005 that there was a rapid increase (221 percent) in phosphate fertilizer application from 42,778 tons in 1985 to 137,311 tons in 2005. After 2007, the amount of phosphate fertilizer applied decreased to 72,660 tons in 2013.

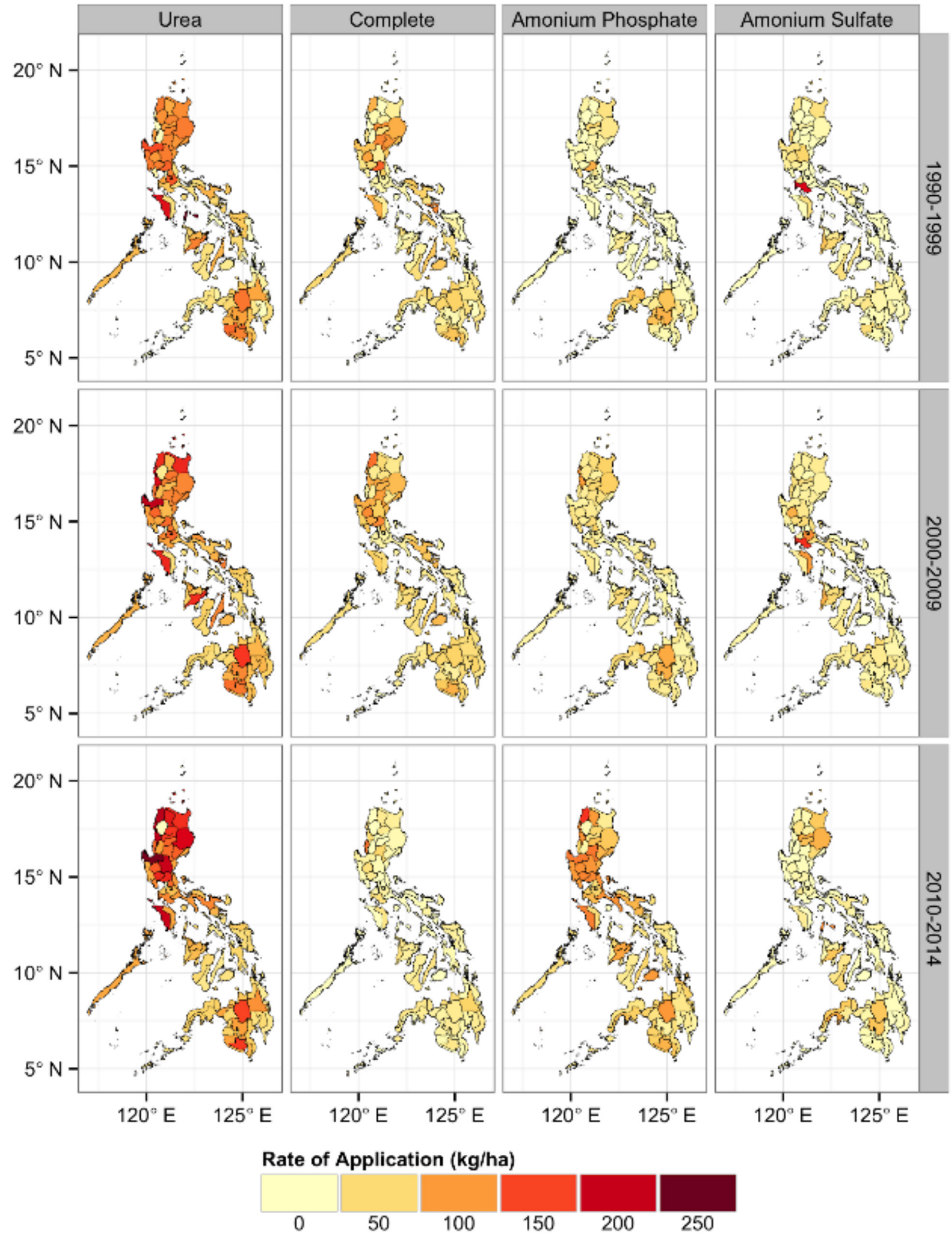
Potassium fertilizers applied generally increased by 105 percent from 19,400 tons in 1961 to 39,794 tons in 2013, except for the dip during the period from 2001 to 2004. From 2010, the amount of potassium fertilizer rapidly decreased by 66 percent from 116,936 tons in 2010 to 39,794 tons in 2013.

To summarize, the national fertilizer application in corn fields increased from 1960 to 2010, but decreased in the past few recent years. In the period from 1995 to 2000, national corn production decreased despite the increasing trend in fertilizer application. One of the reasons for this may be the El Niño phenomenon in 1997. However, in the past 4 years, there is a continuing increase in volume of corn production despite the decreasing trend in commercial fertilizer application. This maybe attributed to the massive campaign of the DA for organic farming. We still have to gather data on the amount of organic fertilizer applied and its management.

3.1.13 *Trends of Fertilizer Application by Type in Various Corn-Growing Provinces from 1990 to 2014*

Among the four major types of nitrogenous fertilizers commonly applied in corn crop, urea is widely applied in greater quantities than the other three types of fertilizer (Figure 33). In the decade of 1990–1999, urea fertilizer was applied in high quantities (100–150 kg/ha) in

Figure 33: Trends of four major types nitrogenous fertilizer application in corn from 1990 to 2014



Source: Based on PhilRice 2016 data.

Northern and Central Luzon, Western Mindanao, and Occidental Mindoro. In the following decade (2000–2009), the rate of urea fertilizer application increased (150–200 kg/ha) in these areas particularly in the provinces of Cagayan, Pangasinan, Occidental Mindoro, Bukidnon, and Iloilo. In the years 2000–2014, the rate of urea fertilizer application further increased to as high as 200–250 kg/ha in the Northern and Central Luzon.

Complete fertilizer was applied at a lower rate (50–100 kg/ha) in almost all corn-growing provinces all over the country from 1990–2009. Provinces in Region I and II applied complete fertilizer at a relatively higher rate (100 kg/ha). However, in the years 2000–2014, the rate of complete fertilizer application decreased all over the country to about 50 kg/ha.

All through these years, ammonium sulfate was applied in lower quantities (50 kg/ha) except for the province of Batangas wherein this fertilizer was applied at a rate of 150 kg/ha since the 1990s until 2009 (Figure 33).

3.1.14 *Nitrogen Applied in Soil and Nitrogen Removed by Rice Crop*

To gain an overview of how much nitrogen has been applied into the soil through fertilizer application, we calculated the summation of the nitrogen applied from the application of urea (46–0-0), complete (14–14–14), ammosul (21–0-0), and ammophos (16–20–0) fertilizers. The amounts of nitrogen that has been taken up and accumulated in the harvested rice grain and rice straw were computed by multiplying the volume of harvested rice with 10.9 kg N/ton of rice production and 5.3 kg N/ton of rice production for rice grain and straw, respectively (De Datta 1981). These values were obtained from an experiment on the nutrient removal of a rice crop (variety IR8) conducted in Maligaya Rice Research and Training Center, the Philippines during the 1979 dry season cropping (De Datta 1981). For this simple calculation, we have chosen Nueva Ecija and Aklan Provinces, the highest and lowest rice-producing provinces per unit area (tons/ha) in 2014.

From 1988 to 2014, the amount of nitrogen applied in the soil in Nueva Ecija was greater than the amounts of nitrogen removed from the soil by harvesting straws and rice grain (Figure 34). There was an increasing trend in the total amount of nitrogen applied from 16,605.70 tons in 1988 to 37,054.62 tons in 2014, with an annual average 4.74 percent increase. The amount of nitrogen taken up by the crop and that was harvested in the rice grain was about 33 percent of the applied nitrogen in 1988 and 57 percent of applied nitrogen in 2014. Typical fertilizer recovery efficiencies in irrigated lowland rice with good crop management and grain yields of 5 to 7 tons/ha was 30–60 percent for nitrogen (Better Crops International 2002). The amount of nitrogen harvested in the rice straws may either be returned back into the soil if the rice straw was applied as mulch or incorporated back into the paddy soil during land preparation in the succeeding cropping season or it may be lost into the atmosphere if the biomass was burned and the ash was applied back into the soil for the succeeding cropping.

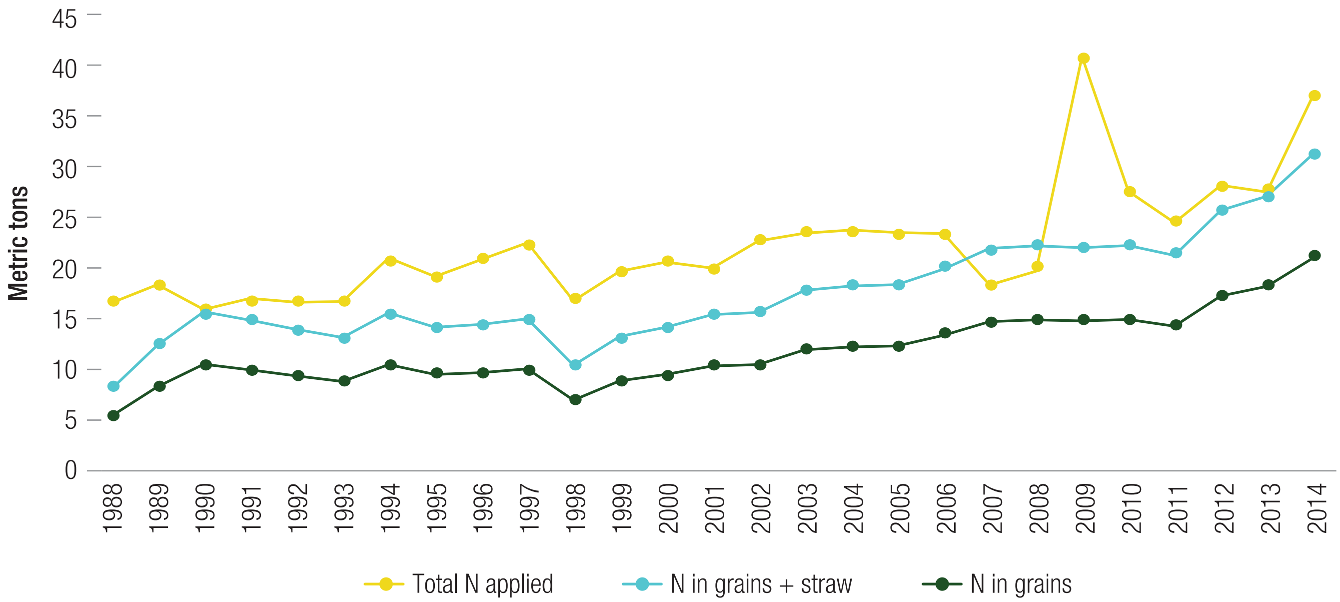
There are many possible sources of available nitrogen for crop growth including the native nitrogen in the soil, nitrogen coming with rain water, nitrogen contributed by nitrogen-fixing organisms, nitrogen released during the decomposition of leaf litter and other organic materials, and nitrogen from fertilizer application. The excess amounts of fertilizer nitrogen applied to the soil may be lost via runoff and leaching, erosion, volatilization, and transformation and immobilization by microorganisms. These various processes vary with environmental conditions primarily temperature and rainfall events. Nitrates (NO_3^-) may be lost via runoff and leaching while NH_4^+ may volatilize or maybe transformed into N_2 and be lost into the atmosphere.

Analyzing the available data on rice crop production and the amounts of nitrogen fertilizers applied, it was observed that provinces with high rice production have similarly excessive amounts of nitrogen applied into the cropping system. These areas are potential hotspots for pollution from excessive nitrogen applied.

Aklan Province is one of the provinces with the lowest rates of nitrogen fertilizer application and rice production through the years. Though, the amount of nitrogen fertilizer is small, 1,834.97 tons in 1988 and 2,022.07 tons in 2014, the amount of nitrogen taken up by the crop and harvested in the rice grain and rice straw is still lesser than the amounts applied (Figure 35). Similar to the case in Nueva Ecija, the excess nitrogen applied in Aklan rice fields may be lost to the environment as pollutants.

From 2007 to 2010, with decrease in the amounts of nitrogen applied, the rice grain and rice straw yield also decreased. Similarly, from 2010 to 2013, with increase in nitrogen fertilizer applied, there was corresponding increase in nitrogen in the harvested rice grain (Figure 35).

Figure 34: Amounts of nitrogen applied, nitrogen content in harvested rice grains, and nitrogen content in rice. Harvested rice grains + straw from 1988 to 2014 in Nueva Ecija

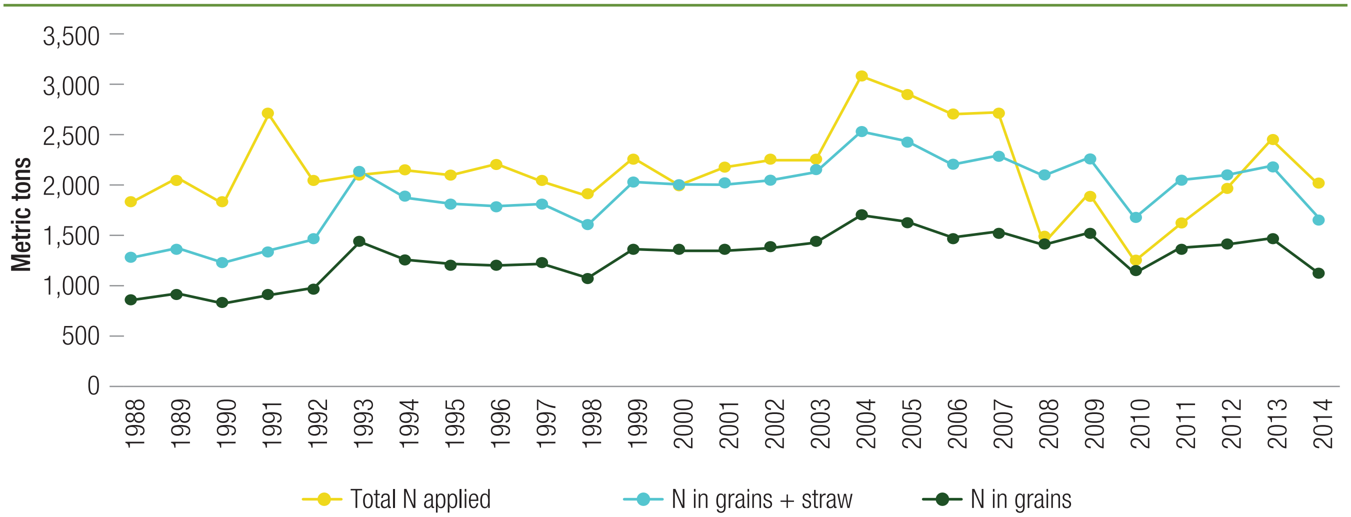


Source: Based on PSA 2015.

3.1.15 *Phosphorus Applied in Soil and Phosphorus Removed by Rice Crop*

Phosphorus is applied in the form of complete (14–14–14) and ammophos (16–20–0) fertilizers in rice crop. In Nueva Ecija, there was an increasing trend in the amounts of phosphorus applied from 4,221.40 tons in 1988 to 13,151.49 tons in 2014 with an annual increase of 8.14 percent in 26 years (Figure 36). Since 1988, the

Figure 35: Amounts of nitrogen applied, nitrogen content in harvested rice grains, and nitrogen content in rice. Harvested rice grains + straw from 1988 to 2014 in Aklan



Source: Based on PSA 2015.

amount of phosphorus applied is much greater than the amounts of phosphorus taken up by the plant and harvested via the rice grain and rice straw.

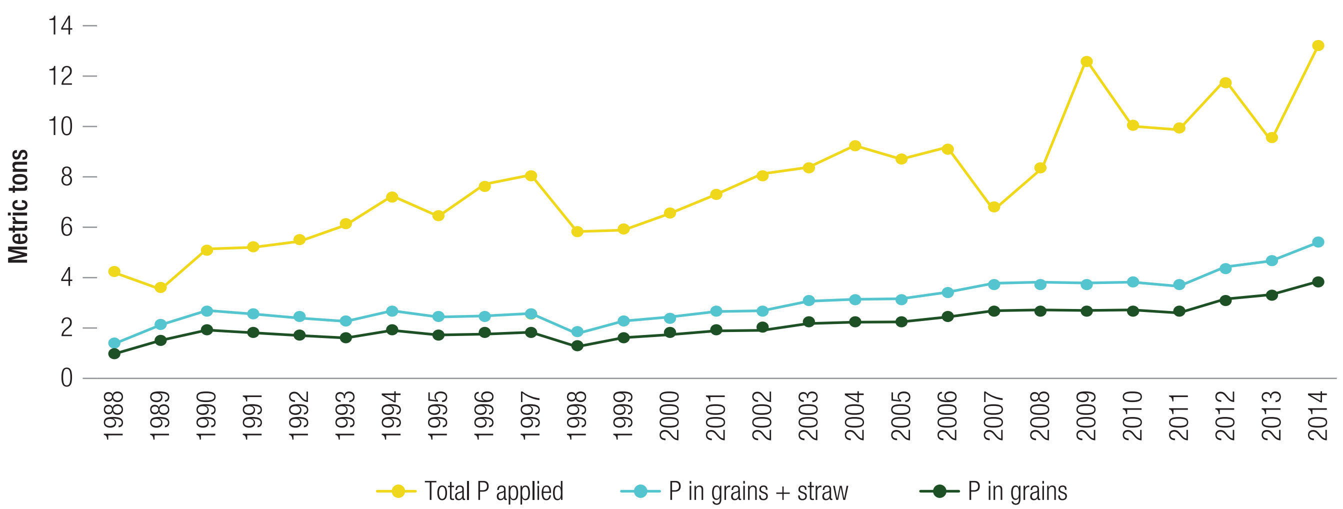
The amount of phosphorus that has been taken up and accumulated in the harvested rice grain and rice straw was computed by multiplying the volume of harvested rice with 2.0 kg phosphorus/ton of rice production and 0.8 kg phosphorus/ton of rice production for rice grain and straw, respectively (De Datta 1981) These values were obtained from an experiment on the nutrient removal of a rice crop (variety IR8) conducted at the Maligaya Rice Research and Training Center, the Philippines during the 1979 dry season cropping (De Datta 1981). Similar to Nitrogen, for this simple calculation, we have chosen Nueva Ecija and Aklan Provinces, the highest and lowest rice-producing provinces per unit area (tons/ha) in 2014.

The rate of increase in the phosphorus harvested in rice grain is 285 percent from 1,004 tons in 1988 to 3,862 metric tons in 2014. The rate of increase in phosphorus taken up by the rice grain is much less than the rate of increase in phosphorus applied in the soil. The excess phosphorus applied in the soil may be lost via leaching, erosion and runoff. At lower rates of phosphorus fertilizer applied in the late 1980s, the amount of phosphorus taken up by the crop was about 35 percent and from 2009 to 2014, with higher rates of phosphorus fertilizer application, the amount of phosphorus taken up by the crop is about 23 percent (Figure 36). Typical fertilizer recovery efficiencies in irrigated lowland rice with good crop management and grain yields of 5 to 7 t/ha is 10–35 percent for phosphorus (Better Crops International 2002). In Aklan, though the amounts of phosphorus applied were low, the amounts removed by the crop and harvested via the rice grain and straw is less compared with the amounts of phosphorus applied (Figure 37). The proportion of phosphorus taken by the crop ranges from 55 percent to 73 percent of the phosphorus fertilizer applied. The excess phosphorus applied may also end up as pollutants in water and soil.

3.1.16 *Potassium Applied in Soil and Potassium Removed by Rice Crop*

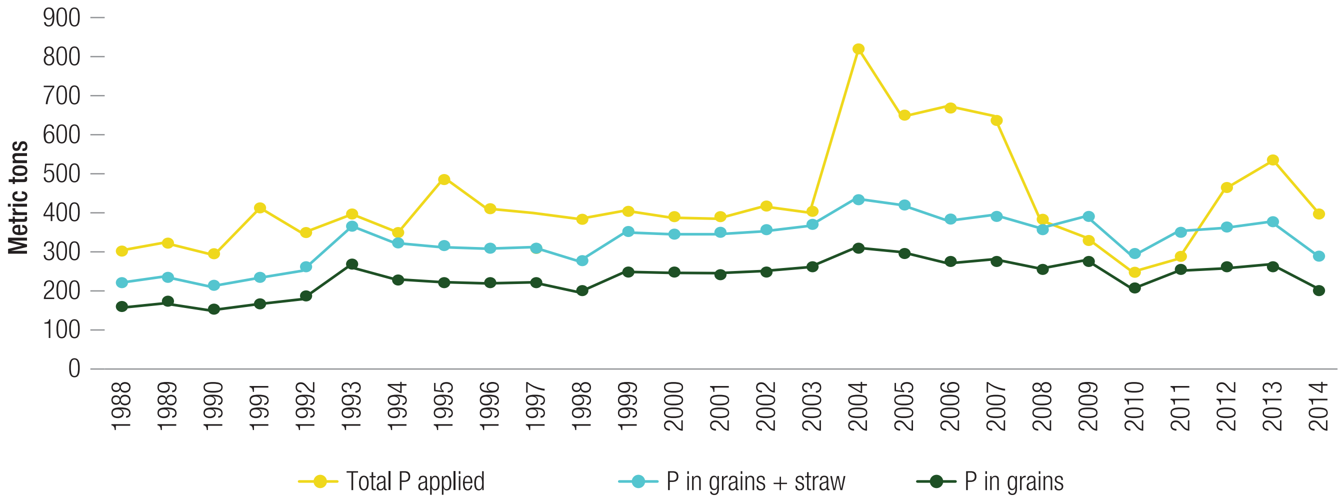
The amount of potassium that has been taken up and accumulated in the harvested rice grain and rice straw were computed by multiplying the volume of harvested

Figure 36: Amounts of phosphorus applied, phosphorus content in harvested rice grains, and phosphorus content in rice. Harvested rice grains + straw from 1988 to 2014 in Nueva Ecija



Source: Based on PSA 2015.

Figure 37: Amounts of phosphorus applied, phosphorus content in harvested rice grains, and phosphorus content in rice. Harvested rice grains + straw from 1988 to 2014 in Aklan



Source: Based on PSA 2015.

rice with 3.1 kg potassium/ton of rice production and 13.6 kg potassium/ton of rice production for rice grain and straw, respectively (De Datta 1981). These values were obtained from an experiment on the nutrient removal of a rice crop (variety IR8) conducted in Maligaya Rice Research and Training Center, the Philippines during the 1979 dry season cropping (De Datta 1981). As with the calculations for nitrogen and phosphorus uptake by rice crop, we have chosen Nueva Ecija and Aklan Provinces, the highest and lowest rice-producing provinces per unit area (tons/ha) in 2014.

Unlike nitrogen and phosphorus, the amount of potassium fertilizer applied (from complete fertilizer) in rice crop in both Nueva Ecija and Aklan Provinces is much less than the amounts taken up and accumulated in the rice straw and rice grain (Figures A-38 and A-39). Most potassium uptake is accumulated in the rice straws, being larger than potassium harvested in the rice grains which is almost near the values of the amounts of potassium applied as fertilizer. Hence, rice plants have to exploit native potassium available in the soil and potassium in the rain water. If rice straw is not returned to the fields, the soil potassium pool will be depleted in future.

The ratio of N:P2O5:K2O fertilizer use in Southeast Asia is about 8:2:1 (Mutert and Fairhurst 2002). This unbalanced fertilizer consumption may deplete the potassium reserves in the soil. Research results have shown that there are negative balances of 40 to 60 kg K/year in intensified rice systems in the Philippines, Thailand, Indonesia, and Vietnam (Sheldrick, Syers, and Lingard 2002; Syers, Sheldrick, and Lingard 2001).

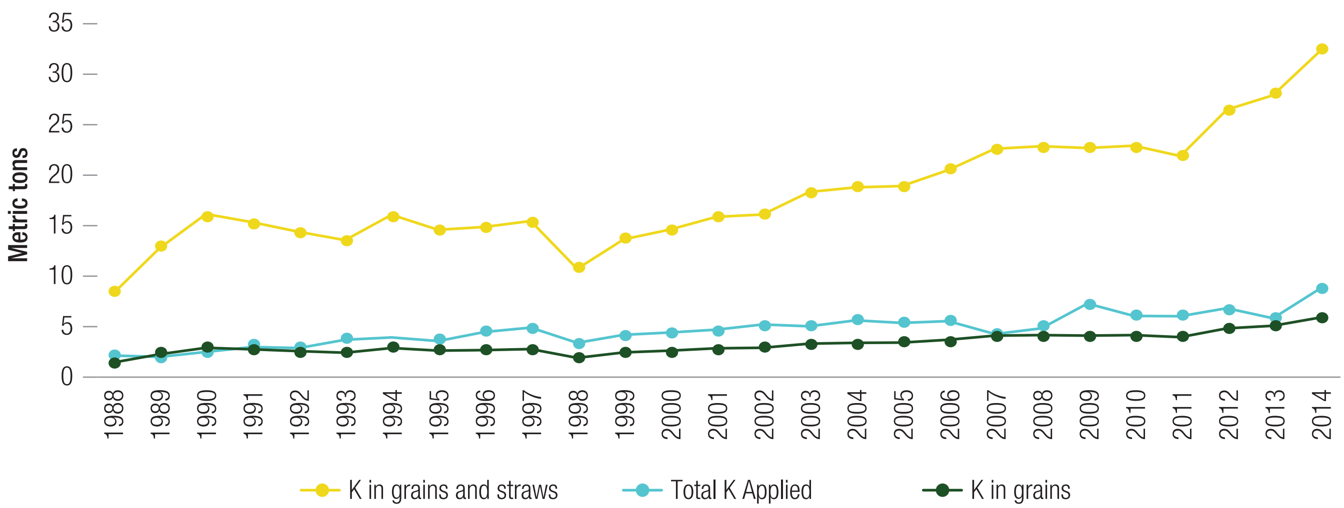
With regard to pollution, the current low application rates of potassium fertilizer in Nueva Ecija and Aklan indicate that potassium will not pose a pollution hazard.

Typical fertilizer recovery efficiencies in irrigated lowland rice with good crop management and grain yields of 5 to 7 tons/ha is 15–65 percent for potassium (Better Crops International 2002).

3.1.17 *Nitrogen Crop Uptake and Loading to the Environment*

In 2010, the amount of nitrogen fertilizers applied in 712,520 ha of croplands in the subwatersheds surrounding the Manila Bay totaled to 52,102 tons nitrogen loss into the environment from croplands (rice

Figure 38: Amounts of potassium applied, potassium content in harvested rice grains, and potassium content in rice. Harvested rice grains + straw from 1988 to 2014 in Nueva Ecija

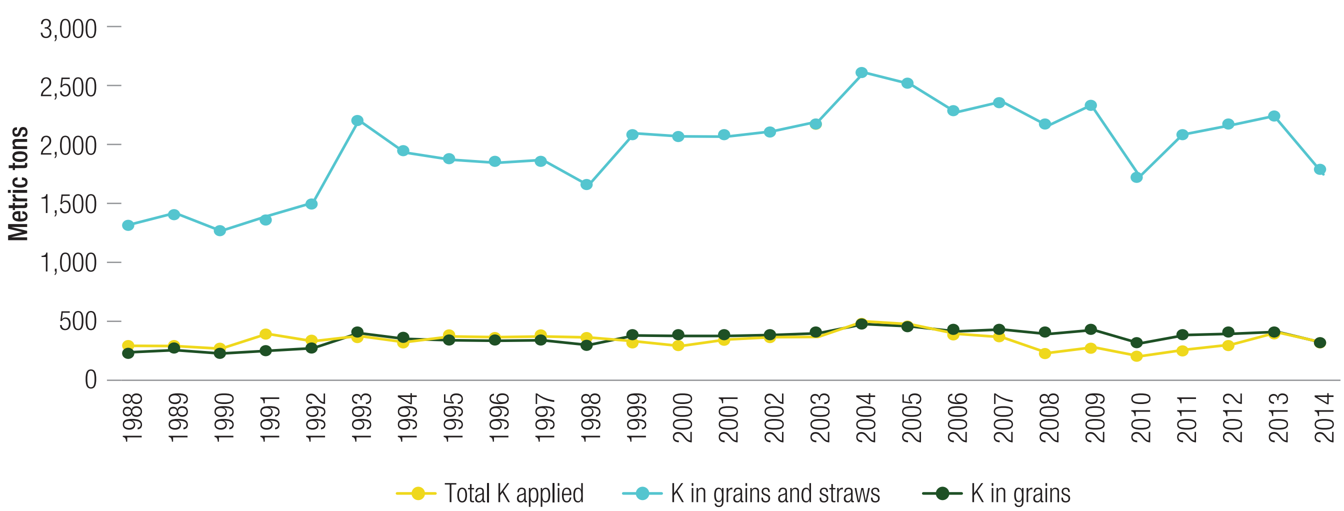


Source: Based on PSA 2015.

lands, corn lands, sugarcane, and coconut areas) and was estimated at 51 percent of the applied inorganic fertilizer amounting to 26,491 tons. Assuming that the amount of nitrogen lost as surface runoff ranged from 1 percent to 13 percent, the values of nitrogen lost range from 482 to 6,264 tons (Samar 2012).

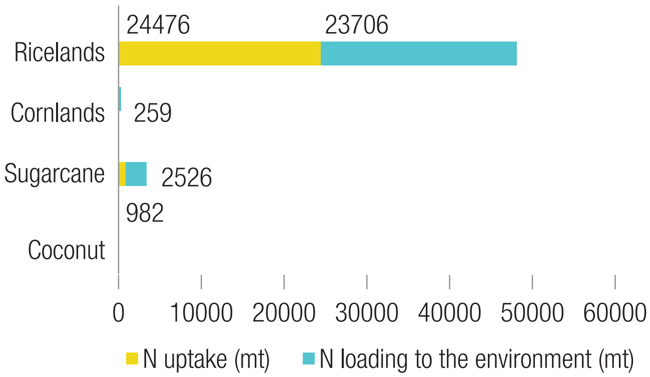
In the Manila Bay system, among the four major crops grown, it is the rice cropping system that contributes greatly to nitrogen loading into the environment (Figure 40), amounting to 23,706 tons. Coconut areas are not applied with nitrogen fertilizer, thus they do not contribute to nitrogen loading to the environment.

Figure 39: Amounts of potassium applied, potassium content in harvested rice grains, and potassium content in rice. Harvested rice grains + straw from 1988 to 2014 in Aklan



Source: Based on PSA 2015.

Figure 40: Nitrogen crop uptake and loading to the environment in the Manila Bay, 2010

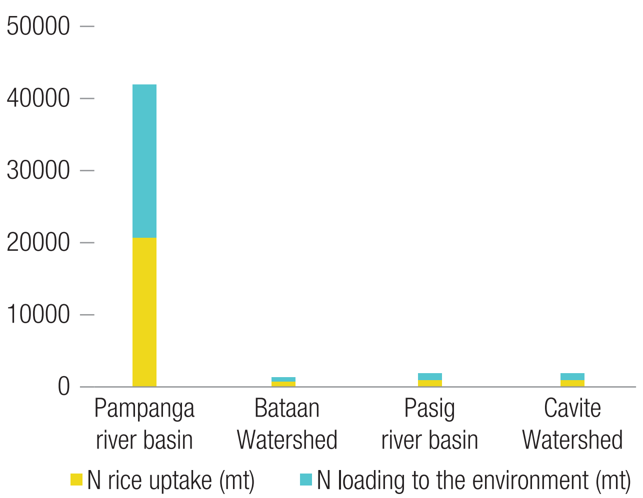


Source: Samar 2012.

Instead, application of salt is a common practice in coconut areas.

Among the four subwatersheds in the Manila Bay system, the rice cropping area is highest in Pampanga River Basin, thus nitrogen loading to the environment is the highest (Figure 41). Nitrogen loading to the environment accounts for 51 percent of the applied nitrogen fertilizer and this shows the low nitrogen use efficiency of rice cropping systems.

Figure 41: Nitrogen uptake and loading to the environment by rice crop, 2010



Source: Samar 2012.

BSWM recommended that immediate efforts on improving nitrogen use efficiency of crops will lessen the nitrogen load to the environment and at the same time help farmers to reduce wastage of chemical inputs. Increasing the nutrient use efficiency by various crops has been a major challenge through the decades. Roy, Misra and Montanez (2003) reported that 50.7 percent of applied nitrogen is taken up by rice. In 1993, it was determined that about 52 percent to 73 percent of applied nitrogen is lost in corn (Francis, Schepers and Vigil 1993) and this was supported by a report in 2002 that corn takes up 37 percent of applied nitrogen fertilizer (Cassman, Dobermann, and Walters 2002). Likewise, sugarcane has low (28 percent) nitrogen fertilizer use efficiency (Meyer et al. 2007).

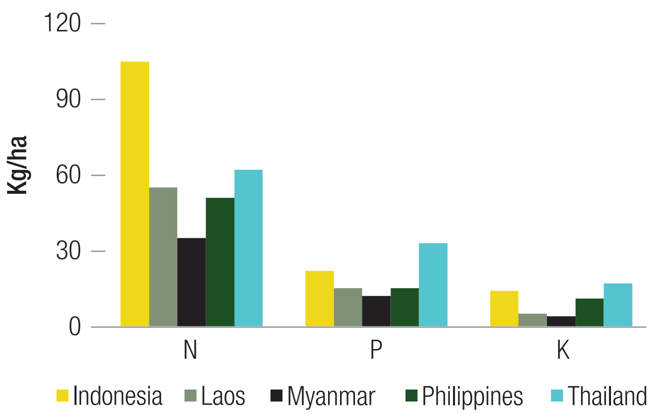
3.1.18 *Comparison of Fertilizer Application Rates in Rice, Corn, and Sugarcane in Southeast Asian Countries*

In Southeast Asia, the Philippines has the highest phosphorus and potassium fertilizer application rates in corn and sugarcane while it is low in rice.

In Southeast Asia, the amount of nitrogen fertilizer applied in rice crop in the Philippines is lower (51 kg/ha) than the application rates in Indonesia (105 kg/ha), Thailand (62 kg/ha), and Laos (55 kg/ha) (Figure 42). Similarly, the amount of phosphorus fertilizer application rate in rice in the Philippines (15 kg/ha) is lower than in Thailand (33 kg/ha) and Indonesia (22 kg/ha). The amounts of potassium applied in the five Southeast Asian countries were also low, ranging from 4 to 17 kg/ha, with the Philippines applying at a rate of 11 kg/ha.

However, in corn crop, the Philippines has the highest nitrogen fertilizer application rate (58 kg/ha) than Thailand (56 kg/ha), Laos (50 kg/ha), Myanmar (35 kg/ha), while Indonesia has the least application rate (5 kg/ha). Thailand has the highest application rates for phosphorus and potassium fertilizers (Figure 43) while the Philippines has lower phosphorus (16 kg/ha) and potassium (10 kg/ha) application rates.

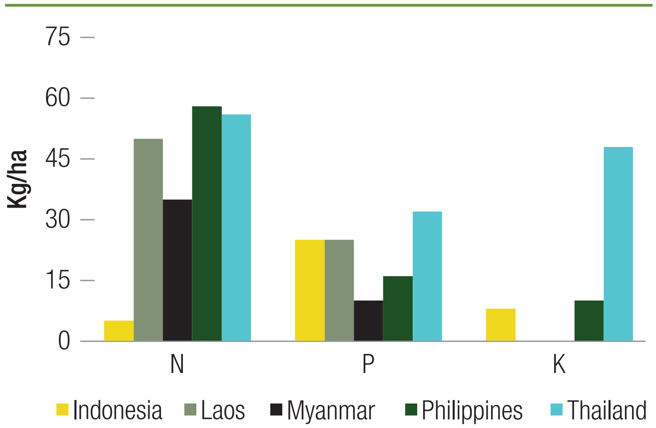
Figure 42: Fertilizer application rates in rice in Southeast Asian countries in 2001



Source: Fertistat 2001.

The Philippines (85 kg/ha) ranks second to Indonesia (90 kg/ha) in the application rates of nitrogen fertilizer in sugarcane (Figure 44). Among the five Southeast Asian countries, the Philippines and Thailand have the same rate of phosphorus fertilizer application (55 kg/ha) and this rate is higher than the other three Southeast Asian countries. Potassium fertilizer application rate in sugarcane in the Philippines (30 kg/ha) is lower than in Thailand (65 kg/ha).

Figure 43: Fertilizer application rates in corn in Southeast Asian countries in 2001



Source: Fertistat 2001.

3.2 Pesticide Use

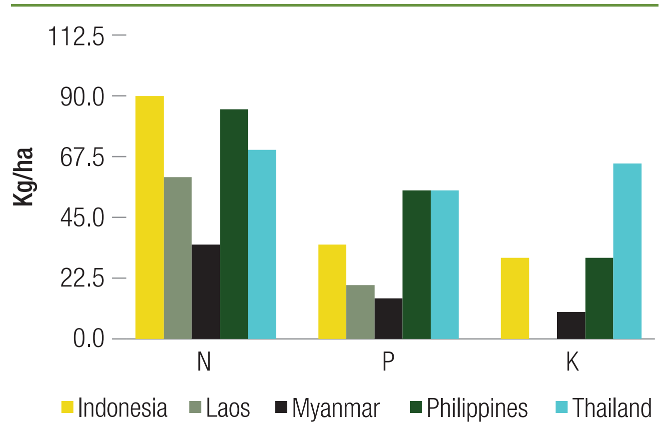
3.2.1 *Trends in Pesticide Use*

Before the 1970s, pesticide application in the Philippines was mainly concentrated in plantation crops (Tirado and Bedoya 2008). Use of pesticides in smallholder farms started with the Green Revolution package in the mid-1960s that included high-yielding crop varieties, improved irrigation, fertilizer and pesticides. Increase in the application of pesticides in smallholder farms commenced in the 1970s when disease and pest outbreaks occurred following the introduction of new varieties and with government credit scheme. The most widely used pesticides in the country are carbofuran, endrin, parathion, and monocrotophos while the most commonly used insecticides are organophosphates, carbamates, and pyrethroids.

3.2.2 *Total Pesticide Imports*

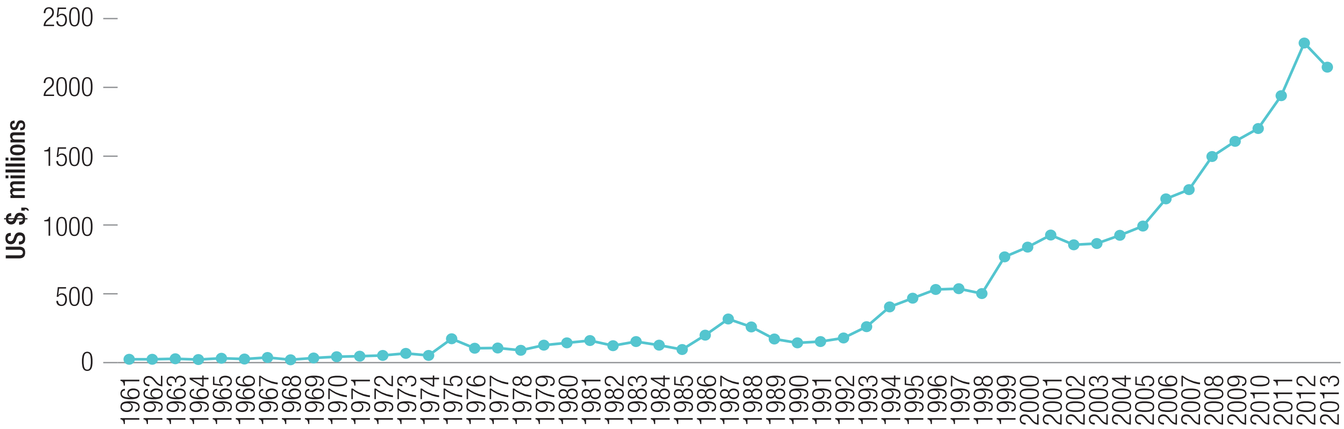
The Philippines imports a variety of pesticides including insecticides, herbicides, fungicides, disinfectants, and others. From 1961 to 1975, the total import values of pesticides were below US$5 million. In 1987, the value of pesticide imports peaked at US$31 million. From 1990, the import values of pesticide started to increase sharply from US$14 million to US$214

Figure 44: Fertilizer application rates in sugarcane



Source: Fertistat 2001.

Figure 45: Import values of pesticides in the Philippines



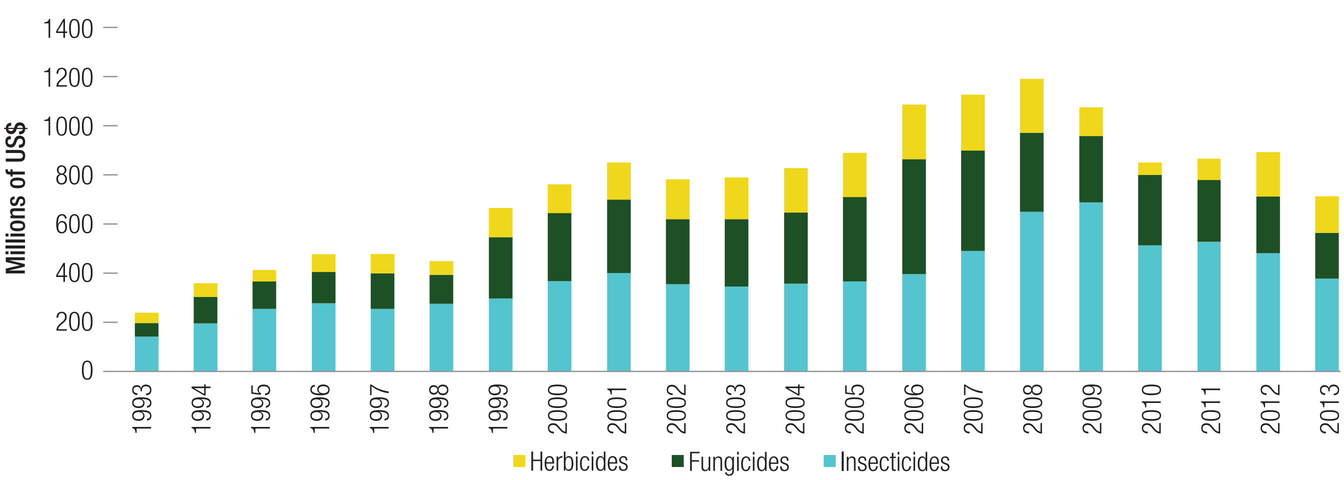
Source: FAO 2014.

million in 2013 (Figure 45). This translates to 1,428 percent increase in pesticide imports with an average increase of US$8.7 million per year.

3.2.3 *Import Values of Insecticides, Herbicides, and Fungicides*

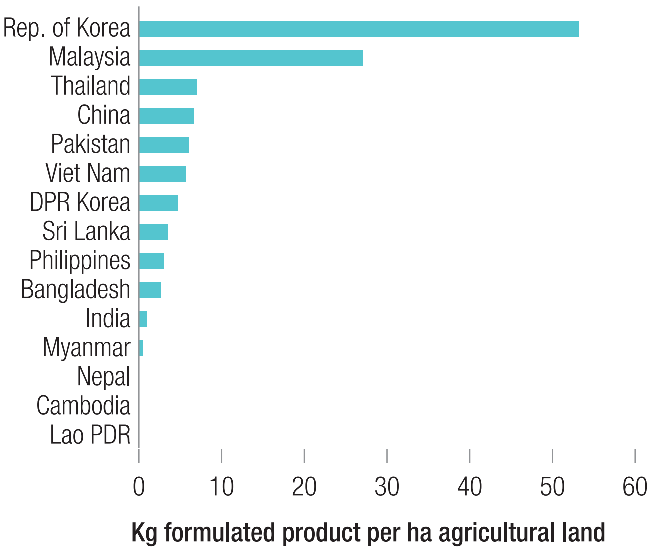
In this section, we only considered the three major groups of pesticides commonly used in crop farming systems: insecticides, herbicides, and fungicides and their proportional import values. Since 1993, the share of the import values of insecticides was greater than fungicides and herbicides, ranging from a minimum of 36.5 percent in 2006 to a maximum of 64 percent in the year 2009 (Figure 46). Import values of fungicides rank second and herbicides rank third. The import values of these three types of pesticides increased by 396 percent from US$24 million in 1993 to US$119 million in 2008. Beginning from 2009, there was a gradual decline in the import values of these pesticides used in cropping systems. Organophosphates, carbamates, and pyrethroids are the most widely used pesticides in cropping systems (Tirado and Bedoya 2008).

Figure 46: Import values of pesticides in the Philippines per type



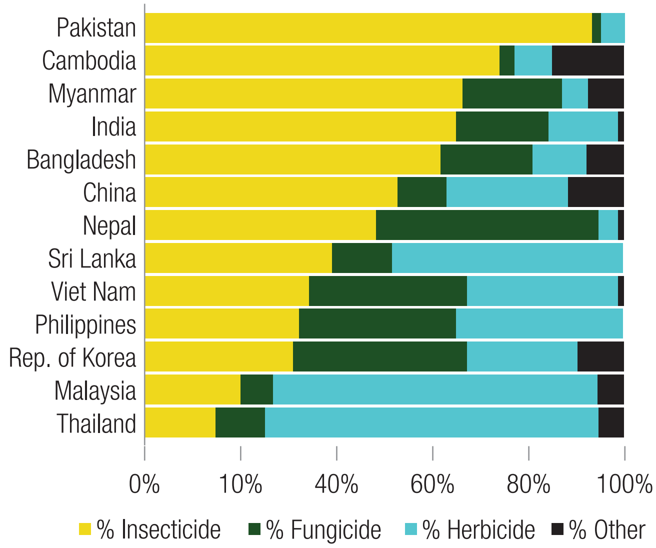
Source: FAO 2014.

Figure 47: Comparative pesticide use per hectare of agricultural land in Asian countries



Souce: FAO 2005.

Figure 48: Pesticide use pattern in the different Asian countries



Souce: FAO 2005.

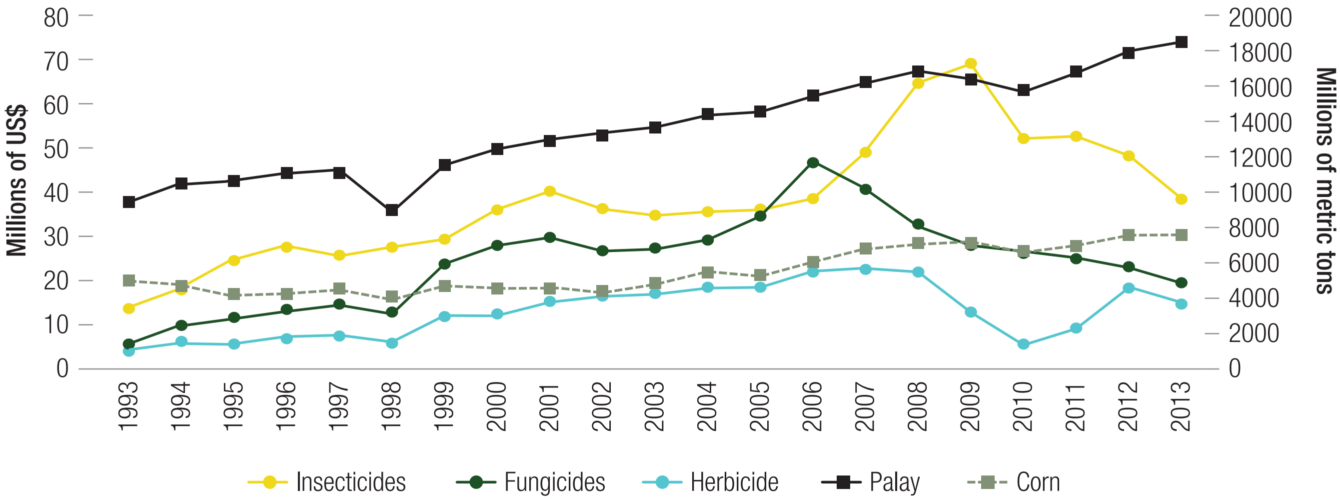
Pesticide use per hectare of agricultural land in the Philippines is much lower compared with neighbouring Asian countries including the Republic of Korea, Malaysia, Thailand, China, Pakistan, Vietnam, Democratic People's Republic of Korea, and Sri Lanka (Figure 47) (FAO 2005). Commonly used pesticides are composed of insecticides, fungicides, and herbicides (Figure 48). Insecticides are the widely used pesticides in Pakistan, Cambodia, Myanmar, India, and Bangladesh. On the other hand, herbicides are the widely used pesticides in plantation crops in Thailand, Malaysia, and Sri Lanka (FAO 2005). In the Philippines, pesticides that are used are composed of insecticides, fungicides, and herbicides.

Palay yield increased by 101 percent from 9,434,208 tons in 1993 to 18,439,420 tons in 2013. During the same period, corn production increased by 62 percent from 7,770,603 tons in 1993 to 4,797,977 tons in 2013 (Figure 49). On the other hand, import values of insecticides increased by 382 percent from 1993 to 2010; herbicides increased by 428 percent from 1993 to 2007; and fungicides increased by 761 percent from 1993 to 2006. About half of the total insecticides, at least 80 percent of herbicides, and 4 percent of fungicides consumed in the Philippines are applied in rice production systems (Pingali and Roger 1995). Starting in 1987, molluscicides are being applied to control snail infestation in rice fields.

The total amount of pesticides used in rice and corn production systems in the Philippines is small compared with other Asian countries including Japan, China, South Korea, Thailand, Vietnam, and Indonesia (Gerpacio et al. 2004; Pingali and Roger 1995). In corn production systems, corn farmers apply insecticides only when the level of corn borer infestation is high and sometimes, the availability of insecticides is constraint by trader-financiers (Gerpacio et al. 2004). Globally, pesticide use in rice cropping systems in the Philippines accounted for only 2 percent of the world market value in 1988 (Woodburn 1990 as cited in Pingali and Roger 1995).

Starting in 2005, pesticide imports in the Philippines started to decline (Figure 49). However, despite this downward trend, corn and palay production continued to increase in the recent years. This maybe attributed to the government support on sustainable

Figure 49: Increase in volume of palay and corn production and trends in the import values of pesticides from 1993 to 2013



Source: Based on PSA 2015 and FAO 2014.

agriculture. Since 2000, sustainable agriculture has become popular and is being supported by the government. Generally, sustainable agriculture is economically practical, ecologically sound, and socially humane. Common practices under it include IPM, synchronized rice planting, crop rotations, deliberate use of animal and green manures, soil and water conservation methods, use of environmental friendly inputs, and training of farmers and consumers. Moreover, sustainable agriculture includes organic farming, conservation farming, green agriculture, ecological farming, natural farming, and so on. These production methods target the goals of profitability, quality of life, and stewardship (Maghirang and Villareal 2000).

The increased importation of herbicides in the past 3 years is due to the rising labor costs to control weeds. Farmers apply herbicides early in the cropping season to control the growth of weeds and to give the crop a head start over the growth of weeds.

3.2.4 *Trends in Insecticide Application in Central Luzon*

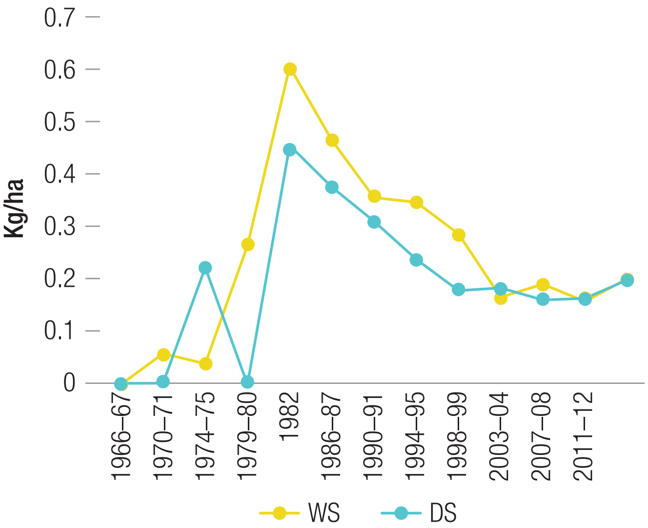
Insecticides were part of the Green Revolution package, together with other modern rice varieties and fertilizers, during the 1960s and 1970s. In Central Luzon, farmers are using insecticides to protect their harvest from pests and diseases such as stemborer, leafhopper, blast, and tungro, among others. They also use molluscicide to protect rice plant from snails. These methods are components of IPM which is deemed helpful in controlling pest attacks (Moya et al. 2015).

The most destructive insect in Central Luzon and in Asia is the brown planthopper (BPH). BPH feeds directly on large numbers of rice plants causing 'hopper-burn'. It carries ragged stunt and grassy stunt viruses. Moreover, it can develop new biotypes that can resist insecticides (Moya et al. 2015).

Based on the Central Luzon Loop Survey from 1966 to 2012, during wet season, the farmers used a very small amount of insecticide in 1966, then suddenly increased in 1982, and remained high until 1990. The peak of insecticide use was recorded around 1980, then it was followed by a continuous decline until around 2000 (Figure 50). Insecticide application during the dry season is lower than the amount applied during the wet season, though they have nearly similar trends from 1966 to 2012.

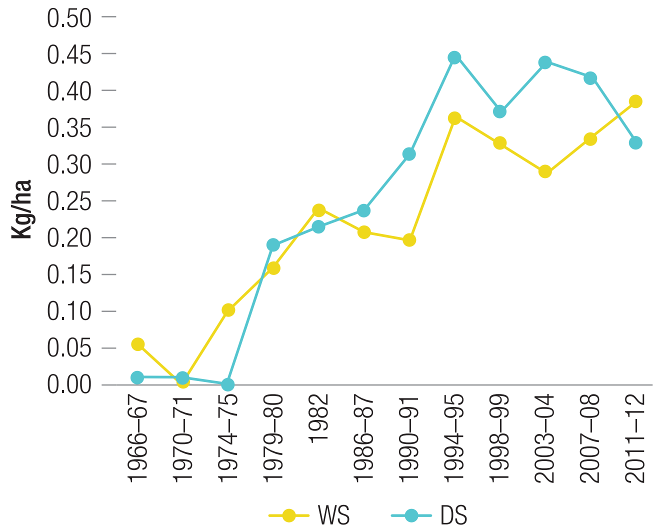
Insecticide application eventually leads to pest outbreak (as in the case of BPH) by eliminating not

Figure 50: Trends in insecticide use (kg active ingredients per ha) during the wet and dry season croppings in Central Luzon



Source: Moya et al. 2015.

Figure 51: Trends in herbicide use (kg active ingredients per ha) during the wet and dry cropping seasons in Central Luzon from 1966 to 2012



Source: Moya et al. 2015.

only the target species (BPH) but also other non-target species that play a key role in the *Regulating Ecosystem Service* as natural enemies of insect pests (Settele et al. 2015). Many rice farmers do not know that rice pests can be controlled by natural enemies and that pesticide application can exacerbate damage through insecticide resistance and resurgence (Cohen et al. 1994).

3.2.5 *Herbicide Use*

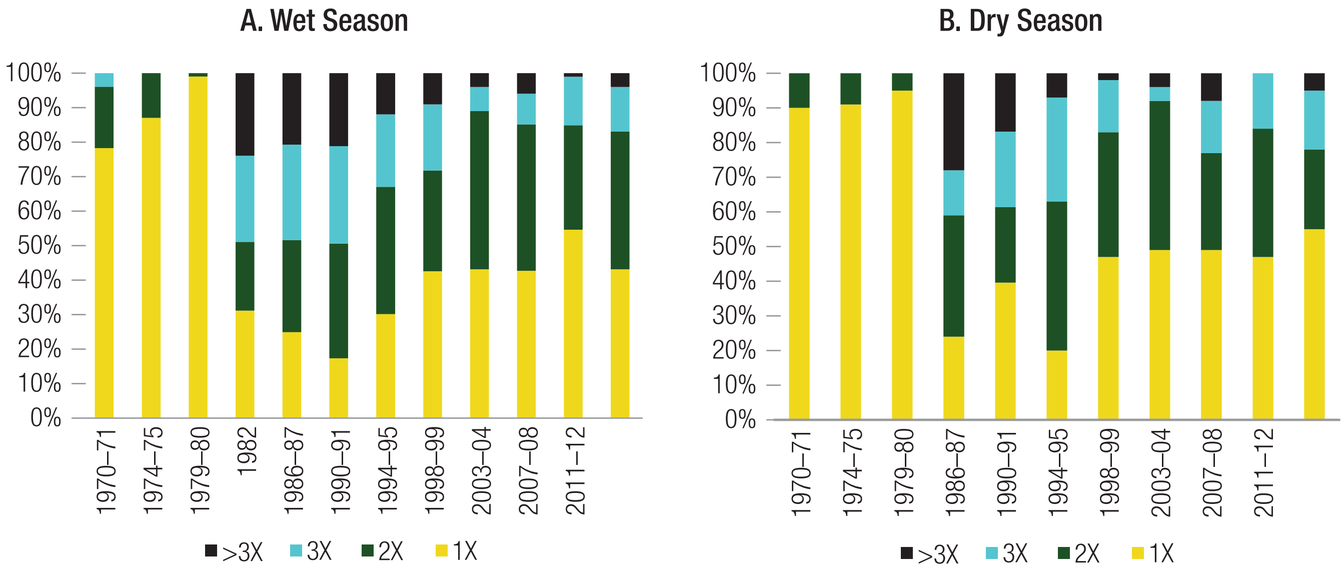
The increasing herbicide use by farmers in Central Luzon is in contrast with the decreasing trend in insecticide use. The increase started after 1974–1975 when the farmers applied herbicide in rice crop during its early growth period (Figure 51). Moreover, the increase was attributed to the decline of farm labor in the area and increase in wage rates (Central Loop Survey 1966–2012). During the dry season, the use of herbicide is slightly higher because the farmers practiced direct seeding which uses herbicide to control weeds.

3.2.6 *Frequency and Timing of Insecticide Application during the Wet and Dry Season Rice Cropping*

The IRRI conducted a five decade-long household survey of rice cropping systems in Central Luzon from 1966 to 2012 primarily to study the structural and economic changes in rice farming. Part of the study is about the changes in crop management practices that include pest management. During the decade of 1970 to 1980, majority of the farmers (>80 percent) applied insecticides once for both the wet and dry rice cropping seasons. Beginning from the 1980s, the frequency of insecticide application increased up to four times during the cropping for both wet and dry seasons (Figure 52).

For both wet and dry cropping seasons from 1979 to 2012, majority of the farmers applied insecticides 16–45 DAT of rice seedlings (Figure 53). During the wet season cropping in 1994–1995 and 2003–2004, and dry season cropping of 1998–1999 and 2007–2008, about 30 percent of the farmers applied insecticide at >60 DAT.

Figure 52: Frequency of insecticides application in (a) wet season and (b) dry season of the surveyed farmers, Central Luzon Loop Survey 1966–2012



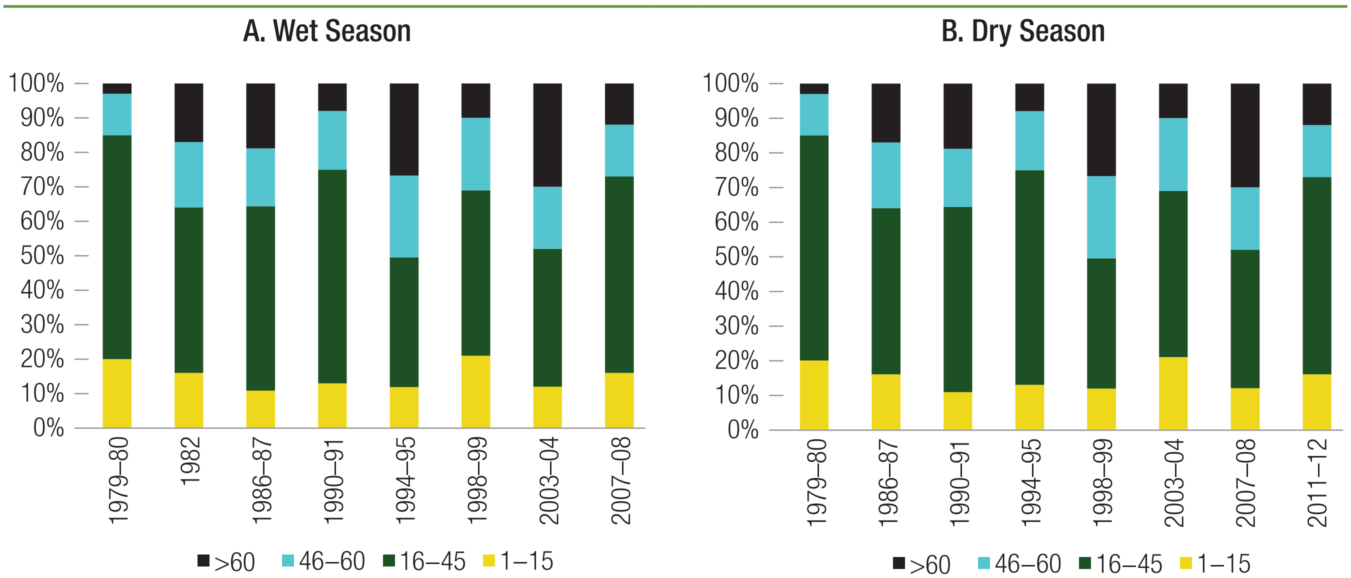
Source: Moya et al. 2015.

3.2.7 *Frequency and Timing of Herbicide Application in Wet and Dry Season Rice Cropping*

From 1966 to early 1970s, all the farmers applied herbicides once during both the wet and dry rice cropping seasons (Figure 54). Beginning in 1974, farmers started to increase the spraying of herbicides to two times or even to three times during both cropping seasons.

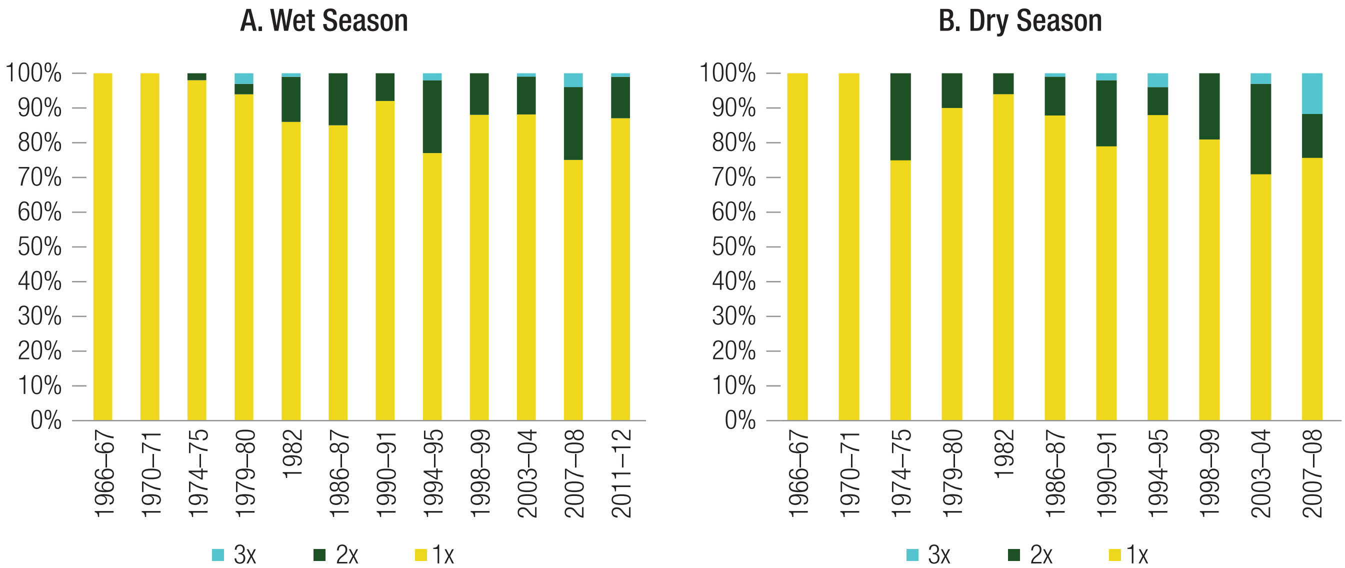
During the wet season rice cropping, except for the year of 1966–1967, majority of the farmers (70–80

Figure 53: Timing (DAT) of insecticides application in (a) wet season and (b) dry season of the surveyed farmers, Central Luzon Loop Survey 1966–2012



Source: Moya et al. 2015.

Figure 54: Frequency of herbicides application in (a) wet season and (b) dry season of the surveyed farmers, Central Luzon Loop Survey 1966–2012



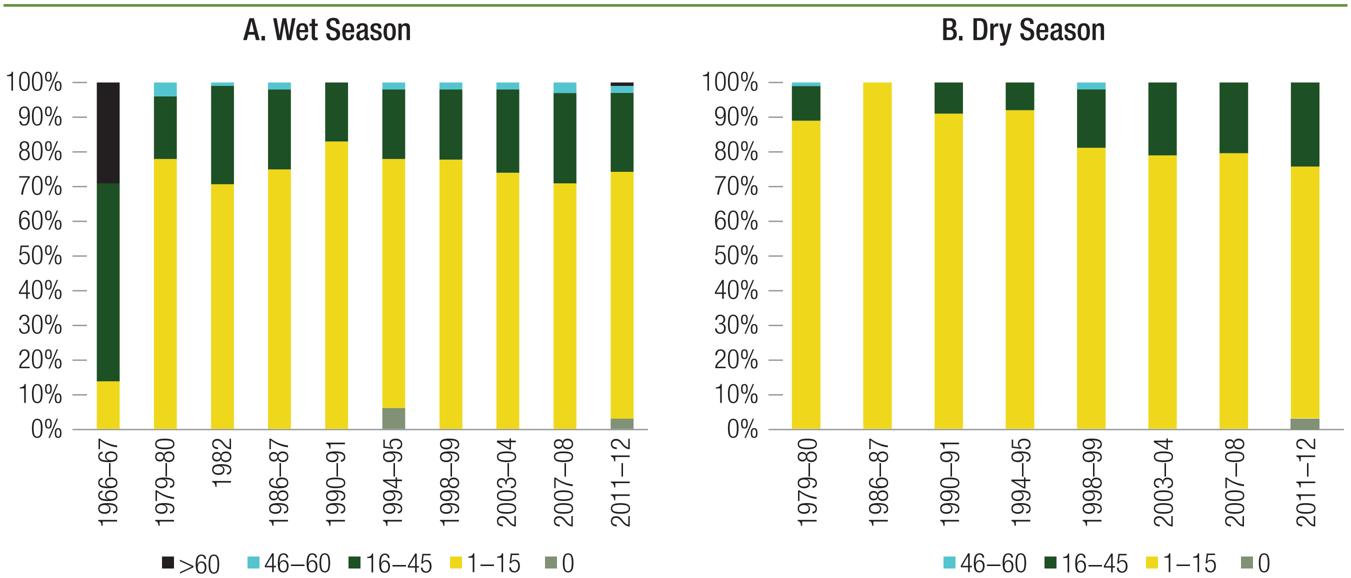
Source: Moya et al. 2015.

percent) applied herbicides 1–15 DAT while the rest of the farmers (5–30 percent) applied herbicides at 16–45 DAT (Figure 55). During the dry season cropping, majority of the farmers (75–90 percent), applied herbicides at 1–15 DAT while the others applied at 16–45 DAT.

3.2.8 *Pesticide Application in Vegetables, Banana, and Rice*

In 2000, ACIAR reported that largest gross application of pesticides among the important crops grown in the Philippines, the rice crop, primarily due to extensive

Figure 55: Timing (DAT) of herbicides application in (a) wet season and (b) dry season of the surveyed farmers, Central Luzon Loop Survey, 1966–2012



Source: Moya et al. 2015.

areas planted with rice all over the country. The other important crops heavily applied with pesticides are vegetable and banana.

The pesticides commonly used in growing temperate vegetables in the provinces of Benguet, Mt. Province, and Ifugao in the Cordilleras belong to the pyrethroid, organophosphates, and carbamate class of pesticides (Table 15, Ngidlo et al. 2013). Organochlorides like DDT and endrin are not used in the area after the restriction of its use in 1980. The brand names of herbicides commonly used in these temperate-vegetable-growing areas are Power, Gramoxone, Clear Out, Afalon, Bio 480, and Redeem.

In agricultural areas cultivated with rice, corn, and cassava in Mindanao, including the provinces of Bukidnon, Misamis Oriental, Misamis Occidental, and Zamboanga del Sur, Perez et al. (2015) reported that pyrethroid, phenoxyacetic acid derivatives, and organophosphate pesticides are commonly used by farmers (Table 16) (Perez et al. 2015). Other pesticides used are salicyanilide, nitro compounds, nereistoxin, aldehyde, and others (Table 16).

Fungicides are the most commonly used pesticides in banana plantations in Mindanao (Table 17). The active ingredients of these fungicides include azoxystrobin, biterthanol, propiconazole, tridemorph, and others.

However, the heavy reliance on chemical control, host plant resistance, and widespread cultivation of HYVs during the Green Revolution resulted in problems caused by weeds, diseases, and insects. This intensive use of pesticides then led to pest outbreaks (Maredia, Dakouo, and Mota-Sanchez 2003). This paved way for IPM to be declared as the national crop protection policy by the Philipipne government in 1986. IPM focused on ecology-based approaches using season-long farmer training, and cost-reducing technology for pest control in rice. Some approaches of IPM include the use of resistant varieties, and cultural methods (sanitation, proper spacing, low use of nitrogen and proper water management, and synchronous planting on large continuous areas). IPM was set as the standard method for crop production wherein farmers were trained on the agroecosystem interactions affecting plant growth and crop management (Maredia, Dakouo, and Mota-Sanchez 2003).

Table 15: Insecticides commonly used in temperate vegetables in the Cordilleras

Name of insecticide	Active ingredients	Frequency of application	Pesticide class
Sumicidin	Fenvalerate	15	Pyrethroid
Bida	Cyhalothrin	10	Pyrethroid
Karate	Cyhalothrin	10	Pyrethroid
Nurell	Cypermethrin	2	Pyrethroid
Selecron	Profenofos	5	Organophosphate
Tamaron	Methamidophos	10	Organophosphate
Silicron	Dimethoate	5	Organophosphate
Lorsban	Chlorpyrifos	3	Organophosphate
Cartap	Dymethylamin	10	Carbamate

Source: Ngidlo et al. 2013.

On the other hand, the study of the Manila Bay river systems also sampled for pesticide contamination. Pesticide residue analysis of soil samples showed that levels of organochlorine, organophosphates, and pyrethoids, are below the limit of quantification (LOQ) at 0.005 mg/kg (Samar 2012). As with fertilizer usage, the use of pesticides in the Manila Bay system crop lands is below recommended levels (and in fact has been declining in the case of insecticides). Hence, pesticide contamination appears to remain at levels that can be managed by natural processes within the relevant ecosystem.

Even though the farmers in the Philippines are using less toxic pesticides, majority of those pesticides are highly poisonous to fish and other aquatic organisms (Fabro and Varca 2012). The pollutants from the agricultural activities within the Pagsanjan-Lumban catchment affect the fisheries in the area (Varca 2012). Among the pesticides used, the pyrethroids were identified to be highly toxic to the tilapia fingerling and freshwater shrimp. Moreover, the sediment-bound contaminants cause changes to the food source of crabs, freshwater shrimp, and fish (Bajet et al. 2012).

Table 16: Active ingredients of pesticides commonly used in rice, corn and cassava in Mindanao

Active ingredient	WHO classification	Chemical family
Cypermethrin	II	Pyrethroid
Lambda-cyhalothrin	II	Pyrethroid
2,4 D IBE	II	Phenoxyacetic acid derivative
Butachlore + propanil	III	Organophosphate
Niclosamide	U	Salicyanilide
Niclosamide ethanolamine salt	U	Nitro compound
Cartap hydrochloride	III	Nereistoxin
Chlorpyrifos	II	Organophosphate
Beta-cypermethrin	II	Pyrethroid
Malathion	U	Organophosphate
Metaldehyde	II	Aldehyde
Diazinon	II	Organophosphate
Carbofuran	IB	Carbamate
Phenthoate + BPMC	II	Organophosphate + Carbamate
Methomyl	IB	Carbamate
Glyphosate IPA	U	Phosphonoglycine
Coumatetralyl	IB	Coumatrin derivative
Thiobencarb	II	Thiocarbamate
Imidacloprid	II	Pyrethroid
Pyribenzoxim	U	—
Beta-cyfluthrin	II	Pyrethroid
Metsulfuron Methyl + Chlorimurone	U	Sulfonylurea
Endosulfan	II	Organochlorine
Fipronyl	II	Pyrazole
Fenoxaprop p-ethyl	III	Aryloxyphenoxypropionate
Difenoconazole + Propiconaloze	II	Azole
Zinc phosphide	IB	Inorganic zinc
Monochrotophos	IB	Organophosphate
Deltamethrin	II	Pyrethroid
Chlorantraniliprole	III	Oxadiazine
Copper hydroxide	III	Copper hydroxide
Tebuconazole	II	Triazole
MIPC (Isoprocarb)	II	Carbamate
Diuron	U	—
Thiophanate Methyl	U	—

Source: Perez et al. 2015.
Note: II = moderately hazardous; U = unlikely to present acute hazard (WHO 2009).

Table 17: List of fungicides used by banana plantation companies in Mindanao (2006)

Active ingredient	Product/brand name	Documented health effects
Azoxystrobin	Bankit 250 EC	Highly toxic to fish and aquatic invertebrates; not allowed for use in Canada
Biterthanol	Baycor 300 EC	Possible source of birth defects; not allowed for use in U.S. farms
Propiconazole	Bumper 250 EC	Possibly carcinogenic/cancer-causing; contains reproductive toxins
Tridemorph	Calixin 750 EC	Causes birth defects; not allowed for use in Canada
Chlorothalonil	Daconil 720 F	Carcinogenic; highly toxic to fish and aquatic invertebrates; it builds up in fish
Mancozeb	Dithane 448 F	Carcinogenic; contains reproductive toxins; (commonly used) may cause birth defects; suspected to disrupt endocrine in aerial spraying
Diteconazole	Sico 250 EC	
Mancozeb	Vondozeb Plus 80 WP	Potential cause of birth defects
Thiophanate	Topsin M 70 WP	Very highly toxic to catfish; toxic to earthworms; Methyl causes damage to the thyroid gland, leading to hyperthyroidism

Source: Fuertes 2006.

3.2.9 *Evolution of Pest and Disease Management in Rice*

Rats and Rodents. Bautista and Javier (2005) mentioned that a pair of adult rats can inflict at least 50 percent rice yield loss.

It was reported by Camus (1921) as cited by Bautista and Javier (2005) that destroying the habitats of rodents and rats by setting them on fire—and in turn killing these pests—is an economical way of pest control. Camus also recommended the field application of poisonous chemicals such as white arsenic, barium carbonate, or strychnine sulfate but reminded to apply these with extra care to avoid possible effects to humans and animals.

A more sustainable rat management technique was developed based on the biology and behavior of rats. Community trap barrier system or CTBS, is 'an environment-friendly, cost-effective, and sustainable community-based approach' where farmers work in groups (Joshi 2003 from Bautista and Javier 2005). The CTBS involves installing rice plants with plastic around them as barriers 2–3 weeks before actual transplanting dates of the community in time when rats are reproducing. Rats would be able to find the crop in the CTBS with their strong sense of smell. The CTBS has an opening on one side of the barrier leading to the cage or trap designed like a cone to allow the rat to enter but not to escape.

Birds. 'Mayang pula'and the 'Mayang paking' are among the most destructive birds to the rice plant. Farmers control them by catching them for food or driving them away all day. However, these birds get accustomed to farmers driving them away and are not easily impelled away from the rice plant. Thus, other methods such as trapping the birds using ficus gum in sticks around the farms; using net traps in the field; and manually net sweeping the birds during nighttime were devised.

Insect Pests. Migratory locusts and rice bugs were among the most destructive insects in the past (Bautista and Javier 2005 as cited from Camus 1921). Migratory locusts were destroyed by driving them to pits while the rice bugs were controlled by a 'systematic crop rotation and clean culture'. Other insect management measures were: (a) using a putrefying meat in a bag as bait to attract adult bugs then burning it; (b) early planting of rice as trap crop before actual rice crop is set to allow the rice bugs to feed and live on the rice plants and afterwards burning these with the bugs, and (c) simultaneous and synchronous transplanting of varieties with the same maturity. Yet, the synchronous transplanting was not accepted by all farmers since harvesting by hand was too tedious when all rice plants mature at the same time.

Aragon (1930) as cited by Bautista and Javier (2005) reported that the rice stem borer, another destructive insect, was controlled by cleaning around the field before sowing to destroy the insect's eggs. On the other hand, common pests that infest fields such as leaf folders and cutworms (or army worms) were controlled by clean surroundings and crop rotation. Moreover, the case worms *(aksip na pula)* was as common as rice leaf roller *(Cnaphalocrosis medinalis)*, rice bug *(Leptocorisa acuta)* and stalk borer *(Schoenobius incertellus)* as early as 1930. Case worms are regulated by completely draining the paddy field until the pests are eliminated (Bautista 1949). Almost all of the aforementioned insects were observed in 1952 except for the leafhoppers. Poster campaigns, informative articles, bulletins, circulars about the insects, and effective ways to eliminate and regulate them are some of the control measures enumerated by Bautista and Javier (2005) from Otanes (1952).

The BPH, another rice pest, was widely observed in the Philippines in 1954. It was first detected in Calamba although it became a concern only in 1973 when at least a thousand hectares were destroyed by the BPH. Laguna was continually infested by the BPH through 1974 affecting over 10,000 ha. Moreover, Mindanao was also affected by serious outbreaks in 1976 that caused considerable losses. A grassy stunt virus transmitted by BPH infested Laguna's rice fields, contributing to great losses of yield for rice farmers. Technical personnel, chemicals, and equipment were gathered to control the spread of pests during the infestation. Pest control groups composed of farmers were organized to cover infested areas. Educational drive among farmers was organized to introduce modern crop protection. The Bureau of Plant Industry (BPI) also initiated a rice-planting ban, with the exception of rice variety IR26, in Laguna during the 1974 dry season to attempt to break the BPH cycle with grassy stunt virus (BPI 1981 as cited by Bautista and Javier 2005).

Farmers practice extensive use of chemicals and insecticides as well as calendar spraying, recommended through the Masagana 99 rice program. However, farmers are not informed that not all insects in the rice paddy areas are harmful. Consequently, continuous insecticide spraying caused insect immunity to insecticides which increased their number but killing friendly insects. IPM was developed by scientists to control harmful insect infestation without affecting human health and the environment.

Diseases. The declining yield of modern rice varieties may be attributed to their lack of resistance to increased insect and disease pressure. According to Serrano (1952) as stated by Bautista and Javier (2005), rice *tungro* (an Ilocano term, also known as *aksip na pula* in Bulacan) was considered the most destructive disease in the Philippines during the 1940s. It was estimated that 1.4 million tons (30 percent) of annual rice producion was lost during its infestation in the 1940s. Hundreds of hectares of rice plantation in Central Luzon and Bicol Region were devastated because of rice *tungro*. Rice *tungro* was combated through information campaigns from BPI. Pesticides were also distributed for free to aid the farmers toward disease containment.

In late 1976 rice gall disease, another rice disease was discovered in Mindanao. It affected over 1,000 ha of rice with over 50 percent loss of crop yield. The disease was supressed by using highly resistant varieties such as IR32, IR36, and IR42; along with BPI's vigorous campaign.

3.2.10 Integrated Pest Management

IPM is an ecosystem approach of crop production involving crop protection strategies with minimal use of pesticides. IPM is being promoted by FAO as a pillar of sustainable intensification of crop production and pesticide risk reduction. IPM focuses on ecology-based approaches using season-long farmer training and cost-reducing technology for pest control in rice.

IPM began in the Philippines during the early 1940s when farmers planted disease- or pest-resistant crops. Then, they practiced intercropping, crop rotation, and used botanical repellents or biological control agents in controlling pests and insects. A nationwide rice shortage in the early 1970s intensified rice production through the government's 'Masagana 99 Rice Program'. Pesticides were a part of the production loan under this program. Moreover, it was recommended by the program that pesticides should be applied six to nine times for every cropping season. This then led to pest outbreaks due to heavy use of pesticides (Maredia, Dakouo, and Mota-Sanchez 2003).

During this program, IPM was first tested in identified strategic rice production areas all over the country by the IRRI, Bureau of Plant Industry Crop Production Division, and other state colleges and universities. Then, the late President Corazon Aquino declared in 1986 that IPM would be the core of the crop protection policy. Thus, the different agricultural programs included the development, distribution and transfer of different IPM technology. Moreover, multisector IPM technical working groups, the Training and Extension Committee and the Research and Development Committee were created by the Ministry of Agriculture and Food to support this policy. Since then, IPM has been able to provide economic, social, and environmental benefits (Maredia, Dakouo, and Mota-Sanchez 2003).

Then, the Philippine National IPM Program was created by President Fidel Ramos in 1993. It was named as Kasaganaan ng Sakahan at Kalikasan - Prosperity of the Farm and Nature (KASAKALIKASAN). Under this program, IPM was set as the standard method for crop production (Maredia, Dakouo, and Mota-Sanchez 2003).

IPM focused on ecology-based approaches using season-long farmer training, and cost-reducing technology for pest control in rice. Some approaches of IPM include the use of resistant varieties and cultural methods (sanitation, proper spacing, low use of nitrogen and proper water management, and synchronous planting on large continuous areas).

3.2.11 Biotechnology

In the Asian region, the Philippines leads in the adoption of genetically engineered (GE) corn since 2003 (Corpuz 2015). In 2014, a quarter of the corn-growing areas in the country were cultivated with GE corn. However, commercialization of Philippine GE research has slowed down recently while neighboring Asian countries like Vietnam and Indonesia are poised to commence their commercial GE corn production in 2015.

The the University of the Philippines at Los Baños (UPLB) has conducted a lot of research on corn production. For instance, researches conducted at the Institute of Plant Breeding (IPB) of UPLB include studies on the evaluation of white maize varieties for food uses, development of mass rearing technique, and evaluating the effectiveness of the larval-pupal parasitoid against the Asian corn borer. Salazar et al. (1999) conducted breeding studies to develop yellow and white maize inbred lines, high-yielding hybrids, populations having resistance to Asiatic corn borer, downy mildew, bacterial stalk rot, banded leaf and sheath blight disease, and physiological stresses such as tolerance to water deficit stress, short anther-dehiscence silk interval.

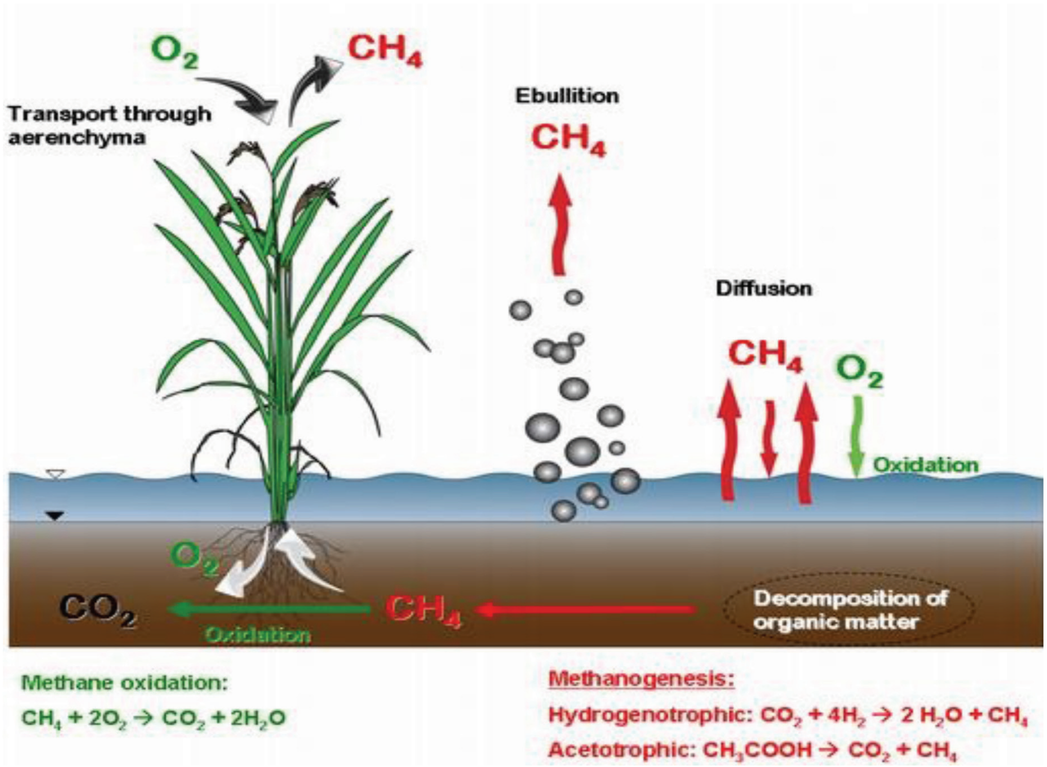
3.3 Sources of Greenhouse Gas Emissions

3.3.1 *GHG Emissions Irrigated Rice fields Are Sources of Nitrous Oxide (N_2O) and Methane (CH_4)*

Methane Production Processes

CH_4 is produced through anaerobic decomposition of organic material and by diffusive transport within the paddy rice ecosystem, is released to the atmosphere (Figure 56). Moreover, its main pathways are the reduction of CO_2 with H_2 and the transmethylation of acetic acid or methanol. The reduction involves hydrogen donors such as fatty acids and alcohols, whereas, the transmethylation involves bacteria which produces

Figure 56: Processes of methanogenesis and methane oxidation in paddy rice



Source: IBP 2015.

methane. The composition and texture of soil and the inorganic electron acceptors in it mainly affect the reduction processes. There are differences between the period of soil flooding and the onset of methanogenesis based on the soil type. However, the effect of soil type on the rates of methanogenesis and CH_4 emission in steady state is still uncertain.

Redox potential, carbon substrate, and nutrient availability are important factors in CH_4 production. A concept in redox potential is the electron activity of soil decreases after irrigation. Patrick, de Laune, and Smith (1981) and Yamane and Sato (1964) demonstrated that CH_4 production from irrigated rice fields will not begin until the electron activity reached –150 mV. Rice straw in paddy fields increases the CH_4 production rate compared with the compost with chemical fertilizer or rice straw (IPCC 1996; Dobermann and Fairhust 2002).

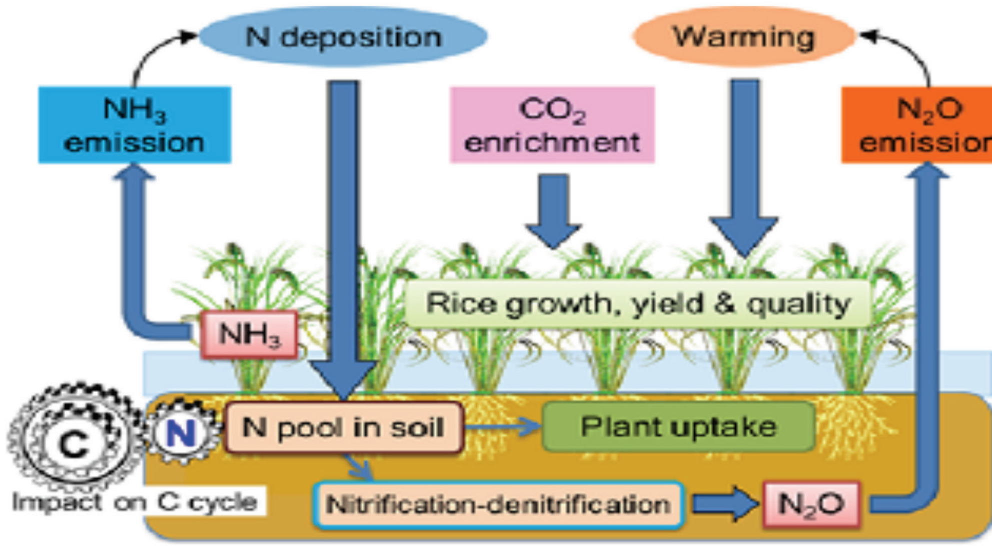
Moreover, the activity of soil microorganisms is affected by soil temperature. The heat capacity and conductivity are lower in dry soil than in wet soil. According to Yamane and Sato (1961), the maximum CH_4 formation is reached at 35°C in wet soil. On the other hand, the rate is slow below 20°C.

Generally, CH_4 production is only efficient in pH ranging from 6.4 to 7.8. Irrigation increases the pH in acidic soils and decreases the pH in alkaline soil. The increase is affected by the reduction of acidic Fe^{3+} to Fe^{2+}.

The nitrate in irrigated soils suppresses the CH_4 production because it serves as a terminal electron acceptor, when oxygen is not available, in anaerobic respiration. The sulfate also suppresses the CH_4 production the same way as nitrate does.

Diffusion loss, methane loss, and CH_4 transport are the processes by which CH_4 is released from rice fields to the atmosphere. The least important among these processes is the diffusion loss across the water surface. The most common and major release process is

Figure 57: Nitrogen transformations in paddy rice ecosystem



Source: NIAES 2012.

the methane loss as bubbles from soils especially during land preparation and initial growth stage of rice plants. The most important process is the CH_4 transport through the rice (Figure 56). According to researchers, among the three processes by which CH_4 is released, more than 90 percent of CH_4 produced during cropping season is emitted through diffusive transport.

3.3.2 *Mechanisms Responsible for Formation of N_2O*

Nitrification by microbes and denitrification processes, with nonbiological chemodenitrification, mainly results in direct nitrous oxide (N_2O) production. Nitrification process is shown below, wherein ammonium ions undergo aerobic microbial oxidation to produce nitrite through NH_2OH then into nitrate (Smith, Bouwman, and Braatz 1999).

$$NH_4^+ \rightarrow NH_2OH \rightarrow NO_2^- \rightarrow NO_3^-$$

Ammonium oxidizers use NO_2 when oxygen is limited. NO_2 serves as a substitute electron acceptor and produces N_2O which is formed through denitrification. As shown below, nitrate undergoes anaerobic microbial reduction successively to nitrite then to gases NO, N_2O, and N_2.

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

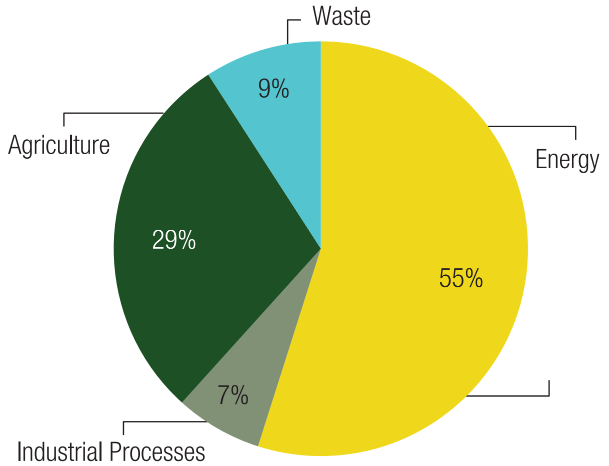
Chemodenitrification is less important than nitrification as a N_2O source from agricultural soil. It involves chemical reduction from nitrite ion into N_2O through amines in organic soil and through inorganic ions such as Fe^{2+} and Cu^{2+} in subsoils.

N_2O production mainly depends on the mineral nitrogen substrates such as ammonium and nitrate in the soil. Thus, there will be major drivers of N_2O production if there is addition of nitrogen from fertilizers and other sources such as crops residues, sewage sludge, animal manures, and N_2-fixing crops (Figure 57). Ammonium is released from these sources through mineralization.

3.3.3 *GHG Emissions from the Agriculture Sector*

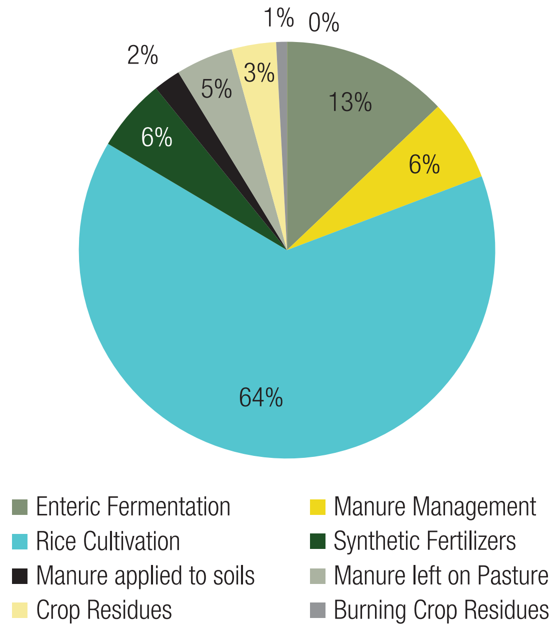
In the Philippines Second National Communication (UNFCCC 2001), the Agriculture sector ranks second (37, 003 Gg CO_2eq) to the energy sector (69,667 Gg

Figure 58: Sectoral GHG emissions in the Philippines



Source: UNFCCC 2001.

Figure 59: GHG emissions from the agricultural sector in the Philippines 2012



Source: FAOSTAT 2013.

CO_2eq) in the amount of GHG emissions in 2000 (Figure 58). GHG emissions from agriculture account for 29 percent of the total national GHG emissions.

In 2012, the total GHG emissions from the Philippine agricultural sector increased by 38 percent from the 2000 GHG inventory to 51,256 Gg CO_2eq (FAOSTAT 2013). Methane emissions from rice cultivation constitute about 64 percent (32,951 Gg) (Figure 59). N_2O emissions from synthetic fertilizer application account for 6 percent (2,887 Gg). Burning of crop residues contribute about 1 percent composed of 309 Gg CH_4 and 118 Gg N_2O. N_2O emissions from the decomposition of crop residues left in the field contribute about 3 percent (1,767 Gg).

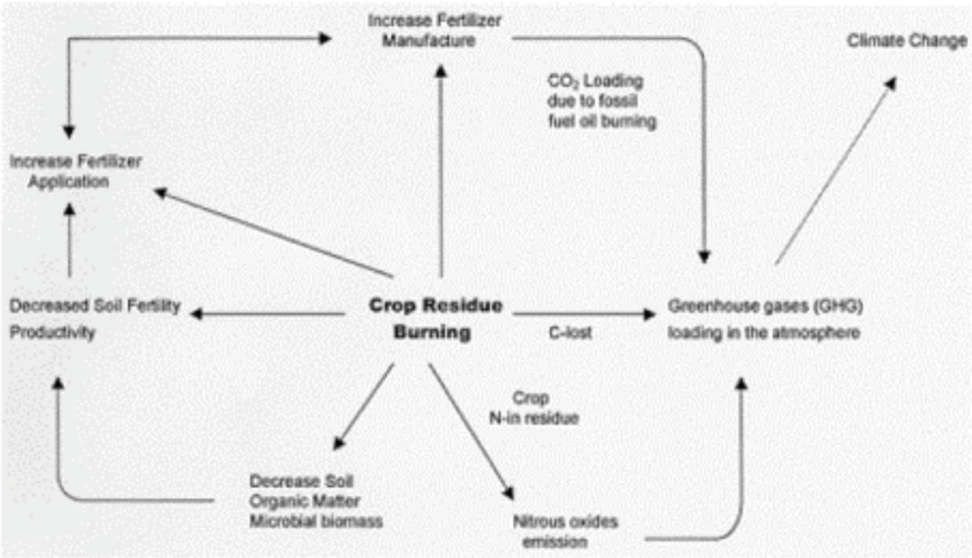
3.4 Open Burning of Crop Residues

Burning of rice, corn, and sugarcane residues is still widely practiced in the Philippines. This practice is being done to minimize labor requirement for land preparation of the farms for the next cropping season. Burning of crop residues is also a way to control pests and part of fertilizer management system. The ashes also serve as an immediate source of phosphorus and potassium and to control pests and diseases. However, burning is also a quick way to lose the precious nutrients (particularly nitrogen) from the residues, contributes to GHG emissions (CH_4 and N_2O), and releases toxic gases into the atmosphere. Crop residue burning results in the decline of soil organic matter and contributes to the gradual decline in soil fertility and productivity (Figure 60).

In the 1970s, burning of crop biomass wastes was done to control the spread of rice tungro virus (RTV) and rodents (Mendoza and Roger 1999). Agricultural biomass wastes may include hull, straw, leaves, stem, bran, cob, stalks, stove, shoots, silage, stalks, bark, root cuttings, branches, twigs, seeds, skin peelings, pith, shell, dust, fiber, trash, bagasse, culms, and flowers (Table 18).

The amount of rice biomass burned increased by 47 percent from 1,748,555 tons in 1961 to 2,579,478 tons in 2012 (Figure 61). The nitrogen content of rice straw may range from 0.5–0.8 percent (dry matter) equivalent to removal of 5–8 kg N/ha with the removal of 1 ton of rice straw (Dobermann and Fairhurst 2002). The phosphorus content of rice straw may range from 0.07–0.12 percent (dry matter) equivalent to removal

Figure 60: Interactive (additive) effects of crop residue burning in relation to GHG loading in the atmosphere



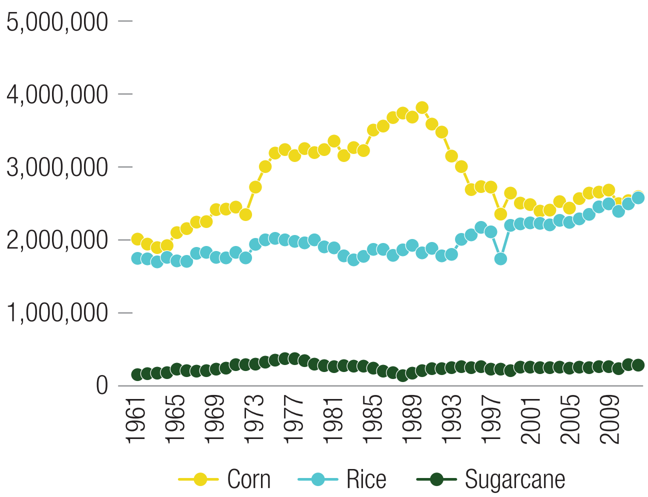
Source: Mendoza and Roger 1999.

Table 18: Biomass wastes from various crops and plants

Crop	Biomass wastes
Palay/rice	Hull, straw, leaves, stem, bran
Corn	Cob, stalks, stove, straw, shoots, silage, leaves
Fruit crops	Stalks, bark, root cuttings, silage, stem, root, residue, branches, twigs, seeds, skin peelings, heart, leaves
Non-food, industrial, and commercial crops	Leaves, stem, roots, residue, cuttings, coconut coir/pith, shell, husk, dust, fiber, cotton gin trash, stalks, straw, core, bark, silage, sugarcane trash, bagasse
Vegetables, root crops, and tubers	Leaves, stem, root, residues
Weeds/grass/ sedges	Hay, mowing wastes, leaves, stem, straw, pellets, silage, culms, roots, flowers/ inflorescence

Source: Mendoza and Roger 1999.

Figure 61: Amount of biomass burned in rice, corn, and sugarcane in the Philippines

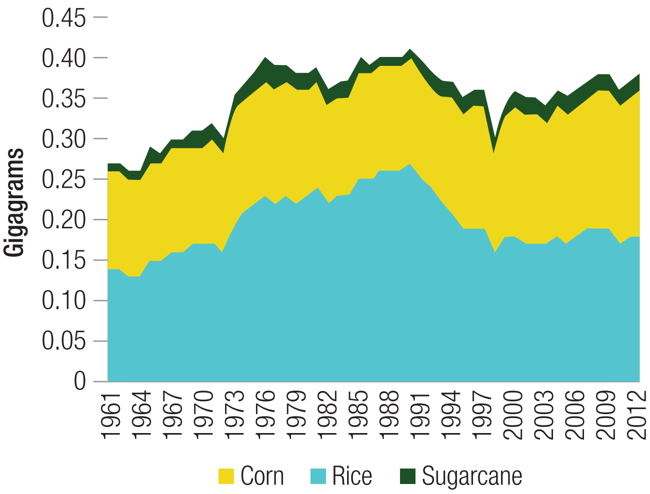


Source: FAOSTAT 2012.

of 0.70–1.18 kg P/ha with the removal of 1 ton of rice straw (Dobermann and Fairhurst 2002). The potassium content of rice straw may range from 1.16–1.66 percent (dry matter) equivalent to removal of 11.62–16.60 kg K/ha with the removal of 1 ton of rice straw (Dobermann and Fairhurst 2002).

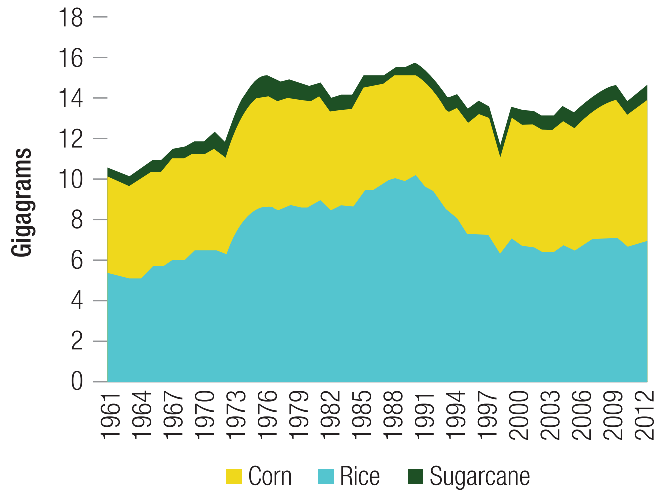
Burning of rice straw causes loss of all nitrogen, 25 percent of phosphorus, and 20 percent of potassium in the straw biomass. The major impact of straw removal is on the soil potassium balance that may eventually lead to increased incidence of potassium deficiency (Dobermann and Fairhust 2002).

Figure 62: Amount of N_2O emissions of burning crop residues



Source: FAOSTAT 2012.

Figure 63: Amount of CH_4 emissions of burning crop residues



Source: FAOSTAT 2012.

In the Philippines, rice straw is piled into heaps at threshing sites and burned after harvest. When the ash is not spread in the field, this results in large losses of minerals including potassium, silicon, calcium, and magnesium through leaching and uneven distribution of minerals in the paddy field (Dobermann and Fairhust 2002).

The amount of corn biomass burned increased by 78 percent from 2,016,270 tons in 1961 to 3,589,460 tons in 1991. After 1991, the amount of corn biomass decreased to 2,593,824 tons in 2012 (Figure 62).

In sugarcane cropping system, after harvesting the cane, it is a common practice to burn the standing crop residues. From 1961 to 1976, the amount of sugarcane residues burned increased by 147 percent from 150,930 tons in 1961 to 372,190 tons in 1976. With the collapse of the sugarcane industry in the mid-1970s, sugarcane crop residues decreased with decline in sugarcane production to 28,376,518 tons in 2011. The amount of GHG emissions from sugarcane residue burning in 2011 was 281,645.7 Gg CO_2.

The amount of total N_2O emissions from burning of rice, corn, and sugarcane crop residues in the Philippines range from 0.27 Gg in 1961 to 0.41 Gg in 1990 (Figure 62). After 1998, there was a reduction in N_2O emissions to 0.38 Gg in 2012. Burning of corn crop residues is the major source of N_2O emissions, followed by the burning of rice crop residues (Figure 62).

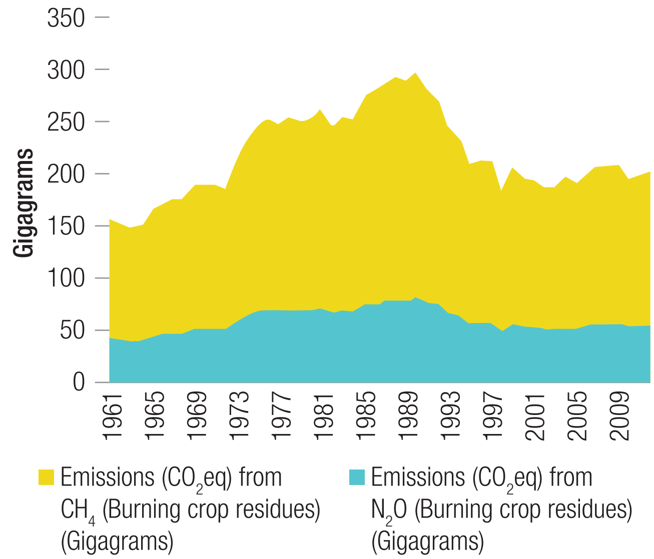
The patterns of CH_4 emissions from crop residue burning is similar to N_2O emissions. Burning of corn crop residues is the major source of CH_4 emissions, followed by the burning of rice crop residues (Figure 63). x CH_4 emissions increased by 35.34 percent from 13.44 Gg in 1961 to 18.19 Gg in 1988. After 1998, CH_4 emisisons from burning crop residues declined and gradually increased to 20.07 tons in 2012.

GHG emissions (CO_2eq) from the burning of corn crop residues in the Philippines increased from 1961 to 1989 with greater contributions from CH_4 emissions than N_2O emissions (Figure 64). The decline in GHG emissions after 1989 is largely attributed to the decrease in CH_4 emissions from crop residue burning.

GHG emissions (CO_2eq) from the burning of rice crop residues in the Philippines continually increased from 137.09 Gg in 1961 to 202.23 Gg in 2012 with greater contributions from CH_4 emissions than N_2O emissions (Figure 65).

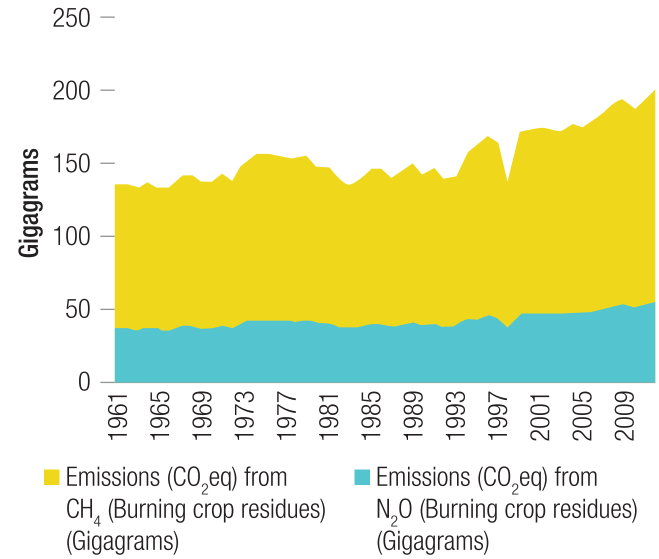
GHG emissions (CO_2eq) from the burning of sugarcane crop residues in the Philippines continually increased from 11.83 Gg in 1961 to 29.21 Gg in 1977. With the decline of the sugarcane industry in 1977,

Figure 64: Amount of emissions (CO_2eq) from burning corn residues



Source: FAOSTAT 2012.

Figure 65: Amount of emissions (CO_2eq) from burning rice residues



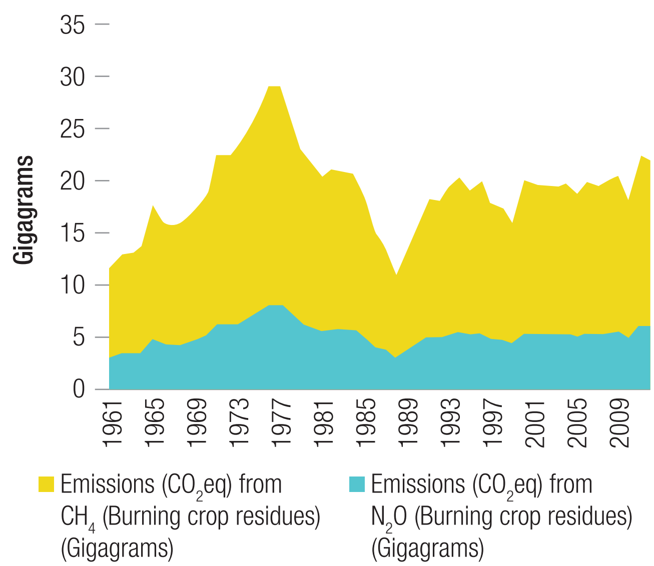
Source: FAOSTAT 2012.

there was decline in GHG emisisons from sugarcane crop residue burning (Figure 66).

The proportion of the rice residue burnt in the open field is the highest in the Philippines (95 percent), followed by Thailand (48 percent), and the least was in India (23 percent) (Gadde, Menke, and Wassmann 2009). Crop residue/biomass residue burning emits poisonous gases such as SO_2, CH_4, CO_2, CO, N_2O, NO_x, NO, NO_2, OC, BC, TC, NMHCs, SVOCs, VOCs, O_3 (Gadde et al. 2009; Guoliang et al. 2008; Sahai et al. 2007). Thus, crop residue burning greatly influences the quality of environment and it also contributes to global warming and climate change.

Open burning of crop residue/biomass significantly increases the level of particulate matter, gaseous pollutants (SO_2, NOx, VOCs, and PAHs, and so on) in atmosphere (Table 19). However, CO_2 emitted from biomass burning is considered to have a neutral effect due to its photosynthetic uptake during plant growth.

Figure 66: Amount of emissions (CO_2eq) from burning sugarcane residues



Source: FAOSTAT 2012.

3.5 Use of Plastics

Plastic bags containing fertilizers and bottles containing pesticides are potential sources of pollutants. The method of disposal of these containers are critical in controlling their impact in polluting the environment.

Table 19: Emissions from rice straw open burning

Name of pollutant	Emissions from rice straw open burning			
	EF (g/kg_{dm})	India (Gg)	Thailand (Gg)	Philippines (Gg)
CO_2	1,460	16,253	11,850	11,850
CH_4	1.20	13	10	10
N_2O	0.07	1	1	1
CO	34.70	386	290	282
NMHC	4.00	45	33	32
NO_x	3.10	35	26	25
SO_2	2.00	22	17	16
Total particulate matter (TPM)	13.00	145	109	106
Fine particulate matter ($PM_{2.5}$)	12.95	144	108	105
we purchased permit for the use of this table				

Source: Gadde et al. 2009,
Note: Gg - Giga gram, g/kgdm = gram per kg of dry matter.
EF= emission factor

Ngidlo et al. (2013) observed that farmers in Ifugao, Mt. Province, and Benguet do not dispose empty pesticide bottles properly. Table 20 showed the methods of disposal of 75 interviewed farmers in the three sites. Empty bottles that are left in the farm are prone in releasing poisonous liquid and can flow to nearby surface water bodies especially during rainy season. Some interviewed farmers also stated that they washed sprayers that they used in spraying pesticides in nearby rivers. These improper methods have negative impacts on soil and water.

In banana plantations, plastic bags coated with pesticides are used to wrap banana fruit bunches to protect them from pests and diseases. These plastic bags contaminated with pesticides are not properly disposed off and some farming households even use them for other domestic purposes. Similarly, plastic mulches used in other cropping systems like strawberries and vegetables are potential agricultural pollutants that need proper disposal.

Table 20: Method of disposal of pesticide bottle containers in temperate vegetable farms in the Cordilleras

Method of disposal	Study sites			
	Ifugao	Mt. Province	Benguet	Total
Leave empty bottles in the farm	15	21	12	48
Keep the bottles at home	3	2	9	14
Leave bottles in wastebins	7	2	4	13
Total	25	25	25	75

Source: Ngidlo et al. 2013.

PHYSICAL IMPACTS ON NATURAL RESOURCES AND ECOSYSTEMS

4

4.1 General Impacts of Cropping Intensification

Cropping intensification would involve 2–3 croppings per year and increased application of inputs like fertilizers, pesticides, and irrigation water in the cropping system. Such cropping intensification would result in environmental degradation including soil acidification, leaching of excessive nutrients into the environment, and soil erosion due to cultivation of particularly sloping upland areas. Evidences of such negative environmental impacts of cropping intensification have been reported.

The *Phaseolus vulgaris L.* or common beans are popular and being intensively harvested in La Trinidad, Benguet, the Philippines. The intensively cropped soils has already become acidic due to the chemical nitrogen fertilization (Gutierrez and Barraquio 2010).

A case study in Ilocos Norte, the Philippines showed that their farmers commonly plant rice in their lowlands during wet season. It is then followed by diversified single or double non-rice crops during dry season. They use more fertilizers for their crops during this season. Thus, there is more nitrogen loss because of the different cropping patterns. This loss can be attributed to the NO_3^- leaching to the groundwater. The largest nitrogen loss was observed in rice-sweet pepper which is their main cropping sequence and main source of income. Irrigation and pesticides are also used in large amounts (Ladha et al. 1998).

The total forest cover in the country declined by as much as 3.54 percent for the period 1990–1995, the fourth highest loss rate in the world. This rapid decline in forest areas can be attributed to the large and rapid conversion of the Philippine uplands into permanent annual cropping areas to meet the food requirements of an increasingly expanding population (Domingo and Buenaseda 2000). However, the productivity of sloping lands has been diminishing at an alarming rate due to soil degradation or erosion brought about by cultivation activities in the sloping upland areas.

Upland rice cultivation resulted in the degradation of land due to soil erosion and loss of essential nutrients particularly nitrogen, phosphorus, and potassium. Soil erosion reduces soil fertility and sometimes, results in irreparable damage to soil fertility affecting the growth and yield of rice crop (Espino, Sangalang and Evangelista 1995). Eroded soil from the upland areas ultimately end up as sediments in nearby water bodies.

The equivalent nitrogen content of eroded soil cultivated with upland rice ranged from 33,000 tons in 1990 to 39,000 tons in 1994. In 1994, nitrogen accounted for 87 percent of the total nutrient loss in the soil while phosphorus accounted for 11 percent, and potassium for 2 percent. These nutrient losses correspond to 197 tons of nitrogen, 26 tons of potassium, and 4 tons of phosphates (NSCB 2000).

From 1988 to 1994, the amount of SS ranged from 2,138,000 to 2,491,000 tons which contributed the bulk of discharges in water while BOD discharges reached 13,000 tons in 1994.

According to Escaño and Tababa (1998), the rates of soil erosion in sloping areas range from 23 to 218 ton/ha/year for bare plots on gradients of 27–29 percent to 36–200 ton/ha/year on plots cultivated up and down the hill. These rates are higher than the acceptable soil loss level of 3–10 ton/ha/year (Paningbatan 1989), and the situation poses a grave threat to the productivity and sustainability of farming in the upland areas.

4.2 NH_4-N and NO_3-N in Surface Water, Ground Water, and Soil

Nitrates in the environment can be in the form of sodium, potassium, calcium, and ammonium. Nitrates are determinants of water quality. Water is considered clean if there is no presence or at least does not exceed the prescribed maximum allowable nitrate level. Nitrates occur naturally in water and soil. However, many studies show that high levels of nitrates in water samples come from septic systems, wastewater treatment facilities, application of fertilizers, and animal manure.

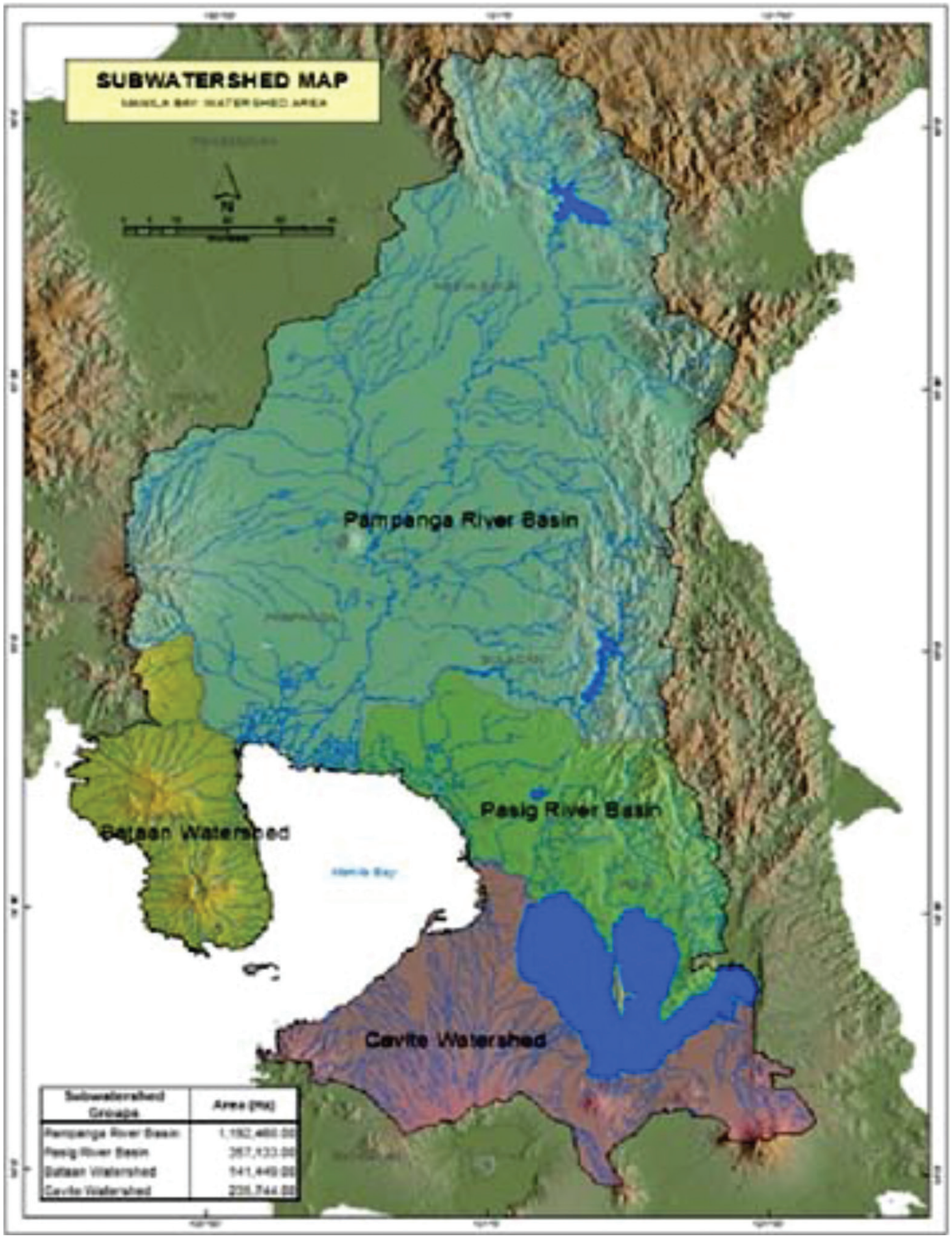
Rice cultivation releases agrochemical residues such as nitrates and ammonium to water due to application of inorganic chemicals and fertilizers. These high concentrated residues are being carried by water to lakes and rivers through runoff erosion and leaching that often result in the contamination of ground water. Also included in the runoff erosion are the soil nutrients, soil sediments, and SS which lead to eutrophication. Eutrophication is an ecological imbalance in water and soil due to enrichment of phosphates and nitrogen. Eutrophication leads to algal blooms which cause stress, impair the immune system, and damage the living organisms, and eventually disrupt aquatic life (NSCB 2000). Presence of nitrate in drinking water interferes with the red bloods cells in carrying oxygen.

In 2010, the Bureau of Soils and Water Management conducted a study on the *Assessment of Non-point Source Pollution from Croplands into the Manila Bay in Compliance to Supreme Court Final Order for the Manila Bay Cleanup, Rehabilitation and Restoration* (Samar 2012). The Manila Bay watershed covers a total area of 1,972,014 ha and four subwatersheds drain into the Manila Bay. These are the Pampanga River Basin, Pasig River Basin, Bataan watershed, and Cavite watershed (Figure 65). The Pampanga River Basin is the biggest, covering 63 percent of the entire watershed area.

Agricultural areas comprise 868,129 ha, making up about 45 percent of the total watershed area distributed into: 813,943 ha of crop lands, 50,378 ha of fishponds, and 3,808 ha of livestock and poutry. The major crops grown in Pampanga River Basin are rice, sugarcane, and corn, while coconut is grown mainly in parts of the Pasig River Basin and Cavite watershed (Figure 67).

The pollution load of NH_4-N, NO_3-N and Total phosphorus were estimated by multiplying the river

Figure 67: The four subwatersheds draining into the Manila Bay



Source: Samar 2012.

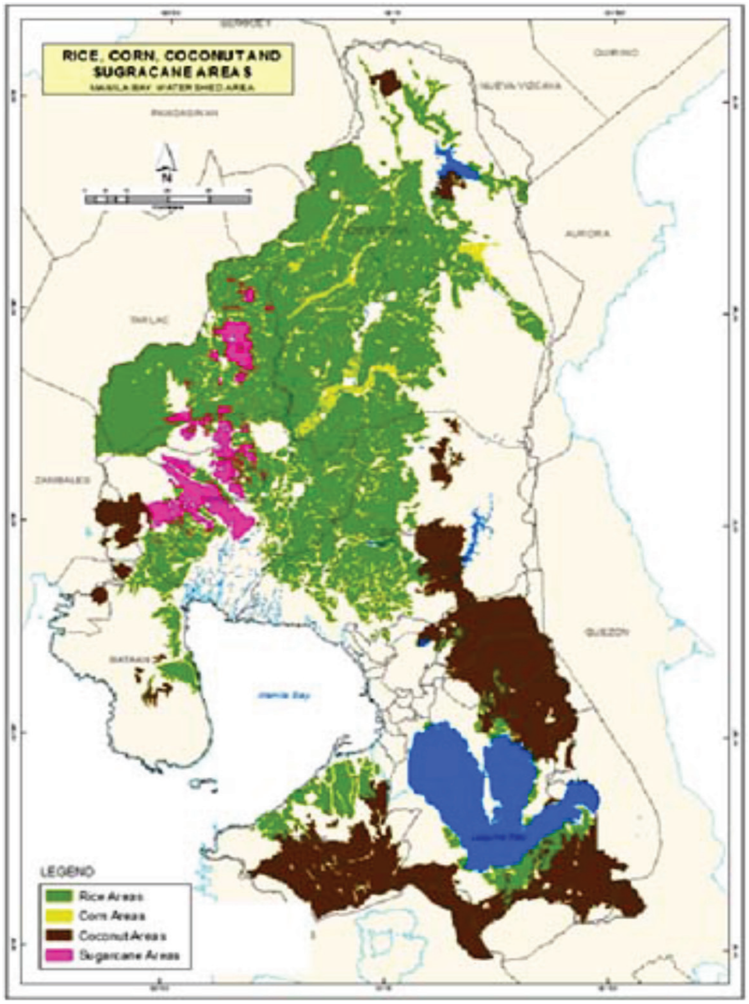
discharge (cm) by the nutrient concentration (g/m^3) and with a conversion factor.

The total NH_4-N loading is 1,245 kg/day and the contributions of the four subwatersheds are: 482 kg/day from Pampanga River Basin, 373 kg/day from Pasig River basin, 275 kg/day from Bataan subwatershed, and 115 kg/day from Cavite subwatershed (Figure 69).

The total NO_3-N loading is 4,526 kg/day, of which the Pasig River Basin is the major contributor (Figure 70) (Samar 2012).

EMB of the DENR, the Bureau of Soils and Water Management (BSWM) of the DA, and the Philippine Nuclear Research Institute (PNRI) of the Department of Science and Technology (DOST) jointly conducted

Figure 68: Major crops grown within the Manila Bay watershed



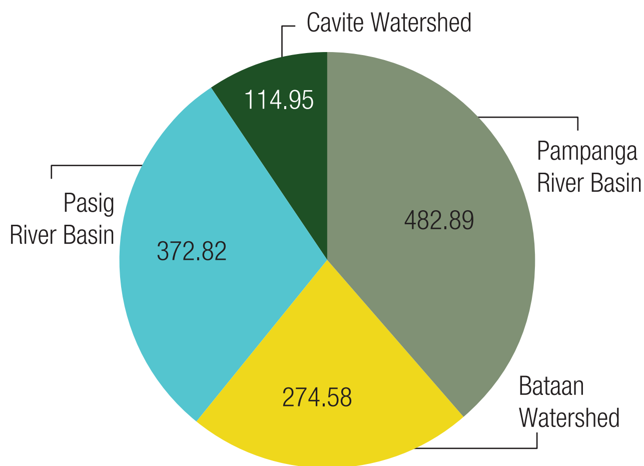
Source: Samar 2012.

a study titled, 'Application of Stable Isotopes to the Assessment of Pollution Loading from Various Sources in the Pampanga River System into the Manila Bay, Philippines'. The primary goal of the study is to clean up, rehabilitate, and restore the Manila Bay and the abutting river systems. This collaborative study is a welcome opportunity for the mandamus agencies to generate a science-based approach toward identification of various sources of pollution and their contribution to the Manila Bay. Such information is important for the planning and management of the Pampanga River Basin toward the restoration of the Manila Bay into class SB.

The Pampanga River Basin provides irrigation, water, and power to Luzon, especially Metro Manila, thus it is critical to the Philippine economy. About 49 percent of net water influx into the Manila Bay comes from the Pampanga River Basin (Jacinto et al. 1998). Nitrate and orthophosphate concentrations in the Manila Bay exceed the Association of South East Asian Nations (ASEAN) marine water quality criteria of 0.06 and 0.015 mg/L, respectively.

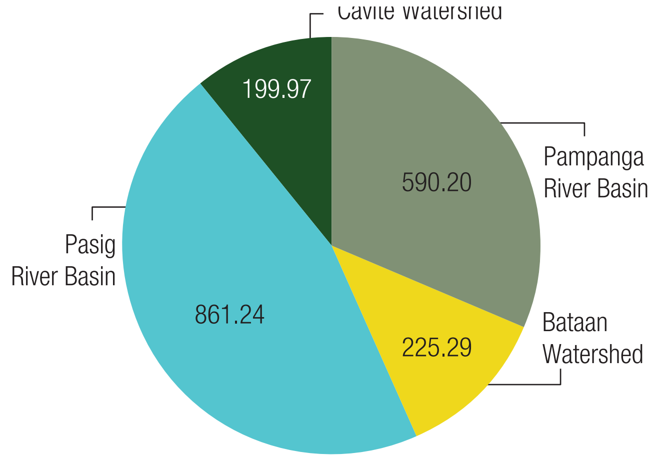
Results of the analysis of water samples taken from several sampling sites along the stretch of the Pampanga River revealed that the river is contributing to nitrate and phosphorus loading in the Manila Bay. The level of nitrates in the river water ranged from 0.02 to 1.69 mg/L during the dry season and from 0.05 to 1.94 mg/L during the rainy season. In many cases the

Figure 69: NH_4-N nutrient loading contribution (kg/day) of the four Manila Bay subwatersheds



Source: Samar 2012.

Figure 70: NO_3-N nutrient loading contribution (kg/day) of the four Manila Bay subwatersheds



Source: Samar 2012.

level of nitrates in the water exceeded the Asian water quality limit of 0.06 mg/L (BSWM 2013). Isotopic mass balance analysis results showed that among the land uses in the Pampanga River Basin, it is the croplands that generally contributed the most to pollutant loading (22 percent to 98 percent) during the wet season while domestic wastes contributed 55–65 percent of pollutant loading during the dry season (BSWM 2013). Analysis of the isotopic composition of offshore sediments showed that 17–30 percent of the organic matter deposited in the Manila Bay comes from agricultural activities (BSWM 2013). The failed overall rating of the Pampanga River is based on the chemical and biological parameters exceeding the allowable limits. The river is in a poor state because of the nitrate, phosphorus, heavy metals, and coliform loading that is discharged into the Manila Bay (BSWM 2013).

A study of agricultural lands in the Cordillera Region in Northern Philippines showed that in the communities of Atok, Benguet, and Tirado, the nitrate levels in surface water and ground well are found to be highly concentrated (Ngidlo et al. 2013). Similarly, 5 of the 18 wells monitored in Bulacan and Benguet, the Philippines showed high levels of nitrate. This is due to the excessive application of nitrogen fertilizers (Greenpeace Report 2007; Ngidlo et al. 2013) and animal manure (Ngidlo et al. 2013).

A study conducted in 2012 showed that the groundwater sources in the agroecosystem in Laguna were contaminated by nitrates. There were higher nitrate concentrations in areas with septic tanks than those without septic tanks. Also, there were higher concentrations in water sources used for domestic purposes than in agricultural purposes (Mendoza et al. 2012).

A study showed that there were higher nitrogen concentrations in the northeastern area near Metro Manila. Specifically, it showed that the Manila Bay is highly eutrophicated with a high concentration of ammonium (Chang et. al. 2009).

The monitoring of nitrate in the 36 Priority Rivers in the Philippines from 2006 to 2013 showed that a total of 27 water bodies met the requirements. The majority (81 percent) of these, which are mostly in Region III, the Philippines, were found to have good water quality. Four water bodies (15 percent) were found to be fair, whereas only one showed poor quality (EMB 2014).

In the Laguna Lake, the largest freshwater body in the country, the total nitrogen emission rate into the Laguna Lake reached 13,800 tons N/year with the livestock and poultry sector contributing 36 percent while fertilizer contributed 11 percent in 1973 (Table 21). In the year 2000, the contribution of livestock and poultry declined to 16.5 percent.

Laguna Lake has a high fish production during the early 1970s because of its hypertrophication. The lake has an extremely high nutrient level from the watershed. During this time, around 5,000 tons of nitrogen was entering the lake. This nitrogen came from livestock and poultry (36 percent), domestic sources (26 percent), Pasig River backflow (22 percent), fertilizers (11 percent), and industrial sources (5 percent). In 2000, a waste load model has increased the total nitrogen to around 13,800 tons. These came from domestic sources (79 percent), agricultural practices (16.5 percent), industrial wastes (4.5 percent), and other sources (0.5 percent) (Lasco and Espaldon 2005).

Water quality reduces due to the rapid increase in industrialization, urbanization, and population. The runoff and discharges from domestic, industrial, and agricultural activities contribute to water pollution (WEPA 2004). According to Lasco and Espaldon (2005), the major pollutants in the Laguna Lake are mainly from domestic (68 percent), industry (19 percent), agriculture (11.5 percent), and forestry (1 percent). Solid and liquid wastes from these sources enter into the lake through the 22 major tributary rivers and the more than 100 rivers and streams.

Table 21: Nitrogen emission into Laguna de Bay

Source of N-emission	1973: 5,000 tons N/year	2000: 13,800 tons N/year
Domestic	26%	79%
Livestock and poultry	36%	16.5% (agricultural)
Fertilizer	11%	—
Pasig River	22%	—
Industrial	5%	4.5%
Total	100%	100%

Source: Reyes 2012.

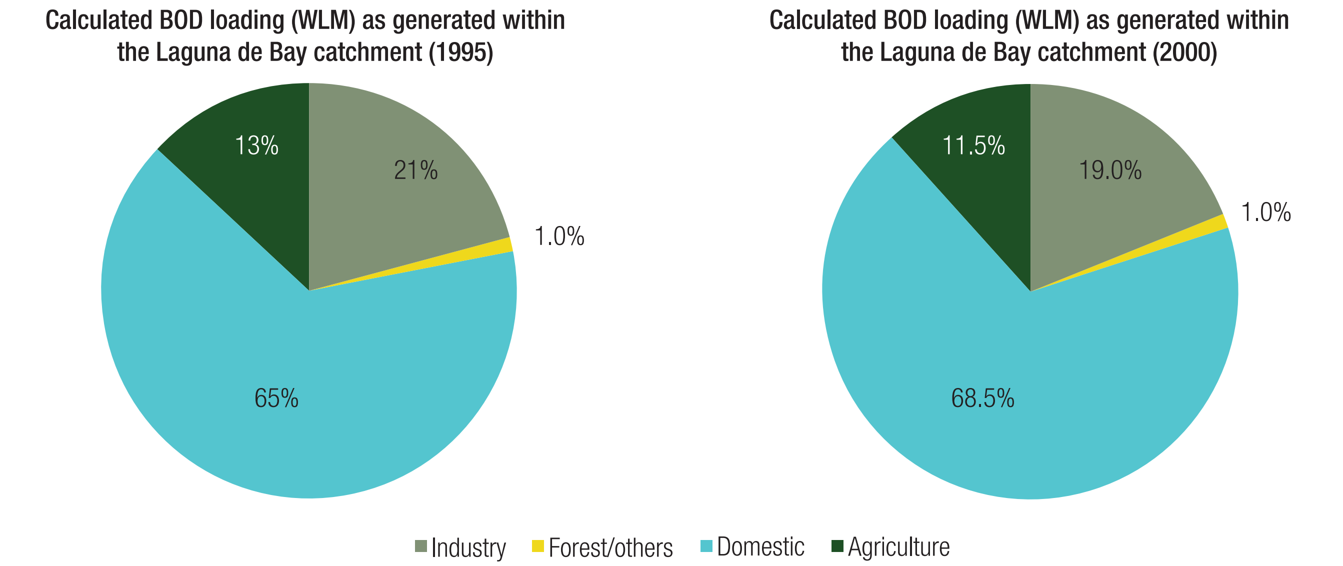
It is expected today that domestic wastes will have higher contribution to the lake pollution because of the crop land conversion to subdivision and proliferating watershed population. According to Lasco and Espaldon (2005), the following are the evidences of domestic wastes' high contribution to lake eutrophication: high density of houses around the lake; absence of latrines; garbage, floating debris, and refuse; and so on. Moreover, due to the lack of proper sewage system, the eutrophication in the Laguna Lake was perpetuating (Lasco and Espaldon 2005).

Waste Load Modeling of Laguna de Bay

The Laguna Lake Development Authority (2003) conducted an inventory of waste loads from the sub-basins into the Laguna Lake including Organic Matter (BOD, COD), bacterial pollutants (E. coli), nutrients (NH_4, NO_3, PO_4), micro-pollutants (Cu, Cd, Pb, oils) and TSS. They identified the different industrial, domestic and agricultural activities that produce these wastes and by considering the estimated water discharges (based on precipitation data), pollution loads into the lake were estimated using the Waste Load Model (WLM). WLM fits geographic information system (GIS) and Delft3D modeling. The total load in 1995 was 66,305 tons/year and in 2000 was 74,300 tons/year. Agriculture contributed 13 percent to total BOD loading in 1995 (8,620 tons/year) and 11.5 percent to total BOD loading in 2000 (8,544 tons/year).

From 1995 to 2005, there were environmental changes in the coastal waters of Bolinao, Pangasinan resulting in major fish kill in 2002. Alongside this event, dinoflagellate Prorocentrum bloom was first reported. This case was attributed to the uncontrolled increase of fish pens and cages. These activities contributed to the organic matter from fecal substances and leftover feeds. Moreover, the increase of fish pens and cages contributed to the stress in the lake which then affected the water quality (McGlone et al. 2013).

Figure 71: Calculated BOD loading (WLM) as generated within the Laguna de Bay catchment in 1995 and 2000



Source: Laguna Lake Development Authority 2003.

In May 2012, another fish kill case happened in Pakil, Pangil and Calamba City, Laguna and in Jalajala, Rizal. This event affected 1,500 fish cages and 20 fish pens. It was attributed to the sudden weather transition from high to low temperature (Szekielda, Espiritu and Lagrosas 2014). The cold surface water layer sinks causing lake overturn because of which the anoxic lake bottom laden with decomposing organic materials surfaces and causes deficiency of oxygen for fish respiration.

4.3 Phosphate in Soil, Surface Water, and Ground Water

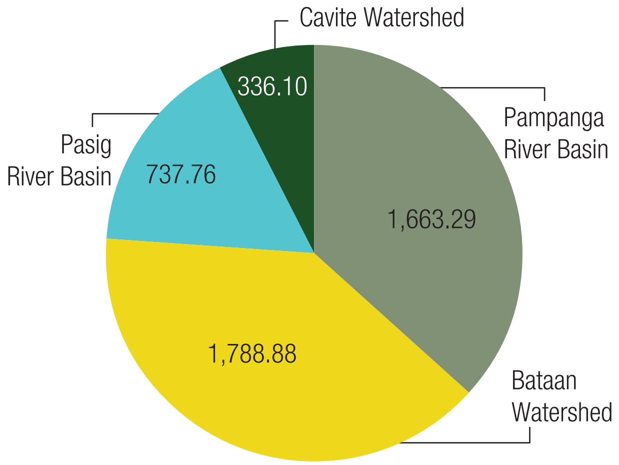
Phosphates can be particulate phosphates or dissolved phosphates. A particulate phosphate is absorbed by organic matter and soil particles from the runoff erosion in cultivated lands. It also serves as a source of phosphates for the aquatic biota. On the other and, dissolved phosphate includes runoff of sediments from grass or forest land.

Phosphates are commonly found in sewage and nutrient fertilizers. A high phosphate concentration causes algal bloom which produce harmful toxins affecting the nervous system and liver. Once a large quantity of algae die, there is oxygen depletion in the water which will then result in massive fish kill.

Large amounts of phosphorus are needed by plants. In the three study sites in the Cordillera Region, Northern Philippines, the phosphorus content of the soils are above the standard limit. It can be attributed to the soils' low pH level. Also, the phosphorus fertilizer in the study sites may have contributed to the high phosphorus concentration in the soil (Ngidlo et al. 2013).

A study conducted by Chang et al. (2009) showed that there are higher concentrations of phosphate and silica near the northern shore of Metro Manila. The monitoring of inland surface water bodies in the Philippines from 2006 to 2013 revealed that there are 53 water body classifications which have phosphate content. Of these, there are only 36 classifications which met the requirement. The study showed that 13 (36 percent) of these had good water quality, while, seven (20 percent) had fair water quality. Unfortunately, 16 (44 percent) had poor water quality. The high phosphate concentration can be attributed to sewage discharge and agricultural activities wherein phosphate fertilizers are being used (EMB 2014).

Figure 72: Total phosphorus nutrient loading contribution (kg/day) of the four Manila Bay subwatersheds



Source: Samar 2012.

In a study conducted by the BSWM in the Manila Bay watershed, the total phosphorus loading is 1,877 kg/day with the Pasig River Basin contributing about 46 percent (861 kg/day) (Figure 72) (Samar 2012).

Throughout the 249.2 km stretch of Pampanga River, the total phosphorus concentrations in the river increased from 0.30 to 0.67 ppm during the wet season and from 0.5 to 0.9 ppm during the dry season toward the river mouth. These results show that areas closer to the river mouth contribute greatly to phosphorus discharge into the Manila Bay. These values are higher than the 0.02 ppm phosphorus set by Bloom (n.d.) as the threshold for algal growth (BSWM 2013).

4.4 Nitrous Gases in Air

Nitrogen dioxide (NO_2) is a gas with reddish-brown color and an odourless and pungent smell. Its main sources are power plants and vehicular emissions. It goes through the chemical reactions in the atmosphere wherein other toxic compounds and nitrates are formed. These can cause respiratory health risk to people. A high concentration of it in the atmosphere can lead to ozone formation once it reacts with the sunlight (EMB 2014). N_2O is also released during the burning of agricultural crop residues.

Application of urea requires exceptionally good agricultural practices to avoid, in particular, evaporation losses of ammonia to the air. Urea should be applied only when it is possible either to incorporate it into the soil immediately after spreading or when rain is expected within the few hours following the application.

4.5 Soil Acidification

Excessive use of chemical fertilizer use can cause several ecological problems—soil acidification, among others. Acidic soils are vulnerable to erosion due to their low electrolyte levels in the soil solution. Also, soil acidity depletes fertility through the toxic levels of iron and by decreasing the amount of the most essentials nutrients in the soil. Soil microbia, responsible for nutrient release in the soil, is also affected (Briones 2005). Soil acidity can also be attributed to continuous planting of corn and sweet potato which exhausts soil calcium, magnesium, available phosphorus, and organic matter levels (Asio et al 2009; Siebert 1987).

Unfortunately, more than 58 percent of the Philippines is covered with acidic soils in the hilly lands. These soils are mainly Oxisols and Ultisols which were formerly slash and burn lands but have been abandoned. Acid-tolerant crop varieties, along with phosphate rock application, have been identified as an effective way of overcoming the widespread phosphorus deficiency (Craswell 1989).

4.6 Pesticide Residues in Soil, Surface Water, Ground Water and Food Crops

A study showed that farmers in Sta. Maria, Pangasinan, the Philippines were using a large amount of insecticides on their eggplant crop to control the various pests.

Around 20 percent of eggplant samples had insecticide residues. The insecticides used were from 25 commercial brands. Two brands are highly toxic, nine are moderately toxic, seven are slightly toxic, and seven are practically nontoxic. The soils from 11 out of 26 farm study sites had insecticide residues. Four farms were found to have residues exceeding the maximum limit. There were no residues detected from the water sample from the 26 farms (Del Prado-Lu 2015).

In another study, there were farmers who use banned pesticides and restricted chemicals to protect their plants. The crops which were frequently sprayed with insecticide and fungicide are cabbage, baguio, beans, string beans, tomatoes, pechay, bell pepper, ampalaya, and rice (Saldivar 1996).

In the farming areas in Benguet, the Philippines, a study showed that 34 out of 78 soil samples were positive for pesticide residues. A water sample was also found to have a high level of pesticide residue which is toxic to aquatic biota (Lu 2009b). The farmers were using three main types of pesticide: pyrethroids, organophosphates, and carbamates. As documented by the National Poison Control and Management Center, pyrethroid was the most common which caused acute pesticide poisoning from 2009 to 2010. It was followed by carbamates and then organophosphates. Tamaron is the specific pesticide which was frequently used from 2004 to 2009. It was followed by dithane.

The following are the off-paddy effects of pesticide use: (a) pesticide runoff, which will then go to surface water and (b) leaching into groundwater, then polluting the potable water (Pingali and Roger 1995). Pesticide residue detected in water inflow in paddy fields ranges from 0.01 to 0.54 ppb which is still within the normal value of 0.000001 to 0.1 ppm in natural surface waters. Pesticide residues are detected to be higher during the wet season than the dry season. Higher residue at 0.001 to 3.46 ppb were detected in drainage water outflow from paddy because the pesticides are carried from treated areas through runoff.

Well water samples taken from paddy fields where pesticides were applied exceeded the acceptable daily intake levels. Insecticides and herbicides were both discovered in the water. Other residues detected in Laguna and Nueva Ecija that were not used by the farmers are DDT, endrin, and lindane. Also, a significant amount of pesticide was detected in the ground water (Pingali and Roger 1995).

Pesticide residues in water samples taken along the Pampanga River were below the LOQ set at 0.1 μL/L. Likewise, pesticide residue analyses of soil samples taken in the Manila Bay watershed are less than the LOQ at 0.005 mg/kg for organochloride, organophosphates, and pyrethroids (Samar 2012).

The NPAL, BPI of the DA is conducting monitoring of pesticide residues in tropical vegetables commonly consumed by Filipinos: bitter gourd, eggplant, pechay, and tomato. The NPAL monitoring team is sampling vegetables sold in public markets and vegetable trading posts in various municipalities all over the country and anayzing the vegetables for pesticide residues. Results of the analysis from 2013 to 2015 are presented in the following maps and graphs.

Bitter gourd

Almost all of the pesticides applied in bitter gourd are insecticides, except for two fungicides (chlorothalonil and difenoconazole) (Table 22). Cypermethrin (pyrethroid, II) is a commonly applied insecticide in bitter gourd in various regions (7/10) of the country (Figure 71). Concentrations of cypermethrin residues above the MRL were detected in three regions (Nueva Vizcaya/Isabela, Cebu/Bohol, and Cagayan de Oro) (Table 22). Bitter gourd sampled from Bohol and Cebu had consistently high concentrations of cypermethrin above MRL in the three years from 2013 to 2015.

Lambda-cyhalothrin (pyrethroid, II) is another insecticide with pesticide residue concentrations higher than the MRL, detected in bitter gourd sampled from Region 10 (Cagayan de Oro) in 2013 and 2014 (Table 22).

Farmers in Mindanao (Regions 10, 11, and 12) apply a combination of several insecticides during the bitter gourd cropping season (Figure 73). As in the

Table 22: Concentration of pesticide residues in bitter gourd sampled from local markets various regions of the country, 2013–2015

Region	Location	Pesticide Residue Detected	2013	2014	2015	MRL
			Concentration (mg/kg)	Concentration (mg/kg)	Concentration (mg/kg)	Concentration (mg/kg)
CAR	Baguio City Public Market; Tuba, Benguet	ND*				
1	Ilocos Sur, Ilocos Norte, La Union	Cypermethrin	0.01,0.05	0.01, 0.07		0.07
		Fenvalerate	0.04		0.04	
		Chlorpyrifos	0.01,0.02,0.02	0.02	0.09	
		Fipronil		0.03		
		Cyfluthrin		0.01		
2	Nueva Vizcaya and Isabela	Deltamethrin	0.01,0.01,0.03			
		β-Cyfluthrin			0.03	
		Cypermethrin	0.44			0.07
		Chlorpyrifos		0.01, 0.03		
3		Dimethoate		0.04		
4	Imus/*Dasmariñas*/*Silang* (*Cavite*), Biñan/Sta. Rosa/*Calamba* (Laguna), Tanauan/Sto.Tomas/ Malvar (Batangas)	Chlorpyrifos	0.03			
		Cypermethrin	0.04	0.13		0.07
		Profenofos	0.33–1.2			
		Permethrin		0.13		
7	Cebu and Bohol	Cypermethrin	0.037, 0.017, 0.7, 0.012, 0.121, 0.039	0.01–0.33	0.04, 0.08, 0.19, 0.08, 0.26, 0.02, 0.09	0.07
		Cyfluthrin	0.021	0.02		
		lamda-Cyhalothrin	0.0149, 0.012, 0.026	0.01–0.21	0.04, 0.16, 0.06, 0.07	0.05
		Chlorpyrifos		0.06		
		Profenofos		0.01		
9	Zamboanga del Sur	Chlorpyrifos			0.02	
		Profenofos			0.03	
10	Cagayan de Oro City	λ-Cyhalothrin	0.04 , 0.05, 0.05, 0.02, 0.03, 0.11, 0.01, 0.02, 0.01	0.01, 0.01, 0.05, 0.05, 0.49	0.01, 0.02, 0.02, 0.01, 0.01, 0.01, 0.03	0.05
		Cypermethrin	0.03 , 0.04 , 0.11, 0.15, 0.03, 0.09, 0.1	0.01, 0.03, 0.01, 0.01, 0.04, 0.06, 0.02, 0.04, 0.05, 0.01	0.01, 0.02, 0.1, 0.01, 0.06	0.07
		Chlorpyrifos	0.7, 0.07, 0.13, 0.4, 0.01	0.04	0.01	
		Dimethoate	1.8		0.02	
		Fenvalerate			0.01	
		Cyfluthrin		0.01, 0.02		
		Profenofos		0.01, 0.01, 0.01, 0.04, 0.02	0.04, 0.01, 0.02	
		Total Endosulfan		0.06, 0.81	0.04, 0.05	2.00

(continued on next page)

Table 22: Concentration of pesticide residues in bitter gourd sampled from local markets various regions of the country, 2013–2015 *(continued)*

Region	Location	Pesticide Residue Detected	2013 Concentration (mg/kg)	2014 Concentration (mg/kg)	2015 Concentration (mg/kg)	MRL Concentration (mg/kg)
11	Davao City, Tagum City, Mati City, Davao del Sur	Total Endosulfan	0.004–0.134			2.00
		Chlorothalonil	0.082, 0.011	0.01		
		Diazinon	0.02			0.50
		Difenoconazole	0.019–0.073			
		Cypermethrin	0.007–0.017	0.02, 0.23, 0.01		0.07
		Chlorpyrifos	0.02	0.01, 0.03, 0.02		
		Lamdacyhalothrin	0.013–0.041	0.02		0.05
		Deltamethrin	0.011			
		Cyfluthrin		0.01, 0.01		
		Profenofos		0.01		
		Lindane	0.002–0.008			
12	General Santos City, Koronadal City, Kidapawan City	Cypermethrin	0.007–0.015	0.01		0.07
		Isazophos	0.03			
		Lamdacyhalothrin	0.015	0.01, 0.01, 0.01	0.01	0.05
		Deltamethrin		0.03		
		Chlorpyrifos		0.01, 0.01		
		Dimethoate		0.03		
		Lindane	0.005–0.006			
		Total Endosulfan	0.006–0.008			2.00

Source: NPAL 2016.

case of Davao, about nine different pesticides were detected in bitter gourd in 2013 (Table 22). These included total endosulfan, chlorothalonil, diazinon, difenoconazole, cypermethrin, chlorpyrifos, lambda-cyhalothrin, deltamethrin, and lindane.

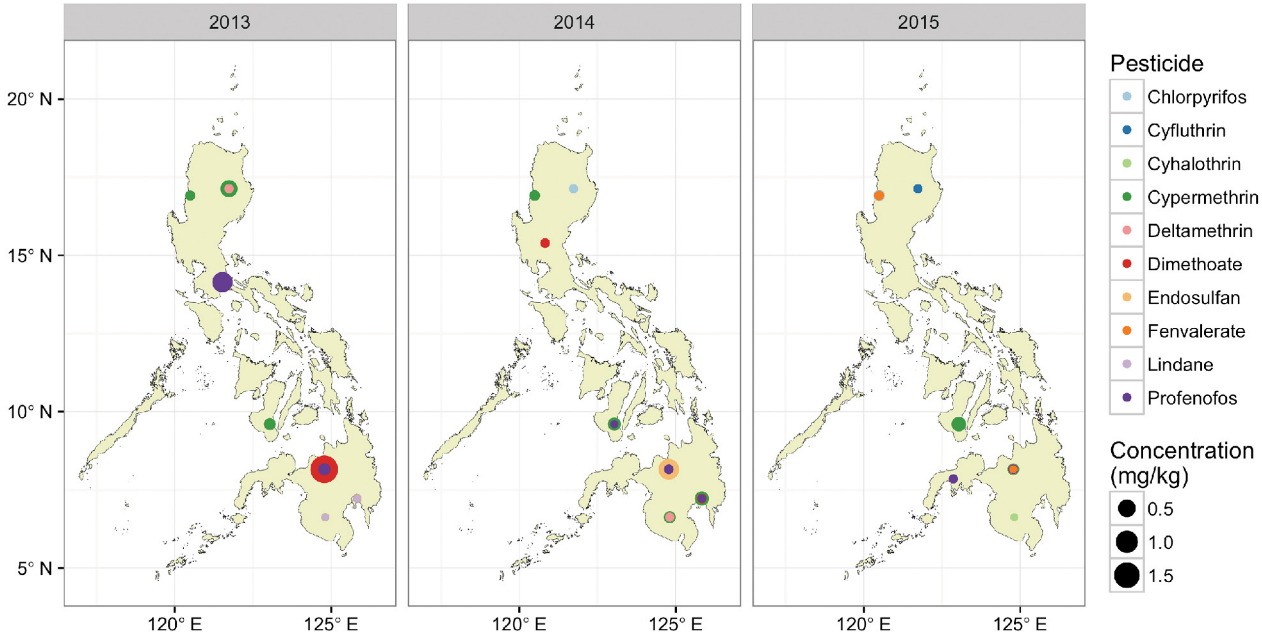
Eggplant

Profenofos (organophosphate) is a commonly applied insecticide in eggplant in various regions of the country from 2013 to 2015 (Figure 74). The concentrations of profenofos residues in eggplant did not exceed the MRL (Table 23). Other insecticides applied in eggplant are cypermethryin, dimethoate, and lindane. In most regions, farmers apply one or two insecticides only in eggplant crop. However, in Ilocos and Davao Regions, up to six different kinds of pesticide residues were detected in eggplant (Table 23). In the Ilocos Region, this is a combination of cypermethrin, profenofos, fipronil, chlorothalonil, chlorpyrifos, and dimethoate. In Davao, this is a combination of total endosulfan, cypermethrin, chlorpyrifos, cyfluthrin, lambda-cyhalothrin, and lindane. Among the pescticides with established MRL, the concentrations detected in eggplant were below the MRL. However, for most of the pesticides being applied, there are no established values for MRL.

Pechay

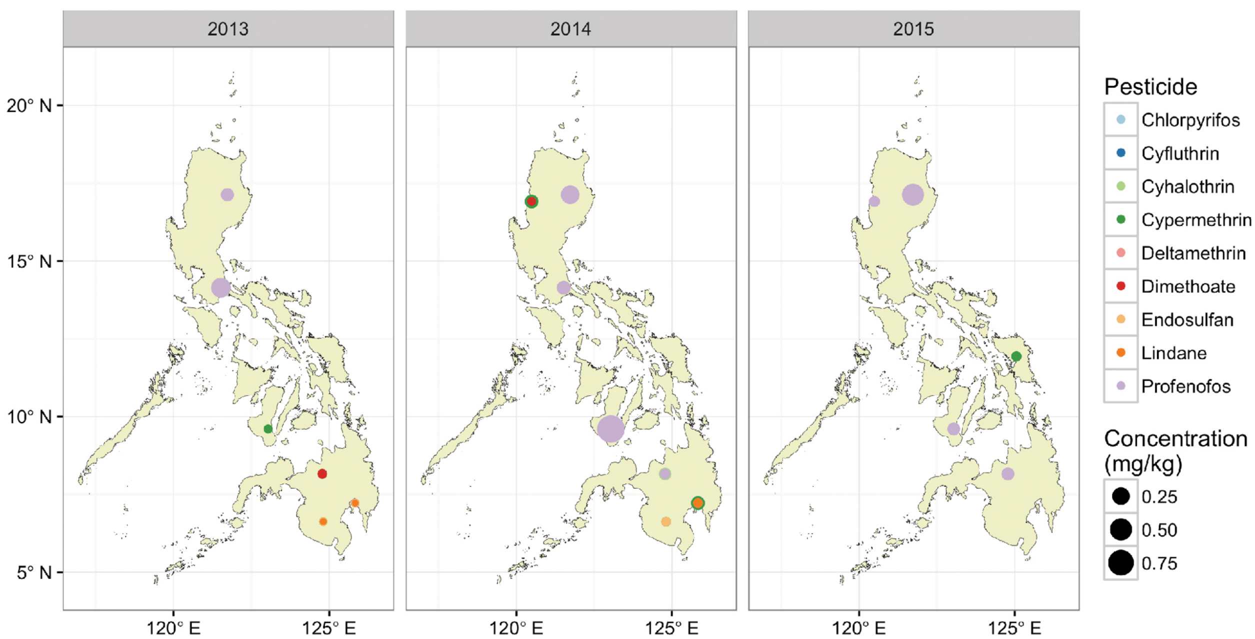
In 2013 and 2014, profenofos was the pesticide commonly applied in pechay in various regions in the

Figure 73: Pesticide residues in bitter gourd bought from public markets in various regions of the country from 2013 to 2015



Source: Based on NPAL 2016 data.

Figure 74: Pesticide residues in eggplant sampled from public markets in various regions of the country from 2013 to 2015



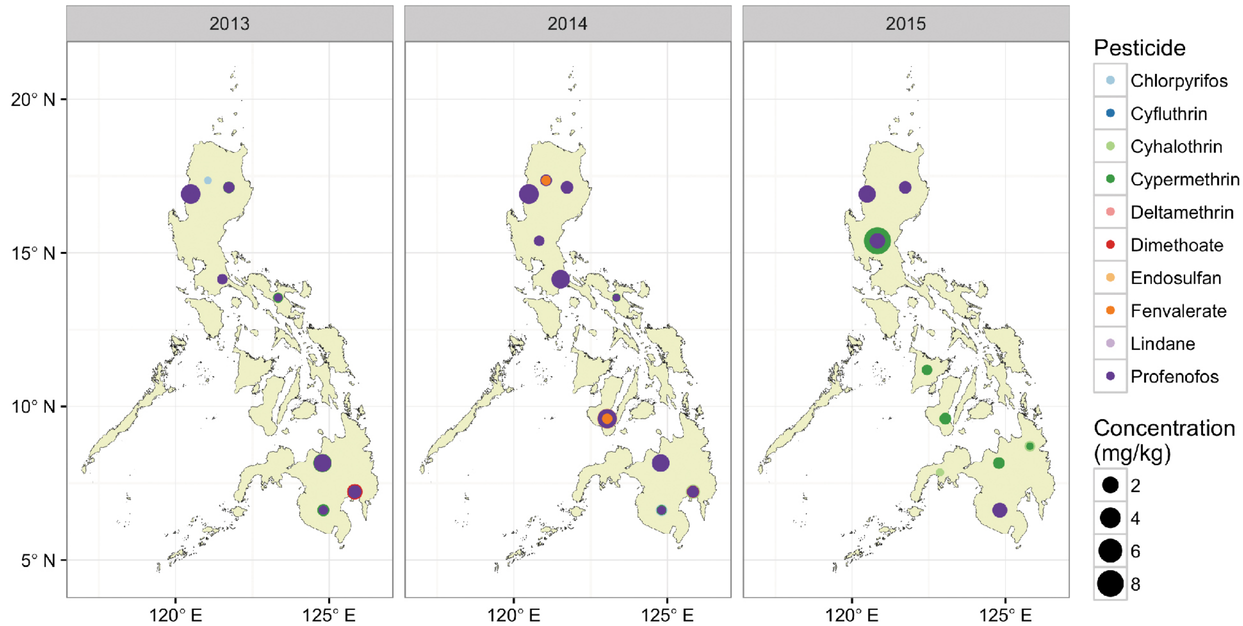
Source: Based on NPAL 2016 data.

Table 23: Concentration of pesticide residues in eggplant sampled from local markets various regions of the country, 2013–2015

			2013	2014	2015	MRL
Region	Location	Pesticie Residue Detected	Concentration (mg/kg)	Concentration (mg/kg)	Concentration (mg/kg)	Concentration (mg/kg)
CAR	Baguio City Public Market; Tuba, Benguet	ND*				
1	Ilocos Sur, Ilocos Norte, La Union	Cypermethrin		0.03,0.03, 0.07	0.01	0.20
		Profenofos		0.05,0.07,0.10	0.04	
		Fipronil		0.06		
		Chlorothalonil		0.02		
		Chlorpyrifos		0.01		
		Dimethoate		0.01		
2	Nueva Vizcaya and Isabela	Profenofos	0.09	0.02, 0.03	0.02, 0.08	
		Chlorpyrifos			0.01	
		Malathion			0.03	
		Cypermethrin		0.01		
		Cyhalothrin		0.01, 0.01		
3	Bulacan, Tarla, Nueva Ecija	Profenofos	0.36			
4	Cavite, Laguna, Batangas	Profenofos		0.11		
		Chlorpyrifos		0.02		
7	Cebu and Bohol	Cypermethrin	0.013, 0.009, 0.01	0.01, 0.05, 0.02, 0.04	0.02, 0.08	0.2
		lamda-Cyhalothrin	0.015, 0.008, 0.14	0.11, 0.01, 0.01		
		Profenofos		0.9, 0.04		
8	Ormoc and Leyte	Cypermethrin			0.03	0.2
10	Cagayan de Oro City	λ-Cyhalothrin	0.01, 0.01, 0.02	0.01, 0.07		
		Cypermethrin	0.02	0.01	0.01	0.2
		Chlorpyrifos	0.02	0.03		
		Profenofos		0.01, 0.02, 0.03	0.01, 0.08	
11	Davao City, Tagum City, Mati City, Davao del Sur	Total Endosulfan	0.005–0.009	0.01, 0.01, 0.01, 0.02, 0.02, 0.02, 0.01, 0.01, 0.01		
		Cypermethrin	0.01	0.1, 0.02		0.2
		Chlorpyrifos	0.012	0.12		
		Cyfluthrin	0.003	0.01		
		lamda-Cyhalothrin	0.003	0.02, 0.01		
		Lindane		0.02		
12	General Santos City, Koronadal City, Kidapawan City	Cypermethrin	0.007–0.009	0.02, 0.02		0.2
		Lindane	0.003			
		Deltametrin		0.01		
		Total Endosulfan	0.008–0.009	0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.02, 0.02, 0.02		2

Source: NPAL 2016.

Figure 75: Pesticide residues in pechay sampled from public markets in various regions of the country from 2013 to 2015



Source: Based on NPAL 2016 data.

country. However, in 2015, cypermethrin was applied in many regions in the country (Figure 75).

In 2013, up to ten different kinds of pesticide residues were detected in pechay in Regions 11 and 12 (Davao and General Santos). In Davao, these include chlorpyrifos, dimethoate, profenofos, cypermethrin, lambda-cyhalothrin, lindane, total endosulfan, difenoconazole, deltamethrin, and cyfluthrin (Table 24). On the other hand, in General Santos, these include residues of profenofos, difenoconazole, deltamethrin, cypermethrin, melvinphos, chlorothalonil, lambda-cyhalothrin, lindane, and total endosulfan. However, the concentrations of these residues were below the MRL.

High concentrations of cypermethrin residues exceeding the MRL were detected in pechay sampled from Cebu/Bohol in 2014 and Cagayan de Oro in 2013–2014. High levels of daizinon residues were also detected in pechay sampled from Cagayan de Oro in 2014 and 2015.

Tomato

Profenofos and cypermethrin are the most commonly applied insecticides in tomato in various regions in the country (Figure 76). Farmers apply a combination of pesticides during the cropping season, from two to as many as nine different pesticides. Majority of the pesticides are insecticides with maybe one fungicide Among the different regions, farmers in Davao apply the most number of pestiticides, ranging from six to nine (Table 25), including combination of endosulfan, chlorothalonil, lambda- cyhalothrin, profenofos, lindane, and cypermethrin in 2013 or combination of cypermethrin, chlorpyrifos, cyfluthrin, deltamethrin, diazinon, fenitrothion, lambda-cyhalothrin, malathion, and permethrin in 2014. The concentrations, though, of pesticide residues were below the MRL. It was only in Cebu/Bohol that excessive concentrations of cypermethrin residues were detected in tomato in 2014. Malathion residues, though it is a banned insecticide, were detected in tomatoes sampled from Davao in 2014. Endosulfan was recently banned in the Philippines, and it was not detected in tomato in 2015.

Table 24: Concentration of pesticide residues in pechay sampled from local markets various regions of the country, 2013–2015

Region	Location	Pesticide Residue Detected	2013	2014	2015	MRL
			Concentration (mg/kg)	Concentration (mg/kg)	Concentration (mg/kg)	Concentration (mg/kg)
CAR	Baguio City Public Market; Tuba, Benguet	Chlorpyrifos	0.03	0.03	0.07; 0.14; 0.06; 0.10	
		Fenvalerate		0.17		
		Profenofos		0.04,0.05,0.12, 0.15,0.51,0.52	0.02; 0.04; 0.14; 0.28, 1.02; 0.25;1.55; 2.25	
1	Ilocos Sur, Ilocos Norte, La Union	Cypermethrin	0.06,0.07,0.11, 0.14, 1.76	0.01, 0.10	0.8; 0.01; 0.02; 0.46, 0.02, 0.03	1.00
		Profenofos	0.06,0.13,0.18, 0.03, 0.07, 0.10, 0.37, 0.07, 0.10, 0.37, 0.42, 3.40	0.02,0.11,0.20,3.5		1.00
		Chlorpyrifos	0.09,0.21,0.37	0.05,0.12,0.19		1.00
		Deltamethrin	0.02, 0.06			2.00
		Indoxacarb			0.03	
		β-cyfluthrin			0.11; 0.37; 0.60	
		Cyhalothrin			0.03	
		Dimethoate			0.71	
2	Nueva Vizcaya and Isabela	Cyhalothrin	0.22			
		Cypermethrin	0.04,0.51	0.01, 0.01		1.00
		Profenofos	0.135,0.15,0.22, 0.24,0.28,0.42	0.07,0.29,0.47, 0.48,0.72,0.74	0.7; 0.08; 0.45	
		Deltamethrin		0.02		
		Dimethoate		0.05		
3	Bulacan, Tarlac, Nueva Ecija	Profenofos		0.33–0.68	0.73, 1.52	
		Chlorpyrifos			0.75, 3.07, 3.94	
		Cypermethrin		0.18	8.35	1.00
4	Imus/*Dasmariñas*/ *Silang* (*Cavite*), Biñan/Sta.Rosa/ *Calamba* (Laguna), Tanauan/Sto.Tomas/ Malvar (Batangas)	Chlorpyrifos	0.03	0.05		1.00
		Cypermethrin	0.18			
		Profenofos	0.31–2.0	0.12–4.61, 2.86–4.26		
		Phenthoate		0.37		
5	Camarines Sur	Profenofos	0.04	0.02		
		Cypermethrin	0.1, 0.25, 0.1	0.08		
		Deltamethrin	0.02			
		λ-Cyhalothrin	0.01–0.04	0.04		0.30
6	Iloilo	Cypermethrin			0.32	1.00
		lamda-Cyhalotrhin			0.03	

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Table 24: Concentration of pesticide residues in pechay sampled from local markets various regions of the country, 2013–2015 *(continued)*

Region	Location	Pesticide Residue Detected	2013 Concentration (mg/kg)	2014 Concentration (mg/kg)	2015 Concentration (mg/kg)	MRL Concentration (mg/kg)
7	Cebu and Bohol	Cypermethrin		2.29–0.01	0.03,0.21, 0.04,0.44	1.00
		Profenofos		3.16, 1.08		
		lambda-Cyhalothrin		0.07, 0.3, 0.03	0.04, 0.08,0.54	
		Fenvalerate		0.09, 0.27		
		Chlorpyrifos		0.03		1.00
		t-Endosulfan		3.6		
9	Zamboanga del Sur	λ-Cyhalothrin			0.05	
10	Cagayan de Oro City	Chlorpyrifos		0.24, 2.51, 0.02, 0.06	0.01	1.00
		Cypermethrin	0.02, 0.22 , 0.25, 2.17, 0.02, 0.08 , 0.12 , 0.27, 0.03, 0.10, 0.22 , 1.1 , 2.78, 0.02 , 0.02, 1.0, 0.06, 0.11 , 0.17, 0.2, 0.5, 0.01	0.01, 0.06, 0.02, 0.14, 0.47, 0.05, 0.06, 1.91, 0.01, 0.02, 0.02, 0.3, 0.31, 0.33, 0.63, 2.09, 0.26, 0.13	0.1, 0.53, 0.02	1.00
		malathion	0.79, 0.01, 0.02			
		Phenthoate	0.04	0.25		
		λ-Cyhalothrin	0.02 , 0.02, 0.03, 0.04, 0.040.07, 0.07, 0.5	0.07, 0.05, 0.34	0.35	
		Profenofos	1.7, 0.03, 0.12, 0.02, 0.1, 0.06, 0.08, 2.3	0.06, 0.07, 0.37, 2.4, 2.29, 1.58, 0.01, 0.04, 0.41, 0.61, 0.91, 0.5		
		Diazinon		0.12, 0.05, 0.04	0.21	0.05
		Heptachlor		0.02		
		Total Endosulfan	0.31, 0.25	0.04, 0.02, 0.22		
11	Davao City, Tagum City, Mati City, Davao del Sur	Chlorpyrifos	0.01–0.132	0.02, 0.06		1.00
		Dimethoate	0.831–1.604			
		Profenofos	0.067–0.43	0.5		
		Cypermethrin	0.124–0.018	0.26, 0.13		1.00
		Lamdacyhalothrin	0.004	0.01, 0.16, 0.06, 1.17		
		Lindane	0.003–0.008			
		Total Endosulfan	0.004–0.011	0.02		
		Difenoconazole	0.014			
		heptachlor		0.02		
		m.Parathion		0.12		
		Deltamethrin	0.012			
		Profenofos	0.02–0.81	0.13, 0.29, 0.4		
		yfluthrin		0.01, 0.01, 0.02		

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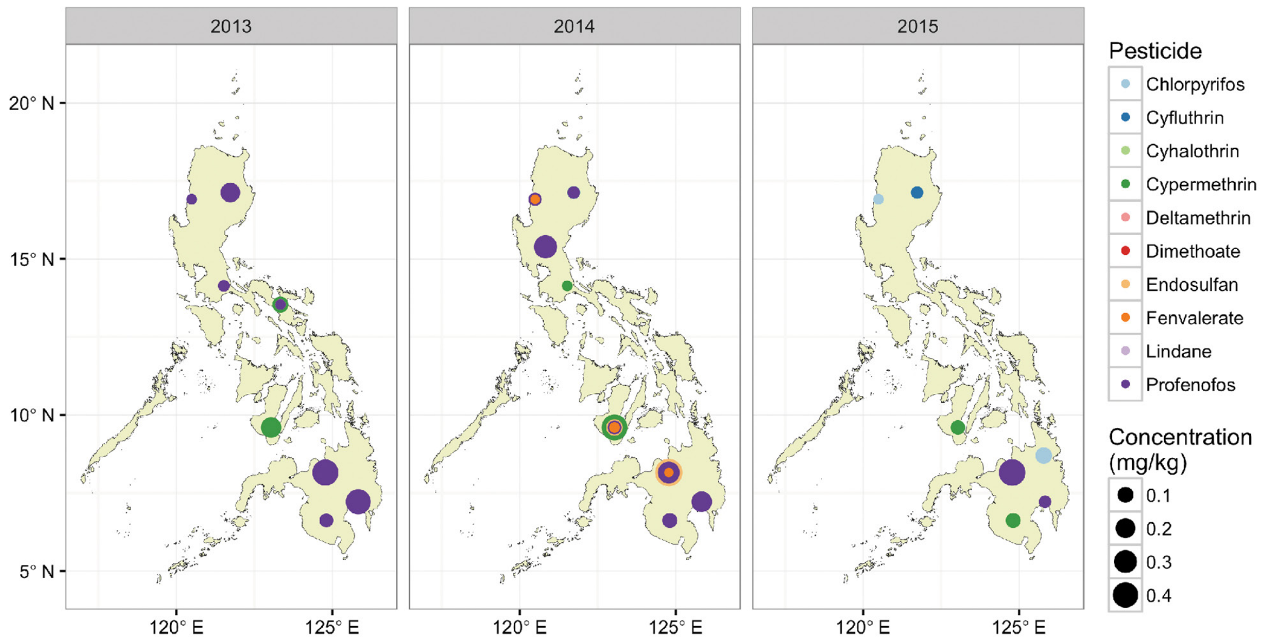
Table 24: Concentration of pesticide residues in pechay sampled from local markets various regions of the country, 2013–2015 *(continued)*

Region	Location	Pesticide Residue Detected	2013 Concentration (mg/kg)	2014 Concentration (mg/kg)	2015 Concentration (mg/kg)	MRL Concentration (mg/kg)
12	General Santos City, Koronadal City, Kidapawan City	Profenofos	0.14	0.02, 0.04, 0.09		
		Difenoconazole	0.018			
		Chlorpyrifos		0.18, 0.24, 0.08, 0.49		1.00
		Deltamethrin	0.017			
		Heptachlor		0.02		
		Cypermethrin	0.007–0.059	0.02, 0.23, 0.01, 0.03, 0.05	0	1.00
		Mevinphos	0.079–0.275			
		Chlorothalonil	0.007–0.009			
		Lamdacyhalothrin	0.006–0.008	0.03, 0.03	1	
		Lindane	0.006–0.038	0.01		
		Total Endosulfan	0.003–0.008			
		Permethrin	0.27			
13	Agusan del Norte	Cypermethrin			0.02	
		λ-Cyhalothrin			0.35	

Source: NPAL 2016.

Figure 76: Pesticide residues in tomato sampled from public markets in various regions of the country from 2013 to 2015



Source: Based on NPAL 2016 data.

Table 25: Concentration of pesticide residues in tomato sampled from local markets in various regions of the country, 2013–2015

Region	Location	Pesticide Residue Detected	2013 Concentration (mg/kg)	2014 Concentration (mg/kg)	2015 Concentration (mg/kg)	MRL Concentration (mg/kg)
CAR	Baguio City Public Market; Tuba, Benguet	ND				
1	Ilocos Sur, Ilocos Norte, La Union	Cypermethrin	0.01	0.01		0.20
		Chlorpyrifos	0.02		0.02	
		Profenofos	0.01,0.02	0.02, 0.05		10.00
		Fenvalerate		0.01		
2	Nueva Vizcaya and Isabela	Chlorpyrifos	0.02	0.02, 0.05		
		Cypermethrin	0.01	0.02, 0.02, 0.02, 0.04		0.20
		Profenofos	0.12,0.19	0.02, 0.04, 0.04		10.00
3	Bulacan, Tarlac, Nueva Ecija	Profenofos		0.31		10.00
		Dimethoate		0.02–0.04		
4	Cavite, Laguna, Batangas	Profenofos	0.03			
		Cypermethrin		0.02		
5	Camarines Sur	Chlorpyrifos	0.02			
		Profenofos	0.02			10.00
		Cypermethrin	0.02, 0.10			0.20
		Deltamethrin	0.02			
		λ-cyhalothrin	0.01			
7	Cebu and Bohol	Cypermethrin	0.085, 0.039,0.214, 0.063, 0.045, 0.123, 0.006, 0.029, 0.174, 0.021,0.04, 0.008	0.01–0.84	0.07,0.02,0.03, 0.1, 0.03, 0.07	0.20
		Chlorpyrifos		0.03		
		lamda-Cyhalothrin	0.011, 0.015, 0.07, 0.006	0.02, 0.04, 0.01	0.04	
		Profenofos		0.06, 0.04		10.00
		Fenvalerate		0.02		
		t-Endosulfan		0.11		

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Table 25: Concentration of pesticide residues in tomato sampled from local markets in various regions of the country, 2013–2015 *(continued)*

Region	Location	Pesticide Residue Detected	2013 Concentration (mg/kg)	2014 Concentration (mg/kg)	2015 Concentration (mg/kg)	MRL Concentration (mg/kg)
10	Cagayan de Oro City	Chlorpyrifos	0.01, 0.02, 0.02, 0.04, 0.05, 0.03	0.01, 0.01, 0.03, 0.01, 0.05, 0.07, 0.02		
		Cypermethrin	0.01, 0.02, 0.02, 0.05, 0.05, 0.1, 0.14, 0.01, 0.03, 0.04, 0.06, 0.08, 0.01, 0.01, 0.03, 0.06	0.01, 0.01, 0.01,0.02, 0.03, 0.05, 0.01, 0.01, 0.02, 0.03, 0.03, 0.04, 0.1, 0.01, 0.01, 0.01, 0.03, 0.03, 0.04		0.20
		Phenthoate	0.01, 0.03			
		λ-Cyhalothrin		0.01, 0.03, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01,0.01, 0.02, 0.01		
		Profenofos	0.1, 0.19, 0.01, 0.04, 0.09, 0.23, 0.4, 0.02, 0.43	0.01, 0.1, 0.26, 0.01, 0.02, 0.03, 0.03, 0.05, 0.14, 0.17, 0.01, 0.06, 0.05	0.11, 0.45, 0.29, 0.01, 0.08, 0.09	
		Endosulfan		0.49		
		Total Endosulfan	0.06			
11	Davao City, Tagum City, Mati City, Davao del Sur	Total Endosulfan	0.044–0.076			
		Chlorothalonil	0.056–0.095			
		Lamdacyhalothrin	0.025–0.054			
		Profenofos	0.38			
		Lindane	0.001–0.003			
		Cypermethrin	0.006–0.01	0.01, 0.04		0.20
		Chlorpyrifos		0.02		
		Cyfluthrin		0.01, 0.01, 0.01		
		Deltamethrin		0.01		
		Diazinon		0.01		
		Fenitrothion		0.01		
		Lambdacyhalothrin		0.01		
		Malathion		0.01		
		Permethrin		0.01		
12	General Santos City, Koronadal City, Kidapawan City	Profenofos		0.01, 0.02, 0.06, 0.08, 0.08		10.00
		Cypermethrin		0.01, 0.01, 0.01		0.20

(continued on next page)

Table 25: Concentration of pesticide residues in tomato sampled from local markets in various regions of the country, 2013–2015 *(continued)*

Region	Location	Pesticide Residue Detected	2013 Concentration (mg/kg)	2014 Concentration (mg/kg)	2015 Concentration (mg/kg)	MRL Concentration (mg/kg)
13	Agusan del Norte	Profenofos	0.02–0.06			10.00
		Cypermethrin	0.005–0.015			0.20
		Lamdacyhalothrin	0.008–0.017			
		Lindane	0.003			
		Total Endosulfan	0.007			

Source: NPAL 2016.

Rice grain and straw do not have pesticide residues because of the 30- to 45-day interval from the last application to the harvesting. Chemicals are quickly degraded in tropical lowland environment (NCPC 1983; Tejada, Varca, and Magallona 1977).

Based on the residue analysis, there was no pesticide built up in the soil. Hence, the best environment for fast pesticide detoxification is tropical flooded soil. Repeated use of the same pesticide increases the growth of decomposing microorganisms which then causes fast pesticide inactivation (Roger 1989).

4.7 Impacts on Biodiversity

Complex food chain of vertebrate (fish, frogs, rats) and invertebrate (crustaceans, microcrustaceans, aquatic insects, annelids, microflora, and microfauna) organisms can be found in rice paddies. The use of pesticide can reduce the number of species, change its composition, and contribute to the residue accumulation in the remaining populations. Aquatic vertebrates quickly decline with the use of pesticides in the first five to seven days after applying the pesticide (Bajet and Magallona 1982; NCPC 1983; Tejada 1985; Tejada, Varca, and Magallona 1977). The residues in the remaining populations were usually small. Due to the reduction of predators, application of insecticides has small effects on invertebrates (Pingali and Roger 1995).

Long-term application of insecticides is harmful to the algal community because it decreases its diversity and causes rapid growth of small crabs, 1–2 mm long. In rice fields, application of insecticides and herbicides is the main pesticide that greatly affects the microflora. Carbamates arw the most harmful insecticides, followed by organochlorines, then organophosphates.

Predator and prey balance can be disrupted if pesticides are applied routinely. The use of chemical pesticides leads to frequent pest invasions. For instance, the brown planthopper or BPH is mainly affected by the frequency, timing, and kind of insecticide applied (Heong 1991).

Isoprocarb is present in fish, frog, and shrimp 45 DAT and after the application of one herbicide and one insecticide because it is less soluble in water. Therefore, it can be easily absorbed through the gills before the toxicant is transferred to flooded paddies. The chemical is less toxic thus the remaining aquatic vertebrates are found in polluted water (Bajet and Magallona 1982). The toxicity of pesticides leads to high fish mortality rather than bioaccumulation (Pingali and Roger 1995).

Eutrophication problems result from the runoff of nitrogen and phosphorus nutrient from fertilizers into the water bodies, as in the case of the Laguna Lake in Southern Luzon, the Philippines, where the nitrogen content of the lake comes mostly (77.2 percent) from agricultural practices. This causes the frequent growth of algal blooms in the lake (Briones 2005).

The pollutants from the agricultural activities within the Pagsanjan-Lumban catchment affect the fisheries in the area. A study on the Lucban River and Salasad Creek in the said catchment revealed that the pesticides used are being transported to the catchment through the drainage water (Varca 2012). Another data from laboratory test showed that there were pesticides in the catchment which affected the selected nontarget aquatic organisms in the Laguna Lake. Compared to tilapia embryos, newly hatched tilapia, and tilapia fingerling, the freshwater shrimp was identified as the most sensitive to the pesticides. Among the pesticides used, the pyrethroids were identified to be highly toxic to the tilapia fingerling and freshwater shrimp. Specifically, the maximum pyrethroids and profenofos concentration in the samples from the catchment posed high hazard to the shrimp. Moreover, the sediment-bound contaminants caused changes to the food source of crabs, freshwater shrimp, and fish (Bajet et al. 2012).

A survey showed that farmers in Lucban and Laguna, the Philippines used insecticides in different crops. The farmers apply pesticides to their rice one to three times per season while they applied insecticides to vegetables two to four times throughout the planting season. The pesticides are used mainly on the vegetables, banana, and rice. They are more intensively applied to vegetable crops. Even though the farmers in the Philippines are using less toxic pesticides, majority of those pesticides are highly poisonous to fish and other aquatic organisms (Fabro and Varca 2012).

Insecticides are widely used pesticides in the Philippines (FAO 2014). Pesticides are mainly applied to rice because large land areas in the country are used for rice production. Farmers are applying pesticides to their eggplant and tomato every 2–3 days during the entire planting season. This study showed that the contamination of creeks and rivers is attributed to the application of pesticides close to the water bodies (Varca 2012).

When it comes to crucifers such as broccoli, pechay, cabbage, radish, cauliflower, and mustard, the diamondback moth is the most destructive pest. Based on the study in 1992 in Atok, Benguet, the farmers were using chemical pesticides to control the diamondback moth. They sprayed it 12 to 32 times per season. They used high dosages of two or more insecticides mixtures on a calendar schedule regardless of the pests' population. There were also instances wherein they applied it until harvest time to maintain the crops' physical value. This intensive use of synthetic insecticides resulted in problems such as resistance to other insecticides, high cost of insecticides, toxic hazards, contamination of soil and water, and reduction of natural enemies and pollinators (Maredia, Dakouo, and Mota-Sanchez 2003).

4.8 Impacts on Ecosystem Functions

Brown Planthopper (BPH) (*Nilaparvata lugens*) and White-Backed Planthopper (WBPH) (*Sogatella furcifera*) were found to cause huge losses in rice yields (Spangenberg et al. 2015). Rice crops develop vulnerabilities to pests due to insecticide spraying, but this eventually destroys natural enemies and ecosystem services. Heong (2009) found that the pattern of damage in crops often coincides with the patterns of insect spraying in the early crop stages (Spangenberg et al. 2015).

But insecticide spraying is not a reliable strategy in cases of acute infestation, does not prevent future damages, resulting from direct feeding and infections due to virus diseases that the hoppers carry. The spraying of insecticide has become a routine, applied prophylactically, and to maximize its effectiveness, the frequency and dosage are increased, or at times, mixed with some other insecticides (Escalada and Heong 2012).

The planthopper infestations are seen to be the primary driving force at the micro level. The occurrence of white-backed or brown planthoppers creates pressure in the ecosystem. Due to this, the standard control measure against insects is applied, that is, insecticide spraying, which kill most of the insects, including the leaf-feeding pests. However, in the growing season, the problem will reoccur and brown planthoppers will appear. Unlike during the first season, the hoppers will multiply this time and spread over the paddy in enormous numbers.

At the macro level, the biological functions of the system are being affected, particularly the reduction of net primary production (Spangenberg et al. 2015).

This leads to reduced service potential that threatens to diminish or possibly to destroy the harvest, even if additional efforts are made. This ecological catastrophe translates into a societal problem, that is, there is a reduced harvest, failure in the local income generation of growers, and even risk in nutrition. The immediate response to this catastrophe will follow the same pattern, spraying of insecticides, in line with the current methods, attitudes, ideologies, and past experiences. This does not work as efficiently as before, in that the number of insects and the speed of their spread, as well as the damage, becomes manifest.

Insecticides are found to be a mitigation and not a prevention strategy. The hoppers are found to be potential vectors transferring viruses thus, they represent multiple simultaneous pressures in the system. Feedback loop from the society to the ecological system is often overlooked at the micro level, however. The first cycle of spraying insecticides induces changes in the environmental process. Individuals and organizations like corporations, extension officers, and agro-administrations are either profit-driven or ideology-driven when they decide to spray insecticides. Existing mechanisms of decision making, routines, attitudes, and legal regulations legitimized by similar ideology of improving the standard of living through intensification, mechanization and chemicalization so as to create additional income and economic growth are being followed in the system of intensified insecticide spraying (Spangenberg et al. 2015).

Pressures caused by human management planned to rescue one ecosystem service in turn threaten other aspects such as water purification and pollination. In this particular case, it has reduced the biocontrol potential of the respective ecosystem. This will be unnoticed in the first round of insecticide spraying. When the infestation materializes for the second time, and the pressure on the ecosystem is turned up, it will be noticeable that the system has increased its sensitivity and its resilience has decreased. It will then no longer able to absorb infestations by limiting their impact, size, and duration. This increases the multiplication and spread of hoppers, leading to partial or total collapse of the entire system or some of its parts. When spraying is done regularly, the system as a whole may flip permanently to a different state, with less potential of important ecosystem services, and less benevolent to humans (Spangenberg et al. 2015).

SOCIOECONOMIC IMPACTS

5

5.1 Human Health

In Asia, only a small dosage of pesticides is being used which greatly affects the tropical flooded areas than the temperate upland areas. Direct and indirect exposure to chemicals have negative health impacts to humans which can cause acute and chronic health diseases. The chemicals being sold in Asia are considered extremely hazardous hence these are banned in the developed countries (Pingali and Roger 1995).

Prolonged pesticide use can cause acute and chronic health problems to the exposed groups. Skin, eye, neurologic and pulmonary problems are associated with this. These health problems may be linked to the use of organophosphates, organochlorines, organotins and phenoxy herbicides (Pingali and Roger 1995).

Prolonged exposure to pesticides may cause several of the abovementioned health problems at the same time. A study showed that in Laguna and Nueva Ecija, a total of 79 percent and 80 percent, respectively, had 3 or more health problems (Pingali and Roger 1995).

Pesticide misuse can cause great health impacts in the farming communities in the Philippines. Numerous researches correlated the extent of direct and indirect pesticide exposure to health hazards such as headache, muscle pain, cough, weakness, eye and chest pain, and eye redness.

Farmer-users are especially vulnerable to health effects attributed to pesticides. Loevinsohn's study (1987) showed that the widespread use of pesticides in Central Luzon was followed by a 27 percent increase in death among the farmers from causes other than physical injury. An average of 503 cases of pesticide poisoning had been reported between 1980 to 1988 (of which 15 percent died every year).

On the other hand, health hazards prevalent among pregnant women include dermal contamination, fetal abnormalities, spontaneous abortion and decrease in cholinesterase level (Lu 2009a).

According to Elazegui (1989), pesticide use has been prevalent in various government national food programs since the launching of the Green Revolution in 1965. McCracken and Conway (1987) mentioned that widely used pesticides (carbofuran, endrin, parathion and monocrotophos) in the country are classified by the World Health Organization as extremely hazardous.

In a study conducted by Perez et al. (2015) among 528 farmers spraying pesticides in rice, corn and cassava farming systems, reported various signs and symptoms presented in Table 26. The most prevalent complaints felt by farmers right after applying pesticides were skin irritation (32.95 percent), headache (29.55 percent), cough (23.30 percent), dry throat (15.34 percent), shortness of breath (14.96 percent), dizziness (14.20 percent), nausea (12.69 percent) and eye irritation (11.36 percent).

Table 26: Reported self-percieved symptoms among the sprayers (N = 528) in Mindanao, Southern Philippines

Symptoms	N	(%)
Skin irritation*	174	32.95
Headache*•	156	29.55
Cough	123	23.30
Dry throat*	81	15.34
Shortness of breath*	79	14.96
Dizziness*•	75	14.20
Nausea*•	67	12.69
Eye irritation	60	11.36
Excessive sweating*•	21	3.98
Loose bowel movement	11	2.08
Excessive salivation*•	4	0.76
Convulsion*•	3	0.57
Fatigue*•	3	0.57

Source: Perez et al. 2015.

Note: *manifestations of pyrethroid poisoning; •manifestations of organophosphate poisoning.

Based on the records of the National Poison Control Management Center (NPCMC), mixed pesticide had been in the top ten poisons recorded during 2004–2009. Mixed pesticides accounted for 104 of the 3,620 poison cases in 2007 and 209 of the 3931 cases in 2008 (Lu 2010). In 2009, pesticide ranked third with 164 cases. For a total of poisoning cases for six years from 2004 to 2009, pesticide poisoning ranks sixth. This means that mixed pesticides have become part of the main causes of poisoning cases in the Philippines.

Based on NPCMC data, pyrethroid had been the most frequent cause of pesticide poisoning from 2008 to 2009. In the year 2008, there were 112 recorded pesticide poisoning cases due to pyrethroids. Then in 2009, 72 cases were recorded.

In Bohol Province located in the southern part of Luzon in the Philippines, a mass pesticide poisoning case among children was reported on March 2005 due to the chemical carbamate commonly used as household and agricultural pesticides. The victims ate cassava contaminated by carbamate. This is a case of unsafe pesticide storage. The pesticide was mistaken for flour that caused the food poisoning of more than 100 children resulting in 27 deaths (Lu et al. 2010)

Health costs can be reduced by regulating the pesticides through eliminating the least productive and most harmful pesticides (Pingali and Roger 1995).

5.2 Farming System

5.2.1 *Land Use*

Rice production is an important industry which contributes a lot to the economy of the Philippines. In this regard, the government continues to expand the rice farms and intensive production of it through increasing the production intensity and intercropping practices. Some of the techniques used to increase the rice production are making more irrigation water available and adopting HYVs.

A study evaluated the land degradation in the Philippines by the amount of nutrient loss attributed to the soil erosion. The main nutrients evaluated are nitrogen, phosphorus and potassium. The results showed increasing trends in the areas devoted for upland rice production. In 1994, nitrogen is accounted for more than 80 percent of the total nutrient loss in soils. It was followed by phosphorus at 11 percent and potassium at 2 percent (NSCB 2000).

A study showed that the agricultural land areas in the Philippines are used for the following: arable lands, cereals, sugarcane; crops mixed with coconuts; coconut plantations; crops mixed with other plantations; fishponds from mangroves; other plantations; other fishponds; and grasslands. The largest portion of the agricultural land is used for arable lands, cereals and sugarcane, while, the smallest portion is used for other fishponds. Through the years, the changes in the country's agricultural land utilization can be attributed to the changes in the forest areas. The forest area has been decreasing over the years. In the same study, the forest cover was 26 percent in 1970 and it decreased to 18 percent in 2000. This showed that in the last three decades, there is a very fast conversion of forest land into other land uses such as residential, commercial, industrial and agricultural uses (DENR-EMB 2002).

The agricultural practices and farming system in the country affect the environment. In the similar study by DENR-EMB (2002), the intensive use of inorganic nitrogenous fertilizer can contaminate ground water and contribute to pests, soil and water pollution. The continuous and intensive use of chemical pesticides can lead to human poisoning, chemical dependency, new pests, resistance to pests and water pollution. Moreover, the cultivation of fragile and marginal upland areas can lead to deforestation, accelerated soil erosion, sedimentation of river and biodiversity loss (DENR-EMB 2002).

The uplands in the Philippines are of great importance and interest because they comprise about 59 percent of the country's total land area. They are dynamic and highly interactive landscape components of the rural system, and also serve as the life support for the lowlands and coastal areas. In addition, they are home to the increasing population of the "poorest of the poor," and are expected to absorb more of the expanding population (Sajise and Ganapin 1991).

The Philippine uplands are a very heterogeneous and fragile resource base (Sajise and Ganapin 1991). Most of these areas are either open grassland, degraded, or occupied by settlers (Villancio et al. 2003). More than 20 million people are estimated to have settled in the uplands, and the number is increasing at a rate of about 2.8 percent annually, which is above the national average of 2.32 percent.

In the uplands, a major problem is food insecurity, which is mainly a consequence of land degradation. There is general recognition of the serious implications of deforestation, soil erosion, declining agricultural productivity, loss of biodiversity, off-site impacts, increasing poverty, and the social costs associated with the biophysical and ecological instability in the uplands. While 53 percent of the Philippines' total land area is classified as forestlands, only 17 percent is adequately covered with forest vegetation.

In fact, the total forest cover in the country declined by as much as 3.54 percent for the period 1990–1995, the fourth highest loss rate in the world. This rapid decline in forest areas can be attributed to the large and rapid conversion of the Philippine uplands into permanent annual cropping areas to meet the food requirements of an increasingly expanding population (Domingo and Buenaseda 2000). However, the productivity of sloping lands has been diminishing at an alarming rate due to soil degradation or erosion brought about by the activities of this population as it grows. According to Escaño and Tababa (1998), the rates of soil erosion in sloping areas range from 23 to 218 ton/ha/year for bare plots on gradients of 27–29 percent to 36–200 ton/ha/year on plots cultivated up and down the hill. These rates are higher than the acceptable soil loss level of 3–10 ton/ha/year (Paningbatan 1989), and the situation poses a grave threat to the productivity and sustainability of farming in the upland areas.

In summary, the uplands can be characterized as degraded and ecologically marginal for agricultural purposes with landscapes that are highly sensitive and of low resilience. The biophysical limitations of these lands affect production, income, and household food security. Diminished food access due to the degraded natural resources, higher food prices, limited income opportunities, and the impact of natural elements leave the upland population a legacy of poverty and food insecurity.

5.2.2 *Productivity, Profitability*

Based on the study by Sebastian, Alviola, and Franciso (2000), the rice production grew during the pre-1965 period. The growth was attributed to area expansion in the production ecosystem. During 1965 to 1980, the production growth rate reached its peak because of the Green Revolution. The intense use of fertilizers and use of HYVs contributed to it. After 1980, there was a decline in the production growth rate and yield level due to the stagnation of area expansion and rise of new biological problems. Due to the regular floods and drought, new strains and biotypes of pests in rice emerged. Moreover, the decline was attributed to the reduced hectarage, urbanization, post-harvest losses and poor irrigation. (Sebastian, Alviola, and Franciso 2000)

On the other hand, a study showed that reducing the application of pesticides from nine to four times has not significantly affected the crop yield. Similarly, the study involving 105 farmers from 1980 to 1983 showed that there was only a 50 percent significant difference between treated and untreated crops. This can be attributed to the existence of natural enemies and use of resistant varieties which implied that the current level of pesticide use is inefficient (Briones 2005).

5.2.3 *Pest Management*

In the IPM program, the farmers were trained on the agroecosystem interactions affecting the plant growth and crop management. The changes in pesticide legislation, guidelines and policies in protecting the human health and environment were included in the 2000 revision of the policies. Overall, the national IPM program has an evident economic impact to the country as the rice and corn yield increased (Maredia, Dakouo, and Mota-Sanchez 2003).

6

SOLUTIONS TO ADDRESS AGRICULTURAL POLLUTION

6.1 Regulation of Fertilizer and Pesticides Prices, Imports, Marketing, and Raising Public Awareness in the Philippines

Regulation of fertilizer prices, imports, and marketing were first done in the Philippines in 1973 by the Fertilizer Industry Authority. The Authority established a two-tier pricing which provided privileges to food manufacturers to obtain fertilizers at lower prices (Briones 2014). By virtue of Presidential Decree No. 1144, the Authority was changed to the FPA in 1977 for pesticide regulation and safety. It regulates the processes concerning pesticides such as its formulation, manufacture, distribution, sale, usage, disposal, and so on. Moreover, it is in charge of the following responsibilities: restricting the use of hazardous pesticides, issuing licenses for pesticide users, disseminating information on the safe use of pesticides, and registering new pesticides. The pesticide registration requirements were based according to the international standards by the FAO and the WHO. Before a pesticide is recommended for registration, a Pesticide Technical Advisory Committee will evaluate and review its toxicology, efficacy, and residue data (Maredia, Dakouo, and Mota-Sanchez 2003).

To successfully overcome the lock in pest incidence, insecticide spraying, and the resurgence of pests, there is a need to address legal institutions, and organizations. Some of them relate to the legal situation such as ban on misguiding advertisements for licensing of pesticide dealers based on qualification tests, and how pesticide selling licences can be obtained for a fee but without qualification testing. Some of the organizational changes should include regular information for farmers through public extension workers. It is suggested that the old system or mental model be replaced with a new one, to incorporate feedback loops and emphasize the complexity of ecosystems managed (Spangenberg et al. 2015).

It is also necessary to employ knowledge brokerage strategies and science-policy interfaces, as well as public education to make stakeholders aware of the fallacy of knowledge regarding the use of insecticides. Public awareness can be through information dissemination via mass media, from which the message should be conveyed in a simplified but meaningful way (Spangenberg et al. 2015).

6.2 PhilRice Long-term Research Programs

The Agronomy, Soils, and Plant Physiology Division of PhilRice has conducted long-term researches which aimed to identify, evaluate, facilitate, and refine the delivery of improved practices in soil, plant, nutrient, and water management. The end goal is to contribute to attain and sustain rice self-sufficiency with the following objectives: "(1) identify and propagate approaches for nutrient and crop management with the integration of management of principal insect pests and disease; (2) develop technologies that will improve soil and water conservation practices; (3) develop practices to manage crop residues for healthy soils in rice ecosystems; (4) strengthen the scientific basis for rice-based cropping system technologies; and (5) assess the impact of developed technologies on environmental quality. Finally, the division is expected to develop crop management protocol, diagnostic tools, and processes toward sufficiency and sustainability" (PhilRice 2016).

The long-term fertility experiment aims to examine the sustainability of intensive double rice cropping and providing early warning indicators of nutrient imbalances and nutrient mining that can occur with intensification in farmers' fields. Another study aimed to assess the yield potential, nitrogen use efficiency and grain quality of different varieties in response to varying nitrogen (N) management.

A long-term experiment on the use of organic fertilizers aims to determine the long-term effects of different organic fertilizers or amendments on the soil physico-chemical characteristics and nutrient availability for paddy rice; assess sustianability of grain yield production and soil health by just the use of organic fertilizers in paddy soils as compared to the use of inorganic fertilizers; assess grain quality, nutrient content, and seed viability of organically nourished rice plants; and create a database for the development of an organic-based rice production management protocol.

There are already several tools and techniques available, from software to hardware, which contribute to overall rice land productivity. The techniques developed contributed to the technical know-how on fertilizer use and its timing of application.

DSSAT is a software developed for crop genotype, soil, and weather options. DSSAT must be calibrated first before it can be fully used to determine potential rice yield under the best crop management in varying locations and weather conditions.

Field NDTs were developed for effective nutrient management in irrigated lowland rice systems. NDTs are less expensive and more practical compared to laboratory procedures.

Crop nutrient diagnostic tools serve as a guide for economical fertilizer use.

6.3 National Organic Agriculture Program (NOAP)

The Philippine Organic Agriculture Act (RA 10068, signed on April 6, 2010) created the NOAP of the DA in an effort to reduce rural poverty by advocating low-input sustainable agricultural techniques that improve land productivity while minimizing adverse impacts to the environment. With this, NOAP targets to attain food security, sustainability, and competitiveness by converting at least 5 percent of the total agricultural area in the country, which is about 483,450 ha of the total area of 9,669,000 ha. The major components of the NOAP include (a) institutional development and strengthening, (b) research and development, (c) production and technology support, (d) extension and capability building, (e) promotion, advocacy and education, (f) market development, and (g) results-based monitoring and evaluation.

As of April 2016, the program has attained 31 percent of its target by converting 151,740 ha of agricultural lands, which has produced 512,680 tons of organic agriculture goods in 2014–2015 distributed to 72 local and foreign markets. The program's advocacy has reached 86,900 farmer beneficiaries and stakeholders, who have been recipients of production and technology services and extension and capacity-building support for organic agriculture. Accomplishments in this area include 29 organic trading posts, 707 vermicomposting facilities, 186 techno-demo farms, 234 organic agriculture learning sites and circulation of more than a million Information, Education and Communication (IEC) materials.

The institutional development and strengthening component of NOAP has established Local Technical Committees in 69 provinces, 100 cities, and 1,086 municipalities nationwide. Under the extension services component, the program has partnered with extension services providers such as Costales Nature Farms, Kahariam Farms, and ACES Polytechnic College.

The Regional Organic Agriculture Research and Development Networks and Centers, in collaboration with the Bureau of Agricultural Research (BAR), has introduced and disseminated to farmers a number of new technologies in organic agriculture. Collaborative efforts with universities and LGUs have also been fruitful in tapping technologies such as Integration of Beekeeping to Coconut Farming System (Cagayan State University), Processing Technology Development and Utilization for Organically-grown Arius Fruits (Batanes State College), and the Production and Management of Multi-Bee Species for Livelihood and Pollination of HVCC (LGU of Batac, Ilocos Norte). Moreover, the program has tapped BSWM technologies and established 377 Small-scale Composting Facilities and dispersed Philmech technologies such as Paddy Huller (Brown Rice Mill), Corn Mill, Coffee and Vegetable Processing Equipment.

On production and technology support, NOAP has established 162 production facilities, 63 production machinery and equipment, and funded 1,085 projects. In 2015, provision and delivery of support services distributed 121,653 kg of seeds, 115,027 planting materials, 11,177 animals and livestock, 81,880 bio-con agents, and 688,039 fertilizer and soil ameliorants.

At the policy level, the program has produced policy resolutions particularly on soil fertility and ecosystems' management support systems, certification subsidy, regulation of organic input, registration and labeling of organic products, and sustainable land management.

Extension and capability-building efforts have enhanced farmer competencies and training is being given to extension workers and farmer groups. So far, 697 trainings have been conducted with 6,679 farmers trained. These training activities include Farmer Field Schools (FFS), Training of Trainers (TOT), trainings to support the Installation of Internal Control Systems and Training of Agritecture.

6.4 Organic Agriculture, Bio-Fertilizers and Bio-Pesticides

Organic agriculture excludes the use of pesticides, manufactured fertilizers, insecticides, herbicides, fungicides and even hormones, food additives, genetically modified organisms, and livestock antibiotics. It evolved from the traditional practices in farming communities over the years and is an integral part of sustainable agriculture. If a production system passes the standards of the International Federation of Organic Agriculture Movements (IFOAM) or PNSOA and meets the requirements of national organic certification, then that farming system will be certified organic (Maghirang and Villareal 2000).

Realizing that bio-fertilizers are promising alternatives to inorganic fertilizers, researchers at BIOTECH are developing efficient, locally available, and cheaper substitutes or supplements to inorganic fertilizer. The bio-fertilizer technologies developed by the institute include BIO-N, the most popular and one of the most effective; VAMRI; Brown Magic; BioGroe; Mykovam; NitroPlus; microbial inoculants for the bioconversion of crop residues and agro-industrial by-products into bio-fertilizers; Cocogro or plant growth hormones from coconut water; and BioCon (Javier and Brown 2009). Bio-fertilizers are very cheap, easy to use, safe, and do not require repeated applications. Several training courses and workshops have already been conducted to disseminate and transfer the bio-fertilizer technologies to target clientele (Javier and Brown 2009).

Bio-pesticides are promising alternatives to chemical pesticides. The National Institute of Biotechnology and Applied Microbiology (BIOTECH) at the (UPLB) is also developing bio-pesticides derived from natural materials including animals, plants, bacteria, and certain minerals. This technology needs massive campaign to increase awareness among Filipino farmers. A promising strategy for widespread introduction and utilization of this technology is through organized IPM programs by the LGUs (Javier and Brown 2009).

6.5 Farming System Technologies

The technologies developed to improve rice production, their benefits, and some strategies for their implementation have considered major factors for production of rice including: (a) seeds, (b) soil and fertilizer management, (c) water management, and (d) pest management. Notable examples of technology interventions included: (i) application of optimum fertilizer amounts; (ii) proper management and recycling of crop residues; (iii) use of foliar fertilizers to improve grain filling percentage; (iv) re-introduction of green manures in rice-based farming systems; (v) organic fertilizer application to enhance BNF; (vi) integration of bio-fertilizers in rice production systems; (vii) re-introduction of slow release nitrogen fertilizers; (viii) expansion of irrigated areas through installation of shallow tube wells, water harvesting structures, irrigation facility repair and rehabilitation, among others (Velasco et al. 2012) (ix) research on endophytic fungal isolates from different rice ecosystems in relation to biological control of sheath blight, (x) rice variety-site specificity trials like planting low-yielding rice for the sloping uplands, medium-yielding rice for the unfavorable flatlands, and high-yielding rice for the favorable flat uplands, (xi) upland variety resistance to leaf rollers, among others.

There are approximately 0.85 million ha of marginal uplands planted with native corn in the Philippines. The development of high-yielding maize hybrids that have resistance and tolerance to a number of biotic and abiotic stresses could help improve maize yields in the country. Recognizing that white corn can be an alternative to rice as a staple food crop, the government, particularly the DA, has looked into enhancing the production and consumption of white corn to address food and nutrition insecurity in the country. White corn has the potential to contribute to food self-sufficiency, since the country only imports 10 percent of its total national food requirement. Moreover, corn is cheaper than rice; thus, it is more affordable especially for the rural population. Similar to rice, a number of technologies on white corn, have been developed: (a) improved cultivars; (b) combined inorganic-organic fertilization; and (c) post harvest and processing through distribution of corn mills and dryers.

6.6 Ecological Engineering

There is a need to manage the present rice production systems to reduce the harmful effects of ongoing land use intensification. Sustainable management should be done to conserve and enhance biodiversity, as well as for the provisioning of ecosystem services (Godfray and Garnett 2014).

Ecological engineering, that is, the provision of habitats for beneficial arthropods, has recently gained considerable attraction as a method to reduce pesticide inputs and enhance biological pest control provided by natural enemies (Gurr et al. 2011). Habitat management through ecological engineering with flower strips can have beneficial and synergistic effects on biological pest control, pollination, and cultural services including landscape aesthetics and recreation (Westphal et al. 2015).

The flower strips program within ecological engineering is a possible solution to increase pest regulation, pollination, and services as recreation in rice production landscapes (Settele et al. 2015). Ecological engineering is also effective in reducing input costs, as well as reduction of health risks for both producers and consumers (Spangenberg et al. 2015).

This flower strips program, however, needs more experimental studies for identifying seed mixtures and analyzing potential interactions between different spatial scales and ecosystem services. Ecological engineering requires active participation from rice farmers in the development, research, and evaluation of its programs. It is recommended that more comprehensive ecological engineering programs combining participatory approaches, mass media campaigns, and flower strip implementation are necessary to motivate the farmers and eventually to increase sustainability of rice production in Asia and enhance ecosystem services (Settele et al. 2015).

6.7 Biotechnology

Biotechnology offers a sustainable and practical solution to numerous problems in rice production, specifically on pest protection. This technology could aid the development of cultivars with higher yields that offer resistance against major pests in the Philippines.

The adoption of biotech or genetically engineered crops had greatly reduced the global pesticide market in 2009. The global insecticides market decreased by half billion dollars from US$10.65 billion in 1998 to US$10.19 in 2009. The same trend was observed in the global fungicide market with US$400 million less than the 2008 market (Fernandez 2011). The shrinkage in the crop protection market starting from 2009 is attributed to the continued shift from planting of conventional to genetically modified (GM) crops. GM crops like Bt corn produce natural pesticide against pests, notably the Asiatic corn borer, thus greatly reducing the need to apply insecticides. In 2010, about 270,000 farmers planted Bt corn in about 541,000 ha in the Philippines. These farmers spent much less or virtually nothing on pesticides to control corn pests.

6.8 Agroforestry Systems

Agroforestry is a dynamic, ecologically based, natural resource management system that, through the integration of trees into farms, diversifies and sustains smallholder production for increased social, economic, and environmental benefits (Leaky 1996). Introducing trees within the cropping system can help prevent land degradation, increase biodiversity, and at the same time allow the continued use of the land for agricultural crop production (Wise and Cacho 2002).

Mature trees in agroforestry systems can yield numerous positive effects on cropped fields (Garcia-Barrios and Ong 2004). Among these are improved soil fertility and physical properties via organic matter addition from litter; reduced soil erosion through stabilization of loose soil surface by tree roots; recovery of leached nutrients from deep soil layers inaccessible to crops; reduced soil evaporation, leaf temperature, and evaporative demand by crops via tree shade; increased soil infiltration rate; protection against wind and runoff; reduced weed population; and reduction and potential slowdown of windborne pests and diseases. In a system where nitrogen-fixing trees are used as hedgerows, alternative sources of nitrogen for trees can significantly reduce competition with crops.

The introduction and adoption of an agroforestry system among upland farmers has enhanced their earning capacity and food security (Magcale-Macandog 2014). Agroforestry is an essential part of the effort to feed the hungry people in the uplands. While agroforestry efforts cannot substantially alter the social, economic, and political factors that cause food supply inequalities, they can help build up household food security. The integration of trees in agroforestry systems can also help prevent land degradation, increase biodiversity, and at the same time allow the continued use of the land for agricultural crop production.

6.9 Agricultural Ecotourism

In the Philippines, the active involvement of local communities in agricultural and environmental activities of agritourism and ecotourism programs are trending (Aquino 2010). Filipinos have developed an interest in promoting and visiting ecotourism sites. Activities such as crop harvesting, fruit and flower picking, food preparation, and environmental protection and conservation schemes such as precision agriculture are increasingly attracting the attention of tourists. These advances in agritourism allow tourists to immerse in the local agricultural activities and raise appreciation for local produce. Moreover, agritourism not only has become the vehicle to promote environmental aesthetics but has also become a venue for educational tours and community activities showcasing the agricultural landscape.

These improvements in agritourism shed light on potential business opportunities in the sector, leading to people's empowerment and widened access of local communities to comprehensive development programs and tourism initiatives. Foreign tourists visiting the country each year contribute to the rich ecotourism market. In fact, their visit to the country had contributed around PHP 129 billion to the gross domestic product (GDP) in 2003. This number is equivalent to 10.6 percent of the total GDP in that year (Aggangan 2004).

6.10 Feedstock for Bioenergy

A feedstock is any renewable, biological material that can be used directly as a fuel, or converted to another form of fuel or energy product. Biomass feedstocks are plant and algal materials used to derive fuels like ethanol, butanol, biodiesel, and other hydrocarbon fuels. Examples of biomass feedstocks include corn starch, sugarcane juice, crop residues such as corn stover and sugarcane bagasse, purpose-grown grass crops, and woody plants.

The Philippines is implementing various bioenergy policies to reduce dependence on imported oil, enhance economic growth, increase energy efficiency, and contribute to climate change mitigation (DA 2011). The growing focus toward a cleaner and greener environment has directed the Philippine government to the search for more alternative renewable sources of fuel and energy. The most prominent policy is the Biofuels Act of 2006 approved on January 12, 2007, which mandates a 2 percent blend of biodiesel into all diesel fuel in 2008 and 10 percent blend of bioethanol into all gasoline fuel in 2010.

The Philippines has a large potential for bioenergy production since crops that are used as feedstock are indigenous or locally grown. Further, instead of burning, corn and sugarcane crop residues can be used as biomass feedstocks. Other benefits that can be achieved by growing traditional crops as bioenergy is that, it increases utilization of agricultural land, promotes investment, and creates jobs. Biofuels will give the otherwise traditional crops a boost toward value-added processing (DA 2011).

DATA GAPS AND RESEARCH CHALLENGES

7

The major data gaps that this study has identified are the lack of available data on the kind and amount of pesticides actually applied in various cropping systems like rice, corn, vegetables, pineapple, banana, tobacco, and other crops grown in the country. There is no national agency that collects and monitors the application of pesticides in various crops.

Fertilizer consumption in rice and corn cropping systems are the only data available. Data on the amount and timing of fertilizer application in all other crops grown in the country are lacking. Data on fertilizer and pesticide consumption in plantation crops like pineapple and banana are not available despite the common knowledge that massive amounts of pesticides and fertilizers are applied by multinational companies in these systems.

Pesticide residues in tropical and temperate vegetables would likely have a direct impact on human health, thus it is critical to obtain data on the amount, timing, and manner of application of pesticides in these food crops. Close monitoring of pesticide residues in vegetables locally sold in community markets is necessary to ensure food safety of consuming these commodities.

The only water bodies where studies on the impacts of pollution are being monitored are the Manila Bay and Laguna Lake. Studies on the impacts of agricultural pollution on the other major water bodies and river basins is lacking in the country.

Furthermore, pesticide application has adverse impacts on nontarget species and there is lack of studies that investigate the impact of pesticides on the population and interactions among the various life forms (biodiversity) that make up the food chain in the agricultural systems, particularly the herbivores, pollinators, and predators.

CONCLUSION

8

The rich natural resources of the Philippines including fertile volcanic soils, varied topography, abundant rainfall, and warm tropical temperature with plenty of sunshine make it highly suitable for growing various important economic crops. This study has gathered enormous data on the magnitude and extent of the major crop production systems in the various provinces and islands in the country. In the past two and a half decades, it was demonstrated that due to increasing food demand for the increasing population, the agricultural areas expanded to marginal uplands, and led to the conversion of forested areas. Production of major staple food crops like rice and corn increased since the introduction of the Green Revolution in the mid-1960s. This increased crop production was achieved through the introduction of cropping inputs including HYVs, inorganic fertilizers, pesticides, and irrigation. The amounts of nitrogen and phosphorus fertilizers applied in rice and corn farming systems are much higher than the amount of nitrogen and phosphorus actually taken up by the crop and removed from the system during harvesting from the 1960s. This excess nitrogen and phosphorus are lost into the environment via leaching into the ground water, runoff into the surface water, or volatilization into the atmosphere. Further, the continuous application of inorganic fertilizers leads to environmental degradation such as soil acidification, contamination of ground and surface water with nutrients originating from the chemical fertilizers which may either be hazardous to human health (nitrates in drinking water) or may cause eutrophication of bodies of water (ammonium, nitrate and phosphates) leading to algal blooms that may result in fish kill. There were no data gathered from the government agencies on the amounts of inorganic fertilizers applied to the other major crops grown in the country. It was hoped that fertilizers applied in sugarcane and coconut may have been available at the attached agencies of the DA (Sugar Regulatory Authority [SRA] and the Philippine Coconut Authority [PCA]). As for the other major crops grown in the country like pineapple, banana, temperate and tropical vegetables, there are no available data on the amount of fertilizer consumed.

Chemical pesticide application has negative impacts on the ecosystem as the pesticide may affect not only the target pest but may also affect other organisms in the ecosystem that are important in the functioning of the ecosystem like pollinators, herbivores, and other predators. Further, excessive application of pesticides may leave residues in the harvested crop that may be harmful for human consumption, or the pesticide residues that may end up in bodies of water and land that may negatively affect the biology of other organisms. Data on the amount of pesticides applied and timing of application are not being gathered or monitored by any government agency in the Philippines, thus no data were collected. The analysis of pesticide use was only related to the volume of pesticide importation by the country. There are isolated reports and case studies that have shown evidences of contamination of water resources and soil with inefficient applications of fertilizers and prevalent use of pesticides in rice paddy systems in Laguna and Nueva Ecija, temperate-vegetable-growing areas in Benguet, and tropical-vegetable-growing areas in Laguna. There were reports on the brand names and active ingredients of pesticides being applied in banana plantation areas in Davao, and some of these may be banned brand names. Further, the amount and timing of pesticides, particularly, fungicides applied in banana plantations are not available. Another rapidly expanding agricultural commodity is the commercial plantation and consolidated smallholder farms contracted to pineapple growing in Bukidnon and other provinces in Mindanao. There are no available data on the amounts of fertilizers and pesticides applied in these cropping areas.

Temperate and tropical vegetable growing also entails heavy applications of pesticides. There are fragmented reports on evidences of pesticide residues in water and soil resources where these vegetables are being grown, however, there are no available national data. Vegetables commonly bought in public markets and consumed by Filipinos including bitter gourd, eggplant, pechay, and tomato were found to have traces of combination of pesticide residues ranging from as low as two to as many as ten different pesticides (NPAL 2013–2015). Concentrations of cypermethrin residues in bitter gourd, pechay, and tomato; lambda-cyhalothrin in bitter gourd; and chlorpyrifos and diazinon in pechay exceeding the MRL were detected.

Another possible source of pollution from agricultural systems are the plastic containers of pesticides and fungicide-coated plastic bags used to wrap banana fruits. There are no proper guidelines in the country for the proper handling and disposal of these plastic waste materials from agricultural systems.

Next to the energy sector, the Philippine agriculture sector is the second major source of GHG emissions. The CH_4 gas emitted by growing rice plants in irrigated paddy fields, N_2O emissions from inorganic fertilizer application, and CH_4 and N_2O gases emitted by burning crop residues are the major contributions of cropping systems to GHG emissions for the agriculture sector.

Vast amounts of data and evidences expounded in this study have shown that intensification of growing agricultural crops in the Philippines has contributed to pollution of land, water, and air resources in the Philippines. The potential and magnitude of pollution have not been totally quantified due to the lack of available data for all crops grown in the country. It is mainly in the rice and corn cropping systems that fertilizer consumption has been monitored and where data are available. Fertilizer application on other crops grown in the country is not being monitored. As for pesticide use, there is no monitoring activity that is being done in the country.

The decline in the national consumption of fertilizer and pesticides in the past recent years isattributed to a combination of government programs and developments in technologies/biotechnology. The massive campaign on organic agriculture by the NOAP and IPM by the DA may have significant impact on these recent trends. The development of insect-resistant corn varieties (like Bt corn) may have significant impact on the reduced application of insecticides in corn.

Increasing labor cost, however, may be an important factor in the increasing trends in herbicide application as farmers tend to apply herbicides early in the cropping season to control weeds.

There are a number of solutions including programs and regulations being implemented by the government to address food security and sustainability of crop production that may somehow indirectly address agricultural pollution problems. Government programs that help address agricultural pollution are the organic agriculture and IPM programs. Agricultural research and development programs include long-term research programs which aim to identify, evaluate, facilitate, and refine the delivery of improved practices in soil, plant, nutrient, and water management in rice systems, crop variety improvement for higher yield and pest resistance, precision agriculture, biological control of pests, ecological engineering, agroforestry systems, and agri-ecotourism.

There are still great challenges ahead to address pollution coming from agricultural activities in the Philippines. There are no government programs that directly address problems of agricultural pollution. The legal mandates that may be related to agricultural pollution are the Philippine Environment Code, Clean Water Act, Clean Air Act, and Ecological Solid Waste Management. If ever there are provisions for controlling pollution coming from agricultural pollution, there is a need for strict implementation by the national and local government units.

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