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Analysis Of Strategies For Mitigation And Adaptation To The Impacts Of Climate Change In The Agricultural Sector In Northern Philippines

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ANALYSIS OF STRATEGIES FOR MITIGATION AND ADAPTATION TO THE IMPACTS OF CLIMATE CHANGE IN THE AGRICULTURAL SECTOR IN NORTHERN PHILIPPINES

by

Grace Tan, Bachelor of Science, University of Toronto, 2008

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Abstract

There is widespread evidence that countries in the tropical regions especially the less developed countries will be most affected by the impacts of climate change and global warming. Unfortunately, these countries are highly dependent on agriculture, which is very sensitive to climate change, thereby threatening food security and economic development in the region. Interestingly, agriculture is one of the main contributors to the atmospheric greenhouse gas emissions. Therefore, it is important that actions taken to adapt to climate change do not undermine the effectiveness of mitigation strategies that impact the agricultural sector.

The present study investigates the effects of mitigation and adaptation strategies on the impacts of climate change in the agricultural sector in Northern Philippines and identifies where synergies or conflicts between the two approaches may arise. Further analysis of the selected strategies suggests that one or more adaptation strategies may be ideal to achieve the maximum benefits.

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List of Abbreviations

ACCC	Advisory Council on Climate Change
ADB	Asian Development Bank
AWD	Alternate wetting and drying
CCC	Climate Change Commission
CDM	Clean Development Mechanisms
CH_4	Methane
CO_2	Carbon dioxide
COP	Conference of the Parties
DA	Department of Agriculture
DENR	Department of Environment and Natural Resources
FAO	Food and Agriculture Organization
GHG	Greenhouse gas emission
$GtCO_2eq$	Giga tons CO2 equivalent
Ha	Hectare
JI	Joint Implementation
IPCC	Intergovernment Panel on Climate Change
IRRI	International Rice Research Institute
LGU	Local government unit
LLCAP	Local Climate Change Action Plan

MCE	Multiple Criteria Evaluation
MOP	Meetings of the Parties
$MtCO_2eq$	Metric tons CO_2 equivalent
N_2O	Nitrous oxide
NFSCC	National Framework Strategy on Climate Change
NGO	Non government organization
OECD	Organization for Economic Co-operation and Development
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
REDD+	Reforestation and forest degradation
SSC	Saturated soil culture
SOIREE	Southern Ocean Iron Release Experiment
SWIP	Small water impounding projects
TBS	Trap barrier system
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction and Objectives

In November 2007, prior to the Bali conference on climate change, Sir Nicholas Stern (former chief economist at the World Bank and advisor to the British Government on climate change) delivered the Annual Lecture of the Royal Economic Society in which he offered a grim warning describing the dangers of climate change as "the greatest market failure the world has seen and the seriousness of the risks from inaction or delayed action is now overwhelming" (Stern, 2007).

It is now more than a hundred years since the first scientific evidence indicating the contribution of carbon dioxide and other greenhouse gases (GHGs) to warming the climate. Since then, this thread has been endorsed by the vast majority of the global scientific community. Almost a quarter of a century ago, James Hansen, often referred to as "the Father of Climate Change", addressed a committee of the USA Senate with a dire warning that climate change was real and that immediate action needed to be taken (Hansen, 1981; Keller, 2009), but since then the major governments of the world and well over twenty international climate change conferences have failed to reach agreement and come up with a global plan to address the problem. Currently, there are 84 signatories and 192 Parties to the Kyoto Protocol (UNFCCC, n.d.a), which was first adopted in 1997 in Kyoto, Japan. The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC) with firm commitments to reduce parties' GHG emissions (UNFCCC, n.d.b). However, after more than twenty international "Conference of the Parties" (COP) and Meetings of the Parties (MOP), along with dozen of specialist sub-commitees, very little has been achieved (Aguilar, 2012; Doaa, 2012). The meeting in Durban, known as COP17/ CMP7, is fairly typical, with the decision, sometimes described as “talks to decide to hold more talks” deserted as the original goals of the protocol are on “life support” as Canada, Russia and Japan have confirmed that they will not ratify unless the big polluters, the USA and China, agree to also ratify (UNFCCC, 2011). The current situation is that the decision is to develop a “road map” by 2015 with a pledge to implement by 2020.

The reasons for this state of affairs arise from two main causes (Speth, 1992):

(i) The USA is strongly influenced by the fossil fuel lobby, coal and oil, which have enormous financial resources and lobbying such that they have effectively undermined any attempts to have even a discussion about climate change;

(ii) The developing countries quite rightly consider that it is the industrial world that is responsible for over 80% of the carbon dioxide emissions that are causing global warming and they should therefore contribute to a multibillion-dollar fund to pay their “Carbon Debt”. Countries in the developing world would be able to access this fund to install new clean technologies.

Needless to say, this latter proposal has had a very poor reception from the USA and most of the Organization for Economic Cooperation and Development (OECD) countries (Klein, 2009). This is confirmed during a discussion with members of the Philippines delegation at a recent Durban IPCCC Conference, who expressed considerable dismay over the failure to reach any substantive policy decisions, especially in the failure of the developing countries to acknowledge their climate debt (T. La Vina, Dean of Ateneo School of Government; N. Sano, Philippine Climate Change Commissioner; L. Sering, Vice Chair of Philippine Climate Change Commission & B.D. Muller, Philippine climate change advisor and negotiator, personal communication, January 4, 2012). Their concern was that the outcome from Durban, namely the plan to develop a climate change “roadmap” for all nations by 2015 for implementation by 2020 (Brown, 2011) does not include any binding commitment from the major GHG emitters, USA and China.

Despite these failures and roadblocks, some entities are taking serious steps to address global warming. These include many cities and municipalities and especially counties in the developing world at both the national and regional levels since these countries are already experiencing the storms and adverse weather effects caused by global warming (C40 Cities Climate Leadership Group, 2011).

This situation provided the background and motivation of the present study. The Philippines is already experiencing major damages and serious impacts of climate change. The objective of this study is to address the present strategies and policies that are being practiced to tackle climate change with a focus on agriculture in the Northern regions of the Philippines. This study seeks to identify the potential synergies, conflicts between adaptation and mitigation strategies, and their impacts on productivity. Further, the selected adaptation options are evaluated for their performance on various criteria to identify the most ideal adaptation strategy that will provide the maximum benefits to the people of the Philippines and its environment.

The study has carried out a search of the relevant literature but in addition, much valuable data were acquired by a field trip conducted at the end of 2011 that included meetings with several local environmental NGOs, regional policymakers and especially through discussions with a leading Philippines environmental specialist, Professor Anthony La Vina, Dean of Business Studies at the Ateneo de Manila University. Professor La Vina is an internationally respected expert on climate change and a delegate from the Philippines to international climate change meetings and also heads an experienced group of researchers working in the areas of environmental policy and climate change. Mr. Arun Abraham, an expert on sustainability was a very helpful guide in introductions to the most valuable local contacts.

2. Background

This chapter sets out a general background on the history and challenges in climate change and global warming issues. The opening section sets out the history and scientific evidence for climate change and global warming and rationale for the anthropogenic causes of global warming and the observed and projected impacts of climate change. Section 2.2 examines the global challenges in tackling climate change and illustrates why the two main groups, the industrialized North and the developing South, are embroiled in an ongoing dispute over equitable policy systems to address climate change. Section 2.3 examines the proposed solutions for addressing climate change, principally mitigation and adaptation. This section includes a discussion on the differences between adaptation and mitigation, and the factors that influence different regions in their choice of approach. Section 2.4 provides a background about the study area: the Philippines.

2.1 The History, Science and Politics of Climate Change

The science of climate change is almost 200 years old and can be dated back as early as 1824 when French mathematician and physicist, Jean Baptiste Joseph Fourier, proposed that the Earth's atmosphere has an influence on temperature (AIP, 2011). Subsequently, in 1859, the Irish physicist John Tyndall, discovered that water vapour, CH_4 and CO_2 absorbed heat radiation (AIP, 2011). While the first calculation of CO_2 emission and speculation on its contribution to global warming was made in 1896 by a Swedish chemist, Svante Arrhenius (AIP, 2011) who created the term "greenhouse effect" (Keller, 2009), it was not until the 1980s that climate change became critical as more solid evidence of global warming started to emerge. Today, global warming and the effects of climate change are considered as the greatest challenges facing society (Pettifor, 2006; Azam, 2008).

Global warming occurs as a result of the greenhouse effect whereby the infrared radiation that the earth is emitting back to space is trapped by greenhouse gases (CO_2, CH_4, N_2O, etc.) in the atmosphere. This enhances an increase in temperature at the earth's surface and the lower atmosphere. The CO_2, CH_4 and N_2O gases are the major contributor to GHG's in the atmosphere (approximately 74%, 14%, 8% respectively) based on 2004 data (IPCC, 2007a). While the concentration of CH_4 and N_2O is relatively lower in the atmosphere compared to CO_2, they are 25 and 298 times, respectively, more potent than CO_2 in causing global warming (EPA, 2010).

The main international body responsible for assessing the evidence and impacts of climate change in the world is the Intergovernmental Panel on Climate Change (IPCC), which was formed in 1988 by the United Nations Environment Program (UNEP) and World Meteorological Organization (WMO). Despite an almost universal acceptance by climate scientists that climate change is real and is of anthropogenic origin (IPCC, 1996a), the fact is, in North America, a very large proportion of the public are either unconvinced or actively opposed any ideas on climate change (97-98% scientist vs. 58-80% public) (Anderegg *et al*. 2010; Borick *et al.* 2011).

Leaving aside the differences among experts and the public in North America in their support to climate change, there is the undisputable fact that there is an increasing level of CO_2 in the atmosphere. The CO_2 levels before the industrial revolution, mid 18th century, had been more or less stable at around 270-280 ppm (IPCC, 2007b). By 1990, this level had increased to around 350 ppm (IPCC, 2011) and in 2012, the level had just passed the 390 ppm mark (Tans &

Keeling, 2012). Moreover, despite the commitment at Kyoto to reduce GHG emissions, during the 1990s, the global CO_2 levels were increasing at a rate of over 1.5 ppm/year while during the past decade, the CO_2 levels have increased at around 2 ppm/year (Tans & Keeling, 2012).

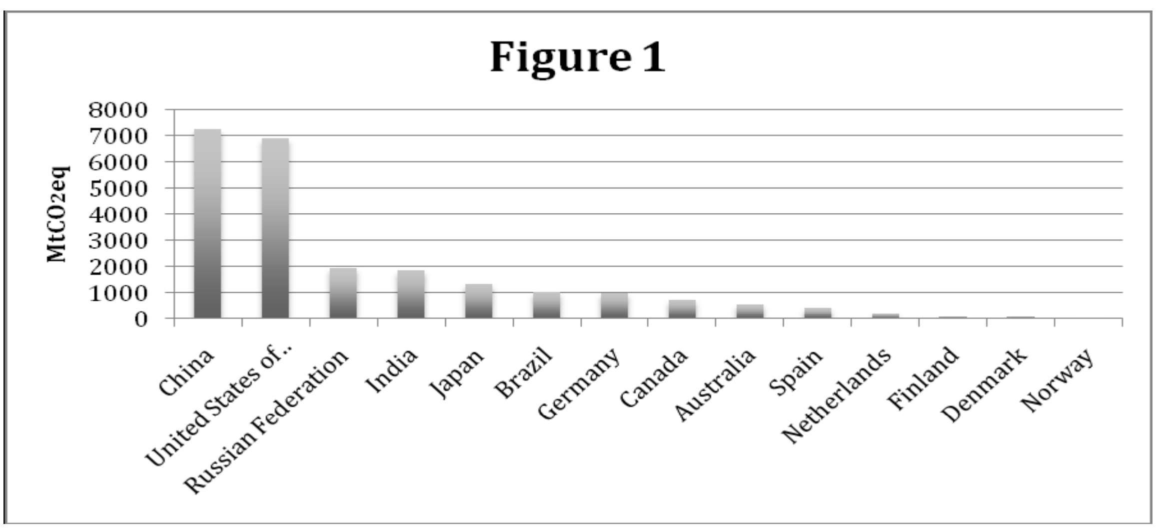
Global warming is linked to other climate changes such as melting of the polar ice caps, changes in precipitation, cloud formations and ocean circulation patterns, which consequently result in rising sea levels, extreme weather events, that in turn lead to social and economic losses, biodiversity losses, and increased risk of famines and diseases (UNFCCC, n.d.c).

Other observed climate changes linked to global warming are significant increases in frequency and intensity of drought and heat waves in the Mediterranean, Southern Africa, and parts of Southern Asia, increase incidences of tropical cyclones in North Atlantic, and of heavy precipitation in eastern parts of North and South America, Northern Europe and Northern and Central Asia (UNFCCC, n.d.c). In addition, evidence of milder winter conditions was reported, for example, Arctic permafrost layer temperature has increased by as much as 3°C (UNFCCC, n.d.c). In 2005, the global average earth's surface temperature has also increased by 0.74°C since the 1900s and is expected to rise further to 1.1-6.4 °C by 2100 (IPCC, 2007b). The wide projected range represents the uncertainty in the absolute level of predicted global warming but in no way undermines the consensus that global warming is taking place, rather, it is simply a reflection of the assumptions in the various climate models. The increase in temperature has caused thawing of ice sheets and decline in snow cover by as much as 10% in the northern hemisphere. Furthermore, the year 2012 showed the greatest level of Arctic sea ice melt on record (NSIDC, 2012), along with the forecast that in the next 10 years to 2100, the Arctic sea ice will have completely disappear (NSIDC, 2012). The thawing of ice sheets eventually resulted in an increase in global average sea level by 1.88mm/year between 1961 and 2003 (IPCC, 2007b). The global sea level is expected to increase by between 0.18 to 0.59 meters by 2100 (IPCC, 2007b). Furthermore, migration and extinction of some plants and animal species have been observed worldwide as a response to climate change (UNFCCC, n.d.c).

2.2 The Challenge: North vs. South

In terms of anthropogenic causes, Figure 1 shows the total amount of greenhouse gases generated by major countries in 2005. China has the most contribution in 2005 with a total of more than 7000 million metric tons of CO_2 equivalent, followed by the USA. While Figure 1 shows the total GHG emission, it is worthwhile noting that Australia was the major emitter per capita in 2005 (WRI, 2011). It is also worth noting that emission per capita in China, was extremely low compared to the USA due first, to its much higher population, and second, to the predominance of industry emission over domestic (WRI, 2011).

Figure 1. Total GHG Emissions from Major Countries in 2005



Source: WRI, 2011

The outcomes of this anthropogenic induced climate change will cost millions of dollars in damages worldwide (Ackerman & Stanton 2006; Hutton, 2011). Studies on the economics of climate change suggest an estimated US$ 57-194 billion in global annual cost of climate change between the periods of 2010 to 2050 (Hutton, 2011). Furthermore, the World Health Organization had estimated that over 150,000 deaths annually are expected to occur as a result of climate change (WHO, 2008). A major constraint is that most developing countries lack the financial resources to address the impacts of climate change and this problem is even more severe for the smaller island nations (UNFCCC, 2007).

Consequently, the United Nations Framework Convention on Climate Change (UNFCCC) was created with the aim of committing countries to reduce their GHG emissions. A total of 195 countries have so far ratified the UNFCCC (UNFCCC, n.d.d). The framework not only asserts that "the largest share of historical and current global emissions of greenhouse gases has originated in the developed countries" (UNFCCC, n.d.e), it clearly states that actions taken to fix the problem should be made "on the basis of equity and in accordance with their common but differentiated responsibilities" (UNFCCC, n.d.f).

In 1997, the Kyoto Protocol was adopted as a protocol to the UNFCCC in combating climate change. Under the Kyoto Protocol, the Annex 1 countries, which include industrialized countries and economies in transition, have collectively agreed to reduce their GHG emissions to lower than the 1990 level by the period of 2008 to 2012 (UNFCCC, n.d.b). Although the Kyoto Protocol expired at the end of 2012, some aspects were retained in the form of commitment to developing a new “roadmap” to climate action. One of the important developments of the Kyoto

Protocol was the introduction of a range of market-based mechanisms for monetizing the mitigation of GHG emissions (UNFCCC, n.d.g) including the following:

(i) Emissions trading or a carbon market which allows countries with excess emission units (allowed emissions) to sell them to countries that have exceeded their targets;

(ii) Clean Development Mechanisms (CDM) which allow countries to implement emission reduction projects such as renewable energy technologies in developing countries and earn credits that can be counted towards their Kyoto Protocol targets; and

(iii) Joint Implementation (JI) which allows countries to gain credits from emission reduction projects in other industrialized countries (or Annex B countries of the Kyoto Protocol that have agreed to GHG reduction target).

Table 1 compares the demonstrable progress of the major developed countries in reaching their Kyoto targets (quantified limitation or reduction commitment from 1990 level). An analysis of the GHG released from major developed countries in 2009, showed that there is an increase in the actual GHG emission in almost all of the major countries including Canada, USA, Japan, Australia and most parts of European Union. Germany and United Kingdom are among the most successful countries in reaching their Kyoto targets (-18.3% and -18.9%, respectively) while Spain shows the least progress in achieving its commitment (+37%).

The failure to achieve GHG emission reduction targets clearly shows that most developed nations are not meeting their commitments, which can potentially lead to a steady increase in global warming, with developing countries and small island nations most likely to have the most severe consequences.

Table 1. Reduction Targets of Major Kyoto Parties and Their Demonstrable Progress

Kyoto Parties	1990 GHG emission (GgCO2eq)	Quantified limitation or reduction commitment from 1990 level (%)	2009 GHG emission (GgCO2eq)	Change from 1990 to 2009 (%)	Deviation from the Kyoto target as of 2009 (%)
Australia	418,470	8	545,858	30.4	22.4
Austria	78,171	-8	80,059	2.4	10.4
Belgium	143,344	-8	122,440	-13.2	-5.2
Canada	591,262	-6	691,834	17	23
Denmark	69,391	-8	62,323	-10.2	-2.2
Finland	70,369	-8	66,344	-5.7	2.3
France	565,987	-8	522,403	-7.7	0.3
Germany	1,247,901	-8	919,698	-26.3	-18.3
Greece	104,565	-8	122,724	17.4	25.4
Iceland	3,441	10	4,649	35.1	25.1
Ireland	54,820	-8	62,395	13.8	21.8
Italy	519,157	-8	491,120	-5.4	2.6
Japan	1,266,553	-6	1,209,213	-4.5	1.5
Liechtenstein	230	-8	247	7.8	15.8
Luxembourg	12,827	-8	11,684	-8.9	-0.9
Monaco	108	-8	91	-15.7	-7.7
Netherlands	211,852	-8	198,872	-6.1	1.9
New Zealand	59,112	0	70,564	19.4	19.4
Norway	49,767	1	51,292	3.1	2.1
Portugal	59,424	-8	74,660	25.6	33.6
Spain	283,168	-8	367,548	29.8	37.8
Sweden	72,536	-8	60,069	-17.2	-9.2
Switzerland	53,122	-8	51,949	-2.2	5.8
United Kingdom	779,387	-8	570,066	-26.9	-18.9
United States	6,166,812	-7	6,608,227	7.2	14.2

Source: WRI, 2011; UNFCCC, n.d.h

In the ongoing series of international meetings on global warming that started since the adoption of UNFCCC, the 2009 meeting in Copenhagen (COP15) was expected to be a landmark and was foreshadowed by great expectations. However, the meeting once again centered on the ongoing standoff between the industrialized and developing worlds (Speth,1992). One important development was that a consortium of developing countries proposed a new global treaty referred to as the “climate debt”. The “climate debt” is based on the argument stated above: industrialized countries have produced the vast majority of global greenhouse gas emissions over the last 200 years. Initially proposed by World Bank chief economist, Justin Lin, the proposed treaty argues that the industrialized nations owe “emissions debt” to the countries of the global South (Lin, 2012). These countries are feeling the burden of the impacts of climate change, and so they are owed an “adaptation debt” by the rich countries of the North whereas in reality the rich countries are only offering “loans” and “aid” to developing countries in response to the climate threat (Lin, 2012).

Despite opposition from major developed countries including the USA, and the failure to reach an agreement in Copenhagen, the concept of “climate debt” has not died and the continued progress has been reported (Klein, 2009). At the “Conference of the Parties” in Durban (COP17/CMP17), many of the negotiators suggested that allowing developing countries access to the UN Green Climate Fund (UNFCCC, n.d.i) could make a start to the “climate debt”. In addition to opposing the disbursement of Green Funds to developing nations, the USA joined the EU in calling for the principal emitters among developing countries, China and India, to move toward internationally binding agreements on GHG reduction targets. However, prior to the meeting a letter from some sixteen major environmental groups was sent to US Secretary of State Hilary Clinton, accusing the USA of being the major obstacle to progress on climate change (EDF, 2011). Moreover, at the Kyoto Protocol negotiations at Bonn in 2009, the chair of the Least Developed Countries group, Lesotho, stated “failure to combat climate change will increase poverty and hardship in our nations, and increase the debts owed to us for excessive emissions by the developed countries” (Bond, 2010). Four countries, Bolivia, Malaysia, Paraguay and Venezuela, formally proposed “climate debt” as the basis for calculating Annex I countries responsibilities (UNFCCC, 2009a).

The Durban climate talks at the end of 2011 was able to save some aspects of the Kyoto Protocol, thus ensuring that there would not be a total collapse of legally-binding climate protection commitments after the first phase of the Kyoto Protocol expired in 2012. The important work carried out on accounting rules, mechanisms and markets are all still valid and should serve as effective tools to leverage global climate action and as models to inform future agreements.

Meanwhile, the concept of “climate debt” is increasingly gaining traction among international environmental groups, thus rejecting the established notion that debt is owed by the South to the North from loans from international finance institutions (Klein, 2009). There is an assumption that the global treaty on climate action, the 2015 “roadmap”, will have more success in adaptation to unavoidable climate change impacts while providing some mechanism to enable green technology transfer between developed and developing nations to address some of the goals of the “climate debt” approach.

However, despite the challenges stated above, many local entities such as cities and municipalities are mobilizing substantial resources to address the issue. For instance, over 500 mayors in the USA have joined the US Conference of Mayors Climate Protection Agreement, which aims at reducing GHG emissions in their respective cities by 7% below 1990 level by 2012 (United States Conference of Mayors, 2008). An international organization, C40, was also formed consisting of major cities around the world aiming at addressing climate change issues (C40 Cities Climate Leadership Group, 2011). In addition, local communities are developing strategies internally, with or without help from their respective governments, to help them adapt to the serious impact of climate change and variation. For instance, local farming community in the Philippines is applying organic farming and modifying the use of fertilizers to mitigate and adapt to climate change (Bernando, 2009).

2.3 Solutions to Address Climate Change: Mitigation and/or Adaptation

Strategies for addressing the challenges of climate change have followed two main pathways: mitigation and adaptation. When climate change was first realized, the major focus was developing strategies that will mitigate climate change (McEvoy *et al.* 2006; Somorin *et al.* 2011). Mitigation includes man-made attempts to develop systems to reduce GHG emissions or capture these gases after they have been emitted. It includes options such as using clean technologies and improved energy efficiency such as wind energy, solar, hydropower and biofuel generation, reduced emissions from reforestation and forest degradation (REDD+) and development of electric vehicles (UNFCCC, 2009b). As discussed earlier, one of the outcomes of the Kyoto Protocol is monetizing the mitigation of GHG emissions through the introduction of market-based mechanisms.

As more evidence of climate change and its impacts are discovered, different nations especially those countries, which lack the resources to pursue mitigation strategies, have focused mainly on developing strategies to adapt to climate change (McEvoy *et al.* 2006; Somorin *et al.* 2011). Adaptation is the modification of the human or natural environment to minimize actual or expected impacts of climate change. It can be divided into three types (IPCC, 2007c):

(i) anticipatory or proactive, which occurs before impact of climate change is observed;

(ii) autonomous or spontaneous, which occurs unconsciously triggered by changes in natural and human systems; and

(iii) planned, which occurs after a policy is implemented and after conditions have changed or are about to change.

There are a number of adaptation options including behavioural, technological, risk management and reduction, conservation, and restoration.

In addressing the issue of adaptation, it is important to define three key characteristics: vulnerability, resilience and adaptive capacity (IPCC, 2007c). Vulnerability is the extent to which a community or a region is exposed to, and unable to cope with, the impacts of climate change and its variability. For instance, developing countries, especially the least developed nations, are the most vulnerable to the impact of climate change due to limited resources to adapt either financially, socially or technologically (UNFCCC, 2007). Resilience is the ability of a community or ecological system to absorb the impacts of climate variations and changes while at the same time being capable of self-organization and restructuring. It may include adopting new technologies while maintaining the traditional knowledge, and diversifying livelihoods to be better able to cope with the stress of climate change (UNFCCC, 2007). Adaptive capacity is defined as the property of a system to adjust its characteristics or behavior in order to expand its coping range under existing climate variability or future change conditions. Implementation of policies for disaster risk reduction and climate risk management is one of the ways that will strengthen a country's adaptive capacity (UNFCCC, 2007).

Another option that was also proposed as the “third” response to climate change alongside mitigation and adaptation is geoengineering (The Royal Society, 2009: Resnik & Vallero, 2011). This option, which is still quite controversial (Centre for Science Technology and Congress at the American Associate for the Advancement of Science, 2010; Resnik & Vallero, 2011), relies on two main approaches. The first approach is based on solar reflectance such as increasing the whiteness of clouds thus reflecting more radiation back into space and reducing the amount reaching the earth’s surface (Vaughan & Lenton, 2011). The second approach is based on carbon capture, the most widely known being the carbon and capture storage technologies that have been proposed with injection of liquefied CO_2 deep underground (Vaughan & Lenton, 2011).

Geoengineering principles, while controversial, are not in fact new and were first proposed during World War II with the aim of altering weather systems in order to obtain more favourable climate conditions on a regional scale (The Royal Society, 2009). One well-known technique is cloud seeding, which has been attempted to induce rain in areas of severe drought as well as a method to reduce the severity of tropical storms (Rosenfeld, 2007). The conclusions of scientific debate on geoengineering indicated that there are serious political and ethical barriers that first have to be addressed (Virgoe, 2009). However, there are now serious proposals to carry out some studies on the pilot scale, while some has already been started. For instance, the Southern Ocean Iron Release Experiment (SOIREE), which dumped approximately 3800 kg of iron sulphate into the Southern ocean has resulted in an increase in growth of specific type of algae, which in turn resulted in changes in cycling of carbon leading to a 10% drawdown of surface CO_2 (Boyd & Law, 2001).

It is also important to consider that, while mitigation and adaptation strategies are categorized separately, the IPCC has recognized that "there is a high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts…adaptation and mitigation can complement each other and together can significantly reduce the risk of climate change" (IPCC, 2007c p.65). While some researchers have attempted to find the optimal mix between adaptation and mitigation strategies (Kane and Shogren, 2000), others have suggested that finding the optimal mix such as the most efficient and least expensive mixture of adaptation and mitigation measures might not be the best solution to address climate change (Klein *et al*. 2005; Swart & Raes, 2007). They proposed that an understanding of the linkages between adaptation and mitigation should be a priority. For instance, a study that has developed an integrated framework in the agricultural sector has recognized that in order to enhance adaptive capacity in agriculture and other related sectors, a significant effort must be made in understanding trade-offs and synergies between mitigation and adaptation (Jarvis *et al*. 2011). Similar recommendations were proposed by other studies in agriculture, water, land and urban planning sectors (Kane & Shrogren, 2000; Rosenzweig & Tubiello, 2007; Swart & Raes 2007; Walsh *et al*. 2011; Smith & Olesen, 2010).

As mentioned, understanding the linkage between mitigation and adaptation is very important to minimize the effect of mitigation strategy undermining an adaptation strategy, or vice versa. However, studies, which deal with linking adaptation and mitigation strategies, are limited and poorly documented (IPCC, 2007d). Sectors that have been studied include: agriculture (Dang *et al.* 2003; Rosenzweig and Tubiello, 2007; Smith & Olesen, 2010), building industry and urban development (McEvoy *et al.* 2006; Hamin & Gurran, 2009; Kua & Gunawansa, 2010; Walsh *et al.* 2010), water resources (Pittock, 2008) and forestry (Damato *et* *al.* 2011). For instance, shifting to low carbon technologies for energy generation such as biofuel production creates demand for water, resulting in competition for water for food production and conflict with conservation of freshwater environment (Pittock, 2008). Furthermore, researchers have found that the synergistic effects of integrating adaptation and mitigation are relatively low (Swart & Raes, 2007) and that there are more conflicts and trade-offs between adaptation and mitigation policies/strategies (McEvoy *et al.* 2006; Hamin & Gurran, 2009; Pittock, 2008). For instance, 50% of land use mitigation and adaptation policies in US and Australia are found to be conflicting rather than complimentary (Hamin & Gurran, 2009). These results are partly due to differences that exist between the adaptation and mitigation strategies in various operational scales, as summarized in Table 2.

One of the important steps to understand the linkage between mitigation and adaptation strategies is by first determining the differences that exist between them. Table 2 summarizes these differences. One of the major differences is the issue of cause and effect whereby mitigation is driven by the desire to affect the cause of climate change, and thus, focuses on reducing GHG emissions or enhancing the GHG sink, while adaptation is driven by the consequences of climate change, and thus, focuses on enhancing adaptive capacity and resilience to reduce vulnerability (Swart & Raes, 2007). In terms of spatial and temporal differences and beneficiaries, mitigation has wider impacts where benefits may be experienced globally and in the long term by future generations, while adaptation may only benefit those who implement it and may only be effective in the short-term, (e.g. diversifying crops in agriculture during drought season) (McEvoy *et al.* 2006; Swart & Raes, 2007). Another difference is that while only few industries are involved in practicing mitigation strategies such as coal, auto, energy, agriculture, mining, forestry and building industries, adaptation involves a much wider range of areas including urban planning, agriculture, water, health, and coastal zone settlement (Dang *et al.* 2003; McEvoy *et al*. 2006; Swart & Raes, 2007). In terms of cooperation, mitigation may require national initiatives in the context of international obligations while adaptation may require local actions in the context of local or regional economies and land managers (Dang *et al.* 2003; McEvoy *et al.* 2006; Swart & Raes, 2007).

Another important difference is that while the risk of climate change will differ from one region to another, it is the developing and poor countries that are most likely to be affected the most and therefore have higher political urgency to implement adaptation without receiving any incentives, while developed countries are more motivated to implement mitigation strategies, usually in exchange for economic incentives (Dang *et al*. 2003; McEvoy *et al.* 2006). In terms of equity, the developed, and newly industrialized countries including China and India are among the largest emitters of GHG but the levels of damaging effects may not be uniform with some developed countries possibly gaining net benefits (Dang *et al.* 2003). These countries have tended to focus on mitigation approaches to reduce dependence on fossil fuels and to shift to clean, green sustainable technologies (Dang *et al.* 2003). In contrast, although national GHG emissions per capita in the poorer countries of the developing world are much lower (except for China and India), it is predicted these regions will be mostly impacted by the effect of climate change and that adaptation may be the only available approach (Dang *et al.* 2003). As a result, adaptation has received increasing attention, especially its importance to developing countries, which have limited resources to adapt: socially, technologically and financially (UNFCCC, 2007). These approaches may include developing practical solutions to assist communities deal with floods, droughts and extreme weather conditions (UNFCCC, 2007). Lastly, in terms of uncertainty, mitigation need to be changed regularly to take into account new projection of atmospheric GHG, while the change in adaptation may wait until concrete evidence of climate impacts is available (Dang *et al.* 2003).

Table 2. Summary of Differences between Mitigation and Adaptation

Issue	Mitigation	Adaptation	References
Cause/Effect	Cause	Consequences	Swart & Raes, 2007
Spatial	Global	Local	McEvoy *et al.* 2006; Swart & Raes, 2007
Temporal	Long-term	Short-term	McEvoy *et al.* 2006; Swart & Raes, 2007
Beneficiaries	Global; others i.e. later generations	Local; only those who implement it	McEvoy *et al.* 2006; Swart & Raes, 2007
Sectors	Few; energy, agriculture, mining, forestry, transport, building industries etc.	Wide; urban planning, water, agriculture, health, coastal zone settlement etc.	Dang *et al.* 2003; McEvoy *et al.* 2006; Swart & Raes, 2007
Decision Maker/Cooperation required	National initiatives in the context of international obligations	Local in the realm of local/regional economies and land managers	Dang *et al.* 2003; McEvoy *et al.* 2006; Swart & Raes, 2007
Incentives	Usually needed	Often not needed	Dang *et al*. 2003; McEvoy *et al.* 2006
Urgency	Lower political urgency	Higher political urgency esp. in poor countries	Dang *et al*. 2003; McEvoy *et al.* 2006
Equity	The free-rider effect: motivated in countries less vulnerable to climate change	Unfair; the “victims” are not always responsible for causing climate change	Dang *et al.* 2003
Uncertainty	Needs to be changed regularly to take into account new projection	Can wait until concrete evidence of climate impacts is available	Dang *et al.* 2003

In addition to the differences discussed above, it is also important to note that strategies to address climate change and the ability to reach emission reduction targets will vary substantially from region to region. Factors such as the country's geographical location, stage of economic development, population growth, availability of resources and finances, accessibility to green technology and industrial base for renewable energy will play a major role (DDCE, 2011).

2.4 Study Area: The Philippines

In addition to the help from valuable local experts and some familiarity with the region, the Philippines is chosen as the study area because of the vulnerability to and existing evidence of climate change in the country, which will all be discussed in the following subsections. It is also a good example of an island state, which is most likely to be affected seriously by the effects of climate change.

Figure 2. Map of the Philippines

Regions of the Philippines

Source: Wikitravel, 2013

The location of the Philippines is between 5° and 20° N. This country is an archipelago consisting of more than 7000 islands (CIA, 2012), which are divided into three main areas, Luzon, Visayas and Mindanao as shown in Figure 2. It is considered to be one of the most biologically rich and diverse countries in the world (ADB, 2009). It has one of the world's longest coastlines with over 36,000 km of coastal areas (ADB, 2009). The total land area of the Philippines is approximately 30 million ha, of which 24% is utilized for forestry (in 2005) and approximately 41% for agriculture (ADB, 2009).

In terms of demography, the Philippine nation is the twelfth most populated country in the world with current population estimated to be over 100 million in 2012 (CIA, 2012), and a population growth rate of 1.9% from 2008 to 2010 (DA, 2011a). It was estimated that the country has already exceeded by three times its carrying capacity in 2008 (ADB, 2009; DENR, 2010). Approximately 89% of the population live within 100km of its coastal areas (ADB, 2009) and about 66% live within urban areas (DA, 2011a). In 2009, approximately 18% of the total population live below the US$1.25/day poverty line, while approximately 42% lives below US$2.00/day (World Bank, 2012).

In terms of economy, the Philippines have undergone rapid economic growth and have coped with the 2008-2009 global economic crisis better than its regional peers (CIA, 2012). The GDP growth rate of the country increased from 1.1% in 2009 to 7.6% in 2010, but has cooled down at 3.7% in 2011 due to lack of government spending on infrastructures (CIA, 2012). The country's economy is highly dependent on climate sensitive sectors such as agriculture, fishery and forestry (DA, 2011a). These sectors have contributed an average of 18.4% to the total GDP and 35% to the total employment of the country from 2004 to 2010 (DA, 2011a).

The following subsections elaborate the observed evidence and projected impacts of climate change in the Philippines (Section 2.4.1) and examine the existing climate change legislations and policies in the Philippines (Section 2.4.2).

2.4.1 Vulnerability to and Evidence of Climate Change in the Philippines

The Philippines climate is tropical and maritime and is characterized by high temperature (except for Baguio, which is in the north and in high altitude), high humidity and frequent rainfall. The country's geographical location, lying within the typhoon belt of Western Pacific and the Pacific Ring of Fire, makes it one of the most disaster prone countries in the world where 30% of all the disasters in Southeast Asia occur (OCHA, 2011). More than 80% of the disasters that occur in the country from 1905 to 2006 are weather related such as flood, drought, typhoon and landslide (ADB, 2009) as shown in Figure 3. These disasters have caused the Philippines thousands of lives and billions of US dollars in cumulative damages from 1900 to 2012 (Table 3). Furthermore, a ten year analysis of the impacts of extreme weather events to population and economy placed the Philippines in the top ten of the world's most at risk to climate change (Harmeling, 2011).

Figure 3. Disasters in the Philippines (1905-2006)

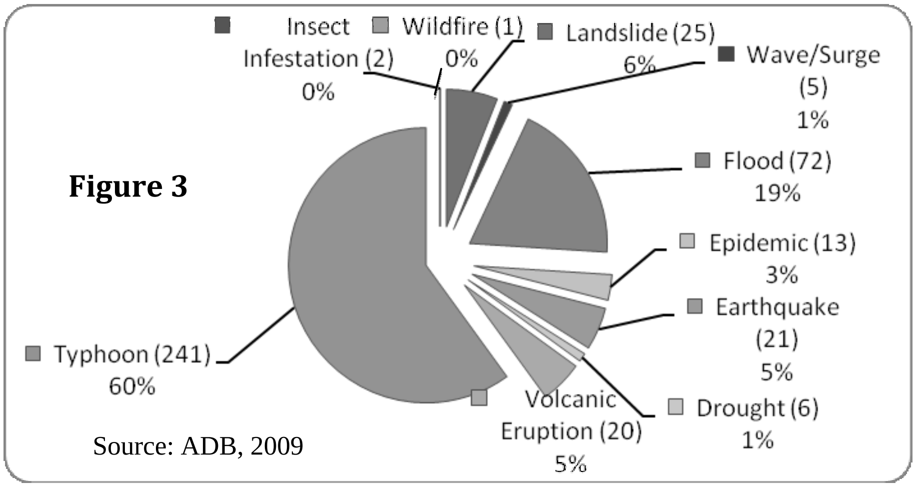


Table 3. Impacts from all Disasters in the Philippines from 1900 to 2012

Human Impacts	Cumulative Total	Average Per Event
People killed	15,269	764
People affected	2,1624,926	1,243,184.5
Damage caused	US$ 1,289,945,000	US$ 8,2567,000

Source: EM-DAT, 2012

There is overwhelming evidence of climate change and variability in the country as summarized in Table 4. The annual average temperature in the country was observed to increase by 0.14 °C per decade from 1971 to 2000 (ADB, 2009; DENR, 2010). This increase in temperature is supported by other studies that found an increase of an average of 0.61 °C from 1951 to 2006 (ADB, 2009; DENR, 2010). Increasing frequency of hot days and warm nights and decreasing frequency of cold days and cool nights were also observed (ADB, 2009; DENR, 2010). Other evidence includes the increased variability in precipitation, such as increases in annual rainfall since the 1980s and the number of rainy days since 1990, as well as changes in rainfall distribution with a decreasing trend in Luzon and parts of Mindanao and increasing trend in Visayas (ADB, 2009; DENR, 2010). Increases in variability and intensity and slight increase in frequency of extreme weather events were also observed. The trend is observed to increase slightly in Visayas and decrease slightly in Mindanao, while, there is no trend observed in Luzon. An average of 20 tropical cyclones hit the country every year with 7 to 9 making landfall (ADB, 2009; DENR, 2010) with the most impact in the northern and eastern parts of the country (World Vision Asia Pacific, 2008). In 2006, the strongest tropical storm in the Philippines was experienced, which had a wind speed of 320 km per hour (ADB, 2009). A comparison of flood/storm occurrences in Southeast Asian countries from 1960 to 2008 shows that the Philippines surpassed other countries such as Indonesia, Thailand and Vietnam by more than double in number of occurrences (ADB, 2009). Increased sea level rise was also observed over major coastal cities with Manila, the capital city, showing the highest increase (ADB, 2009). There has also been increased in seawater intrusion in groundwater resources in Northern Luzon affecting the major agricultural areas in the Philippines (ADB, 2009).

The IPCC has developed different scenarios (e.g. A1B, A1C, A1G, A1T, A2, B1, and B2) describing the world’s future with consideration of various driving forces including population growth and socio-economic development that might influence the GHG emissions (IPCC, 2001). The A2 scenario is at the higher end of the emission scenarios while the B2 scenario represents low-range emissions. The A1B scenario represents mid-range emission scenario where there is rapid economic growth but with a balance across different sources of energy supply (IPCC, 2001). These three scenarios were chosen by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) to predict the country’s climate changes in 2020 and 2050 relative to 1971-2000 climate using a simulation model called

PRECIS (PAGASA, 2011). However, the most ideal scenario in the Philippines, A1B scenario, is only presented in detail by PAGASA and therefore is summarized in Table 4.

Overall, the mean temperature is predicted to rise between 0.9°C to 1.1°C by 2020 and 1.8°C to 2.2°C by 2050 (ADB, 2009; PAGASA, 2011). The rainfall is projected to decrease in most regions during summer season (March-May), while during southwest monsoon season (June-August), transition season from southwest to northeast monsoon (September-November), and northeast monsoon season (December- February), the rainfall is predicted to increase in Luzon and Visayas but decrease in Mindanao (PAGASA, 2011). The number of dry days and hot temperature are projected to increase in all parts of the country, while intensity of rainfall is expected to increase in Luzon and Visayas (PAGASA, 2011). Further, the mean sea levels are projected to rise between 0.19 to 1.04 meters by 2080 relative to 1961-1990 mean sea levels (ADB, 2009).

Table 4. Summary of Observed Evidence and Projected Climate Changes (under AIB Scenario Relative to 1971-2000 Climate) in the Philippines

Observed	Projected (Overall)
An overall increased in annual temperature by 0.14 °C (1971-2000)	An increase in temperature of 0.9°C-1.1°C by 2020, and 1.8°C-2.2°C by 2050 in all areas
An increased variability in precipitation: overall increased in annual rainfall and number of rainy days	A decrease in rainfall in most provinces during summer season; increase in rainfall in most areas of Luzon and Visayas during southwest monsoon and during transition from southwest monsoon to northeast monsoon seasons; but a decrease in rainfall in all areas of Mindanao during southwest monsoon season by 2020 and 2050
Increased frequency and intensity of extreme weather events such as heat waves, floods and drought; Increased variability and slight increased in frequency of tropical storms: no trend in Luzon, slightly increasing trend in Visayas and slightly decreasing trend in Mindanao (1951-2000)	An increase number of dry days in all parts of the country and increase heavy daily rainfall events (exceeding 300 mm) in Luzon and Visayas by 2020 and 2050
An increased number of hot days and warm nights mostly in Luzon and a decreased number of cold days and cool nights mostly in Visayas and Mindanao (1971-2000)	An increase frequency of hot temperatures (maximum temperature exceeding 35 °C) by 2020 an 2050
An increased in sea level rise in major coastal cities and increased seawater intrusion in groundwater resources in Northern Luzon	An increase sea level rise of 0.19-1.04 meters by 2080 relative to 1961-1990

Source: ADB, 2009; DENR, 2010; PAGASA, 2011

In terms of impacts, climate change has affected and will affect all of natural and socioeconomic resources in the country such as water resources, agriculture, forestry, coastal and marine resources, human health, and settlement. Some of these impacts are outlined in Table 5. Among these resources, the most devastating impact will be on agriculture and water resources, as the effects of climate change in these sectors are expected to hinder the food security and economic growth in the country. With the growing population already exceeding the country’s carrying capacity (ADB, 2009), there are already pressures to intensify agricultural production and secure water availability. However, with the current and projected impacts of climate change in both agriculture and water resources, the outcome will have a major impact on the increasing population (Jose & Cruz, 1999; Nath & Behera, 2011).

Table 5. Observed Impacts of Climate Change to Selected Sectors in the Philippines

<table>
<tr><th rowspan="2">Sectors</th><th colspan="3">Climate Changes</th></tr>
<tr><th>Increase in temperature</th><th>Increase variability in precipitation</th><th>Increase sea level rise</th></tr>
<tr><td>Water Resource</td><td>An increased evapotranspiration in rivers, dams, and other water reservoirs leading to decreased water availability for human consumption, agricultural irrigation, and hydropower generation</td><td>A decreased river flows and water level in many dams and water reservoirs, particularly during El Niño years, leading to decreased water availability; increased populations under water stress

An increased stream flow particularly during La Niña years leading to increased water availability in some parts of the region

An increased runoff, soil erosion, and flooding, which affected the quality of surface water and groundwater</td><td>An advancing saltwater intrusion into aquifer and groundwater resources leading to decreased freshwater availability</td></tr>
<tr><td>Agriculture</td><td>A decreased crop yields due to heat stress

An increased livestock deaths due to heat stress

An increased outbreak of insect pests and diseases</td><td>An increased frequency of drought, floods, and tropical cyclones (associated with strong winds), causing damage to crops

A changed in precipitation pattern affected current cropping pattern; crop growing season and sowing period changed

An increased runoff and soil erosion caused decline in soil fertility and consequently crop yields</td><td>A loss of arable lands due to advancing sea level

A salinization of irrigation water affected crop growth and yield</td></tr>
<tr><td>Forestry</td><td>An increased frequency of forest fires as well as area of burnt forests

An increased pest and disease infestation in forests</td><td>Increased forest fire, and pest and disease infestation due to drought

A changed in precipitation pattern, affecting survival of seedlings and saplings

An increased soil erosion and degradation of watershed due to intermittent drought and flooding

An increased population of invasive plant species</td><td>A loss of mangrove forests due to advancing sea levels</td></tr>
<tr><td>Coastal and Marine Resources</td><td>An increased coral bleaching and degeneration of coral reefs</td><td>An increased loss of land due to erosion and flooding of coastal areas

An increased damage from floods and storm surge including damage to aquaculture industry</td><td>An accelerated salt water intrusion inland</td></tr>
<tr><td>Human Health</td><td colspan="2">An increased dengue outbreak, illness and deaths due to heat stress</td><td>A spread of water-borne infectious diseases</td></tr>
</table>

Source: ADB, 2009

2.4.2 Legislation and Policies on Climate Change

The Philippines had emitted very low GHG, approximately 0.9MtCO_2 eq per capita from 1988-2008 (WRI, 2011), into the atmosphere relative to other countries, however, it is one of the first countries that had signed the UNFCCC in 1992 and ratified it in 1998, thereby committing the country to fighting global warming (Pacundar & Pareno, 2008). In 2003, after ratifying the Kyoto Protocol, the Advisory Council on Climate Change (ACCC) was created to coordinate government and non-government sectors positions on climate change convention negotiations (Rincon & Virtucio Jr., 2008). In 2007, the Presidential Task Force on Climate Change (PTFCC) was created, with the Secretary of DENR as the initial chair but this was later amended to designate the President of the Philippines as chair. This institution has the main authority in the Philippines in addressing impacts of climate change through adaptation and mitigation strategies (Rincon & Virtucio Jr., 2008). In 2009, the Climate Change Commission (CCC) was created to "coordinate, monitor and evaluate the programs and action plans of the government relating to climate change" (CCC, n.d.). Three important action plans were developed by this institution, viz., the National Framework Strategy on Climate Change (NFSCC), the National Climate Change Action Plan (NCCAP), and guidelines for Local Climate Change Action Plan (LLCAP) (CCC, n.d.).

A number of adaptation and mitigation measures to climate change across different sectors, which were also aimed at addressing food and water security, have also been put into law. Some examples of the important measures are RA9281 (The Agriculture and Fisheries Modernization Act of 1997), RA9275 (The Philippine Clean Water Act of 2004), RA8749 (The

Philippine Clean Air Act of 1999), RA9729 (Climate Change Act of 2009) and RA9513 (Renewable Energy Act of 2008).

3. Statement of the Problem

As discussed earlier, climate change is a serious problem and its impacts might not be evenly distributed across the globe. The developing countries are most likely to suffer the most due to their limited resources. The Philippines, a developing country, is already experiencing these impacts across different sectors most especially in agriculture. As Philippines rely heavily on agriculture, this could pose a significant threat to its economic development. Therefore, it is imperative that this issue be investigated.

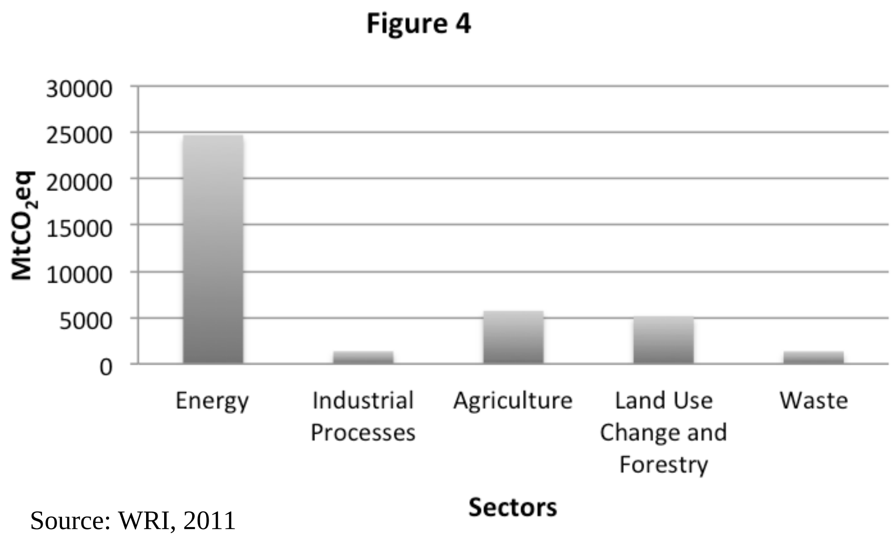
In this chapter, the links between agriculture and climate change is further examined and the challenges that come with them. This serves as the basis of the research problem in this study. Section 3.1 discusses the impacts of climate change in agriculture and the contribution of the agricultural sector to the atmospheric GHG emissions. Section 3.2 further discusses the agricultural contribution to the atmospheric GHGs in the Philippines. Section 3.3 discusses the research questions that this study aims to address.

3.1 The Relationship between Agriculture and Climate Change

Agriculture is one of the most important sectors that will be affected highly by climate change, thereby threatening food security of an increasing population and economic growth especially in developing countries, which rely heavily on agriculture for their economy. The observed impacts of climate change to agriculture, as outlined in Table 5, include decreases in crop yields, increases in livestock deaths and increases in outbreak of insect pests and diseases due to heat stress, increased runoff and soil erosion damaging crops due to severity of drought, floods and tropical cyclones, and loss of arable lands due to advancing sea level (ADB, 2009). The ultimate result is most likely a reduction in agricultural productivity and economic growth due to losses from weather-related events and increased incidence of pests and diseases. For instance, flooding in South and Southeast Asian countries as a result of severe typhoons has cost the regions US$ 1 billion every year in damages and has damaged 10-15 million ha of agricultural areas (Wassmann *et al.* 2009). However, as mentioned earlier, the impacts of climate change will vary from region to region, and while others will experience significant losses, some will gain positively in their agricultural production as a result of climate change. For example, UNEP has projected that some regions in the North will gain by more than 35% of their agricultural productivity while most regions in the South will lose by more than 50% of their agricultural productivity in 2080 due to climate change (Ahlenius & UNEP/GRID- Arendal, 2009).

Figure 4 compares the contribution of different sectors to the global GHG emission in metric tons CO_2 equivalent ($MtCO_2eq$). Despite the impacts of climate change to agriculture, it is interesting to know that agriculture is one of the highest contributors, second to energy sector, of GHGs into the atmosphere. A recent report from the IPCC suggests that in 2005, the agriculture sector accounted for an estimated 10-12% of the total global anthropogenic GHG emissions (IPCC, 2007e). The agricultural sector accounts for approximately 50% of the methane (CH_4) and 60% of the nitrous oxide (N_2O) composition of the global GHG emissions (IPCC, 2007e).

Figure 4. Comparison of the World's GHG Emission by Major Sectors



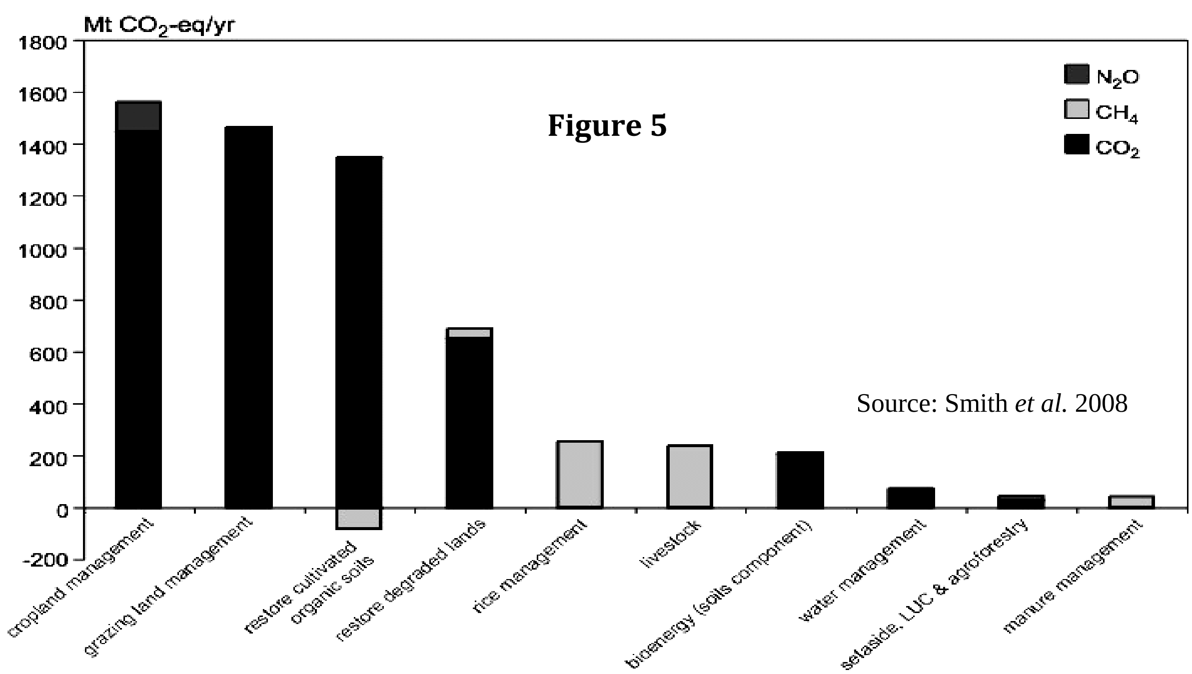
Source: WRI, 2011

All the processes involved in agriculture can contribute significantly to the atmospheric GHG either through a reduction in the carbon sink or an increase in GHG emissions. For instance, intense land cultivation for agriculture can lead to deforestation and land degradation reducing the ability of the vegetation and soil to sequester carbon (Smith *et al.* 2008). Some of the factors that result in the release of CO_2 in the atmosphere from agriculture include fuel consumption used for tractors and irrigation systems and from burning or decaying crop wastes (Smith *et al.* 2008). The majority of the N_2O emissions come from manufacturing, agricultural use, transport and fertilizer distribution, which accounts for 1240.1 Tg CO_2eq or about 2.48% of the total global GHG (IFA, 2009a) and 38% of the total agricultural CO_2eq GHG emission (Smith *et al*. 2008). The bulk of the CH_4 released comes from irrigated rice production, more especially from flooded rice, and enteric fermentation, which account for 44% of the total agricultural CO_2eq GHG emission (Smith *et al.* 2008). A mixture of both gases can also be released from biomass burning and manure handling (Smith *et al.* 2008).

Furthermore, the IPPC report suggests that the agriculture sector has an enormous potential to reduce GHG emission by as much as 2.3-6.4 GtCO_2eq per year at less than US$100/t$CO_2$eq, second only to the building sector (5.3-6.7 GtCO_2eq), based on technologies and practices expected to be available by the year 2030 (IPCC, 2007f).

Further comparison suggests that within the agricultural practices, cropland management, including agronomy and nutrient management, have the highest potential for mitigating CO_2 and N_2O for almost 1600 MtCO_2eq per year by 2030 followed by grazing land management as shown in Figure 5. On the other hand, restoring cultivated organic soils has a negative potential for mitigating CH_4.

Figure 5. Comparison of Mitigation Potential in Different Agricultural Practices by 2030



Three categories for mitigating GHG emissions in agriculture have been identified (Smith *et al.* 2008):

(i) Reducing emission to the atmosphere. For example, through efficient use of fertilizer and livestock feed a reduction in N_2O emission to the atmosphere will be achieve;

(ii) Enhancing removal from the atmosphere through practicing agroforestry and enhancing agro-ecosystem. These practices will enhance the ability of the soil to sequester carbon from the atmosphere; and

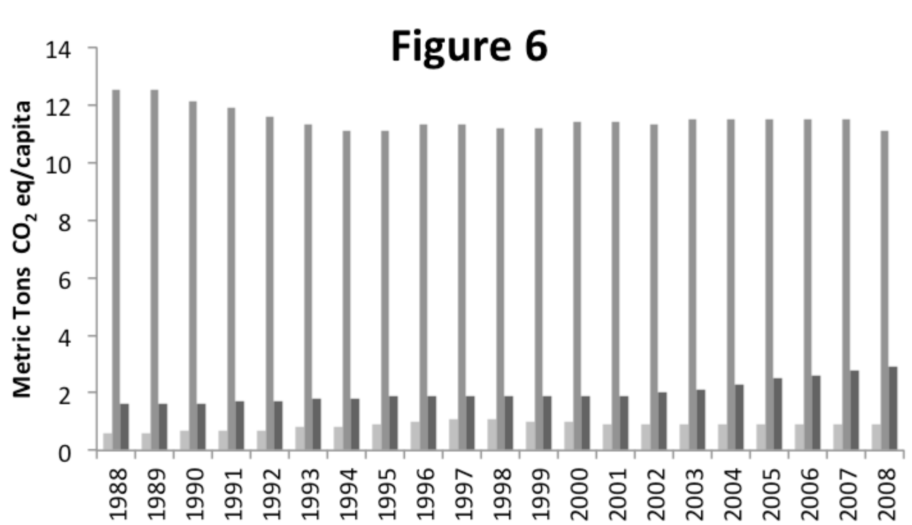
(iii) Avoiding or displacing emissions through development of renewable energy such as biogas and biofuel. This practice will reduce demand for fossil fuel, which is the main source of different greenhouse gases.

3.2 The Philippines Agricultural Contribution to the Atmospheric Greenhouse Gas Emissions

The Philippines has made a very small contribution, relative to Annex 1 and Non- Annex 1 countries (mostly developing countries) to the atmospheric GHG emissions as shown in Figure 6, which only accounts for an average of approximately 0.9 $MtCO_2eq$ per capita from 1988 to 2008 (WRI, 2011). It is also worthwhile nothing that based on this figure, Annex 1 countries contributed an average of over 80% to the total global GHG emission from 1988 to 2008 compared to Non- Annex 1 countries. Figure 7 shows the contribution of major sectors in the Philippines to the atmospheric GHG emissions. Of the total GHG emitted in 2005 (208.7 $MtCO_2eq$), the energy sectors contributed the most (36.00 %) followed by land use change and forestry (33.50%) and agriculture (18.70%). Within the agricultural sector, the majority of the GHG emitted based on 1994 data comes from rice cultivation (40.34%), which releases CH_4, followed by agricultural soils (26.20%), which releases N_2O as a result of intensive fertilizer used (Figure 8).

In the Philippines, rice is very important commodity and a staple food for the survival of almost all Filipinos and accounts to about 47% of the total calorie intake (IRRI, 2011). Each person consumes more than 110kg per year; however, the country's rice production cannot sustain the demand of its population, thus making the Philippines one of the biggest importers of rice in the world (IRRI, 2011).

Figure 6. Comparison of GHG Emissions Per Capita between Philippines, Annex 1 and Non-Annex 1 Countries



Source: WRI, 2011

Figure 7. Contribution of Selected Sectors to the PhilippineNational GHG Emission (2005)

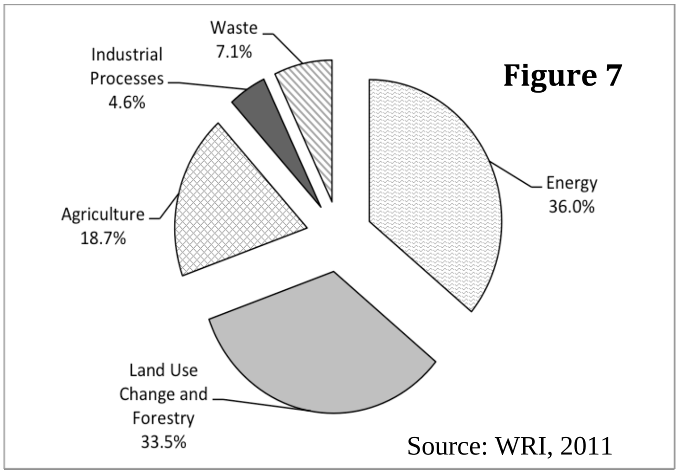
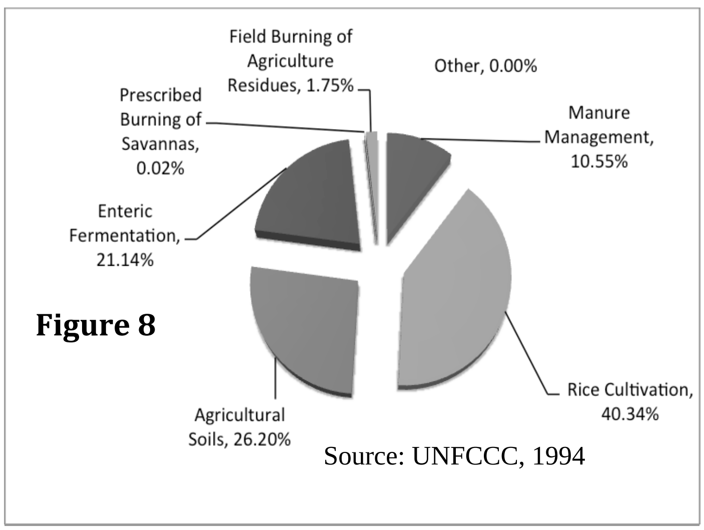


Figure 8. Breakdown of GHG Emissions in the Agriculture Sector in the Philippines (1994)



3.3 Research Questions

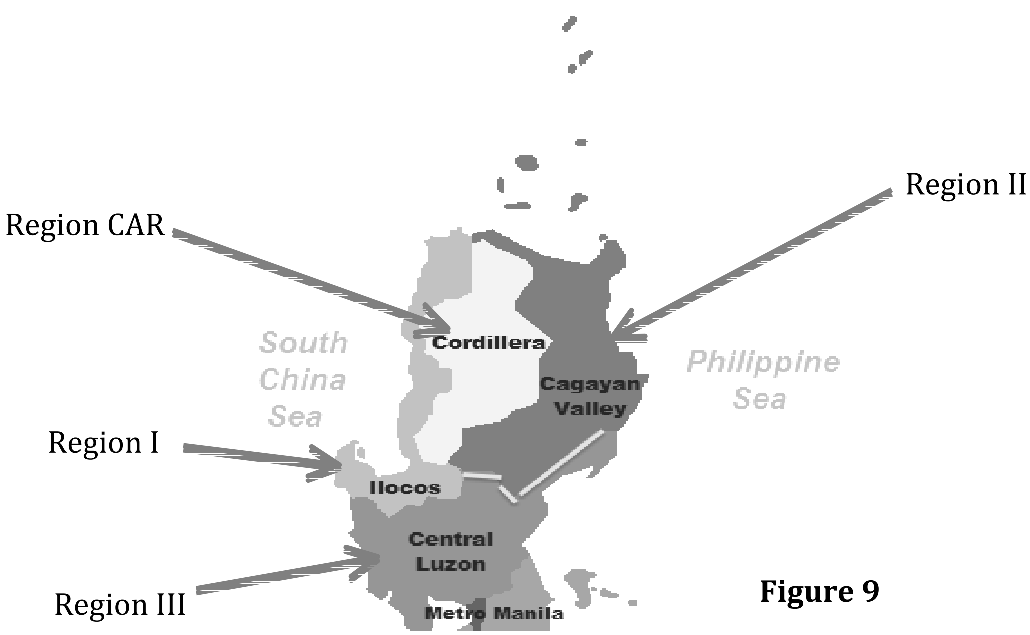
As noted earlier, understanding the linkage between mitigation and adaptation to climate change is very important and should be a priority in order to maximize the effectiveness of either or both strategies. The Philippines, being a developing country with limited resources, have invested in developing and implementing strategies that will help them response properly to climate change. However, are the strategies implemented by the Philippine government especially in the agriculture sector actually helping the Filipinos response successfully to climate change? Or are they making the situation worse and thus making them even more susceptible to the impacts of climate change? Having limited resources, adaptation could be the only available approach in the Philippines, thus, what would be the most ideal adaptation strategy in the Philippines that most likely provide the optimal benefits both to the Filipinos and the environment? These are the research questions that this study aims to address.

4. Research Methodologies

This chapter discusses the research methodologies applied including the focus area, objectives and research methods. Section 4.1 discusses the focus area, the Northern Philippines, and the reasons for choosing this area. Section 4.2 outlines the objectives of the present study while Section 4.3 outlines the methods used to achieve those objectives.

4.1 Focus Area: The Northern Philippines

Figure 9. Map of Northern Philippines



Source: Wikitravel, 2013

The Northern part of the Philippines is chosen as the focus area in this study because firstly, of its importance to the national agricultural production and economy. The Northern Philippines constitute approximately 15% of the national total agricultural areas (BAS, 2012) and include the Ilocos Region (Region 1), Cagayan Valley (Region II), Central Luzon (Region III) and Cordillera Administrative Region (Region CAR) as shown in Figure 9. These regions produced on average approximately 42%, 27% and 8% of the national rice, corn, and banana production, respectively (BAS, 2012). These crops are important in driving the agricultural growth, although recently, their overall shares of the national agriculture productivity have declined dramatically from 2.4% in 2004 to 1.1% in 2010 (BAS, 2012) most likely due to loses and damages brought by extreme weather events (DENR, 2010). A geohazard mapping suggests that most areas in Northern Philippines are amongst the most susceptible to weather- related disasters such as floods and landslides (Mines and Geosciences Bureau, 2009) compared to other regions in Southeast Asian countries (Yusuf and Francisco, 2009).

Secondly, the Northern Philippines is chosen because the agricultural practices in these areas are widely studied and documented compared to the other areas in the country. In addition, due to the importance of the region to the national economy and food security, the government has invested and implemented a number of strategies that will help farmers adapt to the impacts of climate change.

Due to limited data on climate changes in the region, the data obtained nationwide regarding the observed and projected climate changes as outlined in Table 4, are also generalized to Northern Philippines. This means that this study assumes that the predicted climate in Northern Philippines may include increase in temperature, increase in rainfall and heavy daily rainfall events, increase number of dry days, increase frequency of hot temperatures and increase sea level rise.

4.2 Objectives

To answer the research questions stated in Section 3.3, the study aims to achieve the following objectives:

(i) To understand the linkage between climate change adaptation and mitigation policies/strategies in the agricultural sector in Northern Philippines by identifying their potential synergies and conflicts through examination of the agricultural practices implemented by the government, and identification of their adaptation benefits, mitigation potential, as well as, potential impacts on agricultural productivity;

(ii) To identify the most ideal adaptation strategy that will most likely provide the optimal benefits to the people of the Philippines and to the environment through a method that is based on multiple criteria evaluation of the most common adaptation practices identified in the first objective.

4.3 Research Methods

This section is divided into two parts: Section 4.3.1 outlines the methods used in examining the existing and implemented strategies in the agricultural sector in the Northern

Philippines to identify the potential synergies and conflicts that exist between adaptation and mitigation and the potential impacts on the agricultural productivity. Section 4.3.2 outlines the methods used in examining the performance of selected adaptation strategies based on multiple criteria evaluation of the most common adaptation strategies examined in the first objective to determine the most ideal adaptation strategy that will most likely produce the maximum or optimal benefits.

4.3.1 Potential Synergies and Conflicts across Different Strategies in the Agriculture Sector in Northern Philippines

The first objective, determination of possible synergies and conflicts, involves the following steps:

(i) Review of international and Philippines literature on climate change to identify the impacts of climate change on the agriculture sector and the corresponding strategies to address them. This step includes browsing the database from Google Scholar, and ProQuest through Ryerson e-library, and database from the websites of major government agencies in the Philippines such as Department of Agriculture (DA), Department of Environment and Natural Resources (DENR) and Bureau of Soils and Water Management (BSWM), and websites of major international organizations such as Asian Development Bank (ADB), World Bank, Food and Agriculture Organization (FAO) and International Rice Research Institute (IRRI). These agencies were used as the main sources of information as these were referred by local key players during the field trip in December/January 2011/2012 to the

Philippines where private discussion with local experts and NGOs was held (T. La Vina, Dean of Ateneo School of Government; N. Sano, Philippine Climate Change Commissioner; L. Sering, Vice Chair of Philippine Climate Change Commission & B.D. Muller, Philippine climate change advisor and negotiator, personal communication, January 4, 2012; A. Abraham, EcoGov Chief of Party, personal communication, January 3, 2012).

(ii) Some of the keywords used to generate the required literature were “agriculture” and “Philippines” and “adaptation to climate change” and/or “adaptation” and/or “climate change” and/or “global warming” etc. The generated literature was found to contain farming practices, either traditional or conventional, that were supported and funded by the government or private sectors and were implemented to address both current and projected climate change in the country;

(iii) From the collection of literature obtained above, further selection was made to make sure that adaptation strategies focused only in the Northern region of the Philippines. This was done by screening the location to which the adaptation strategy was being implemented. For instance, by using the command key “CTRL-F”, the word “northern” or “northern Luzon” or “north” or the name of provinces and cities in the Northern part of the Philippines was searched within each literature. In addition, the literature was read thoroughly to make sure that the strategies were really implemented in the Northern Philippines;

(iv) Each of the adaptation strategies obtained from the list of selected literature in the Northern Philippines were then listed and/or tabulated;

(v) The identified strategies were also organized and categorized based on their contents for clarification;

(vi) A further review of the identified strategies was made to identify their adaptation benefits, mitigation potential and potential impacts on productivity. Similar to step 1, this involves browsing the database from Google Scholar, and ProQuest through Ryerson e-library, and database from the websites of major government agencies and international organizations. In the case when not enough information was available from the Philippines, then information from other countries in the world especially from Southeast Asia was used.

(vii) Step V provides information about the potential synergies and conflicts between adaptation and mitigation strategies, thus, enhancing the understanding about the linkage between adaptation and mitigation in the agriculture sector. When both adaptation benefits and mitigation potential of a strategy is positive, then there can be a potential synergy. However, when either adaptation benefits or mitigation potential is negative, then there can be a potential conflict.

4.3.2 Prioritization of Adaptation Options in Northern Philippines

As noted earlier, the Philippines is a developing country with limited resources, financially and technologically, that is most likely to be affected by climate change especially in the agriculture sector. For this reason, adaptation could be the only available approach to respond to climate change and therefore, the second objective has focused only on these strategies.

The second objective is based on the study by Dolan *et al.* (2001), which is an evaluation based on multiple criteria evaluation (MCE). MCE is one of the analyses used in decision making to evaluate the potential of alternatives in reaching a specific goal (Dolan *et al.* 2001). Due to limited time and resources, only the qualitative analysis is considered in this paper.

The following steps were taken to achieve the second objective, which is to determine the most ideal adaptation strategy that will produce the maximum or optimal benefits to the Philippines and its environment.

(i) Because a number of literature generated from the first objective pertain to the same strategies even though these strategies were implemented at different locations in the Philippines, the list was further narrowed down to the most common farming practices in Northern Philippines to avoid repetition and for simplicity. This was done by tallying the number of times each strategy identified from the first objective was documented in the literature.

(ii) The most common strategies identified from step 1 were then compared in their performance on various criteria reaching a common goal: to decrease the agriculture's vulnerability to the impacts of climate change. Dolan *et al.* (2001) uses six criteria to evaluate the performance of adaptation options to address climate change in agriculture. The same criteria were utilized in this study and are the following:

1. *Effectiveness* refers to the ability of the adaptation strategy to reduce loss and increase productivity in the presence of extreme weather events.
2. *Economic Efficiency* refers to the economic benefits compared to economic cost of implementing the adaptation option to address climate change.

3. *Flexibility* refers to the ability of an adaptation option to function well in different climatic conditions.
4. *Institutional Compatibility* refers to the degree to which local or national governments align themselves with the adaptation strategy.
5. *Farmer Implemantability* refers to the ability of farmers to perform adaptation strategies without much dependence on external sources.
6. *Independent Benefits re*fer to the ability of an adaptation option to provide benefits such as environmental and socio-economic benefits, other than reducing the risk of loss due to climate change.

(iii) The comparison was done qualitatively whereby the adaptation strategies were given a rating of low, medium or high on their performance on each criterion. A thorough literature review of each strategy was then performed to determine the rating in each criterion by comparing their performance relative to one another. For instance, if one of the strategies gives the maximum benefits in any of the criterion relative to others, then a rating of high will be assigned. Likewise, if one of the strategies performs the weakest in any of the criterion relative to others, then a rating of low will be assigned

(iv) The ratings were also consulted during the personal communication in the Philippines on January, 2012 with experts and important local key players including Dr. Tony La Vina, Dean of Ateneo School of Government, Nasarev Sano, Philippine Climate Change Commissioner, Lucille Sering, Vice Chair of Philippine Climate Change Commission, Bernadita Muller, Philippine climate change advisor and negotiator, and Arun Abraham, EcoGov Chief of Party.

5. Results and Discussion

This chapter is divided into two parts: Section 5.1, which discusses the results obtained from the first objective, determination of potential synergies and conflicts across different adaptation strategies, and Section 5.2, which discusses the results obtained from the second objective, prioritization of adaptation options.

5.1 Potential Synergies and Conflicts across Different Strategies in the Agriculture Sector in Northern Philippines

Table 6 lists the collected strategies in Northern Philippines based only from the published documents and government websites database as discussed earlier. After organizing and categorizing each strategy based on its contents, five categories have been identified:

(i) *Cropland management* consists of strategies implemented to improved or maintain crop production despite occurrences of climate change and variability;

(ii) *Soil management* consists of strategies implemented to conserve the soil and increase resilience to climate change and variability;

(iii) *Water use and management* consists of strategies implemented to improve the irrigation systems in response to drought events and water scarcity;

(iv) *Energy use* consists of strategies implemented to promote renewable energy and help mitigate climate change;

(v) *Institutional Measures* consist of strategies implemented by the government to help farmers and local communities address the impacts of climate change.

The information regarding adaptation benefits and mitigation potential were also reviewed and identified for each strategy and were assigned a symbol of (+) when the impact is positive or (-) when the impact is negative. This can potentially provide information regarding the link between adaptation and mitigation strategies. For instance, when there is positive adaptation benefits and mitigation potential, then potential synergies may exist between the two. However, when either adaptation benefits or mitigation potential is negative then potential conflicts may exist. Furthermore, due to importance of maintaining productivity for the economy and for food security across different regions in the Philippines, impacts on productivity were also reviewed for each strategy. The identified and listed strategies in Table 6 are discussed in detail in the following sections.

Table 6. Potential Synergies and Conflicts between Adaptation and Mitigation Strategies and Their Impacts on Productivity

Agricultural Practices	Impacts on Productivity	Adaptation Benefits	Mitigation Potential
Cropland Management			
Adjusting cropping calendar and cropping patterns	Reduce crop failure from drought or floods, soil erosion and diseases	Maintains cropping production	
Use of alternative crops (drought-resistant crops, high value crops) or crop diversification	Reduce crop failure Increase yield and resistance from climatic events and pest and diseases	Increases resilience through enhance livelihood diversification, and resistance to climatic stress	(+) Can increase carbon sequestration in the soil (+) Can reduce electricity demand or fuel use for pumping irrigation (-) Can also increase dependence on chemical use
Use of cover crops (legumes)	Increase yield due to reduce soil erosion, and pests and diseases problems Increase in soil fertility	Increases resilience through enhance soil management, and soil nutrient recycling	(+) Can reduce emission of GHG from reduction in chemical use such as fertilizer due to nitrogen fixation (in the case of legumes) in the soil (-) Can increase GHG because legumes can also be a source of N_2O
Use of crop rotation and crop mixing	Increase yield due to suppression in pests and diseases problems, Reduction in soil erosion Increase in soil fertility	Increase resilience due to increase soil fertility and water holding capacity Increase livelihood diversification	(+) Can increase carbon sequestration in the soil (+) Can reduce GHG emission from reduction in chemical use such as pesticides and insecticides
Homestead farming	Increase yield	Increase resilience through enhance self sufficiency and livelihood diversification	(+) Can increase carbon sequestration by planting fruit trees (-) Can contribute to GHG emission as a result of land conversion (in the case of vegetable farming)
Greenhouse farming	Increase yield due to reduction in pests and diseases problems Reduce crop failure	Increase adaptive capacity by optimizing crop production without much interruption from climate change and variability	(-) Can increase GHG emission from electricity use for lighting, ventilation and irrigation
Natural pest control measures (trap barrier system (TBS))	Increase yield due to reduction in soil erosion from chemical use, and pests problems	Increase adaptive capacity by enhancing independence from chemical inputs such as pesticides Increase resilience to climate change	(+) Can reduce GHG emission from reduction in pesticide use

Agroforestry (including windbreaks)	Increase yield due to maintenance of soil fertility Increase water conservation Reduce soil erosion and pests and diseases problems	Increase resilience through trees intensification, livelihood diversification Enhance soil and water management Increase biodiversity	(+) Can increase carbon sequestration of the soil (+) Can reduce electricity demand or fuel use for pumping irrigation
Soil Management			
Reduction or removal of inorganic fertilizer inputs and use of organic fertilizer (such as compost)	May increase yield depending on crop variety due to improve soil fertility, and soil nutrient cycling Reduce soil erosion May also reduce yield if crop has not enough nutrients	Increase resilience through enhance biodiversity and reduce environmental degradation impacts from chemical use	(+) Can increase carbon sequestration by enhancing organic matter in the soil (+) Can reduce GHG emission from inorganic fertilizer use
Terracing	Increase yield due to reduced soil erosion and increase soil moisture and soil fertility	Increase resilience through enhance soil and water management and livelihood diversification	(+) Can increase carbon sequestration of the soil (+) Can reduce electricity demand or fuel use for pumping irrigation (-) Can also decrease carbon sink due to land conversion
Slope protection (by integrating lemon tree and vegetable farm)	Increase yield due to reduced soil erosion and water run off	Increase resilience through enhance soil and water management and livelihood diversification	(+) Can increase carbon sequestration of the soil (+) Can reduce electricity demand or fuel use for pumping irrigation
Raising seed beds	Increase yield by converting unproductive land to being productive, and enhance water management	Increase resilience to climate change especially from flood by improving drainage	(+) Can reduce GHG emission (+) Can increase carbon sink
Mulching	Increase yield by increasing water retention in the soil	Increase resilience to climate change by enhancing water efficiency	(+) Can reduce electricity demand or fuel use for pumping irrigation
Water Use and Management			
Saturated soil culture (SSC)	May reduce yield due to water stress	Increase resilience to climate change by enhancing water conservation	(+) Can reduce electricity demand or fuel use for pumping irrigation (-) Can increase fertilizer use to compensate for yield loss
Alternate wetting and drying (AWD) or controlled irrigation	Maintains production at a certain threshold but can also reduce it pass that threshold	Increase resilience to climate change by enhancing water efficiency	(+) Can reduce electricity demand or fuel use for pumping irrigation (-) May increase fertilizer use

Water impounding system (shallow tube wells)	Increase yield by enhancement in water management	Increase resilience to climate change by enhancing water conservation and controlling flood, enhance habitat diversity	(+) Can reduce electricity demand or fuel use for pumping irrigation (-) Can reduce carbon sequestration due to increase crop cultivation
Use of micro- water shed in highland areas	Increase yield by enhancement in water management	Increase resilience to climate change by enhancing water conservation and controlling flood, enhance habitat diversity	(+) Can reduce electricity demand or fuel use for pumping irrigation
Water harvesting and rainwater collection	Increase yield by increasing soil moisture level	Increase resilience through enhance water conservation and promoting self-sufficiency	(+) Can reduce electricity demand or fuel use for pumping irrigation
Energy Use			
Establishment of biofuel farm and ethanol plant	No impact	Depending on the supply required, this may reduce resilience to climate change due to competition for crops for food consumption or energy generation	(+) Displaces the GHG in the atmosphere (-) May increase GHG emission for intense irrigation (in the case of sugarcane)
Establishment of methane recovery plant	No impact	Promotes environmental protection through improved farm manure waste management Potential to increase income from carbon credits and from generating electricity	(+) Can reduce electricity demand or fuel use (+) Can reduce GHG emission
Establishment of wind energy farm	No impact	Increase sources of livelihood of local communities due to tourism development	(+) Can reduce electricity demand or fuel use (+) Can reduce GHG emission
Establishment of hydropower plants	No impact	Depending on the technology used, this may reduce resilience and adaptation to climate change due to potential impacts on fisheries downstream and reduction in hydropower generation during drought season, which consequently can result in electricity price hike	(+) Can reduce electricity demand or fuel use (+) Can reduce GHG emission

Implementation and promotion of efficient-energy program (e.g. “Switch to CFL”)	No impact	May increase resilience to climate change through reduction in energy demand especially during extreme heat events, thus, minimizing events of power outages	(+) Can reduce electricity demand or fuel use (+) Can reduce GHG emission
Institutional Measures			
Development of early warning system	Reduction in agricultural losses from unexpected climatic events Increase productivity	Increase resilience through enhance disaster risk reduction and improve agricultural planning management	(-) May increase GHG emission from electricity demand of equipment
Cloud Seeding	Increase production	May reduce resilience by making farmers dependent on modifying weather conditions to maintain or increase production	
Construction of roads from farm to market	No impact	Increase resilience to climate change by facilitating delivery and trades of goods in the market and increasing communication	(-) May increase GHG emission as a result of vehicle use
Implementation of Crop Insurance	No impact	Increase resilience by reducing risk of farmers to financial losses as a result of climatic events	
Implementation of water pricing and metering	May reduce yield as a result of reduced irrigation from limited financial resources of the farmers	Increase resilience to climate change by promoting water conservation	(+) Can reduce electricity demand or fuel use for pumping irrigation

5.1.1 Cropland Management

With the increasing frequency of occurrences of unpredictable weather in Northern Philippines such as typhoons occurring in a non rainy season, or prolonged periods of drought, one important strategy that the government has implemented to the farmers is adjusting their cropping calendar and cropping patterns. For instance, instead of the usual cropping season of early October to November, farmers in some region in the North have been asked to delay their planting schedule (e.g. from December to February or even May) to avoid potential losses due to the observed climate changes such as frequent droughts and typhoons (Bernardo, 2009; Mitin, 2009). By performing this practice, farmers can increase their resilience to climate change through maintenance of crop production despite changes in weather conditions such as increasing variability in precipitation (Bryan *et al.* 2011).

The concept of crop diversification in the Philippines was introduced in response to decreasing agricultural land area as a result of urbanization, and declining crop productivity (Espino & Atienza, n.d.). Farmers in these regions are also motivated to diversify their crops by other factors such as perception of profits and high market values of other crops, availability of seeds, existence of government support, increase food sufficiency, and insufficient water availability (Gonzales-Intal *et al.* 1989). Recently, though, crop diversification has been highlighted as a strategy to response to changing and varying climate conditions such as in Northern Philippines (Peralta, n.d.; Lin, 2011) There are two different kinds of crop diversification, horizontal and vertical (FAO, 2001). Horizontal diversification involves substitution of new species of conventional crops such as drought resilient crops, or addition of new varieties of crops other than the conventional crops, such as high value crops, while vertical diversification involves adding other value activities such as raising livestock on top of the conventional cropping system to increase sources of livelihood. These can either be introduced in a crop mixing or crop rotation pattern. Aside from the increase in productivity, crop diversification can also increase resilience to climate change by diversifying the source of livelihood. Crop diversification can also improve the quality of the soil by replenishing the nutrients in the soil compared to monoculture cropping, thus, increasing carbon sequestration potential in the soil (Smith *et al.* 2008; ADB, 2009). Crop diversification may sequester carbon from 241 to 398 MgCO_2eq per ha depending on the types of crop and soil, pH and tillage system (Ilao *et al.* 2010). For instance, an experiment in the Philippines suggested that cropping on "Adtuyon" clay soil type, which is developed from weathered rocks as a result of volcanic lava, has higher potential for sequestering carbon relative to other soil type due to the high presence of organic matter in the soil (Ilao *et al.* 2010). This may, however, also result in intense cropping leading to increase in fertilizer use, which will eventually degrade the land enhancing the GHG in the atmosphere (Kane & Shogren, 2000).Farmers have also introduced using cover crops such as legumes and *Calopogonium*, which reduce soil erosion, improve soil nutrient cycling and soil fertility, which in turn can lead to efficient use of fertilizer thus reducing GHG emissions (Magcale-Macandog & Ocampo, 2005). One study in the Philippines suggests that cover crops can sequester carbon up to 394 MgCO_2 eq per ha, depending on the types of crop (Ilao *et al.* 2010). However, legumes can also be a source of nitrous oxide in the air (Smith *et al*. 2008).

The use of crop rotation and crop mixing (or multiple cropping on the same piece of land) are very important strategies in Northern Philippines because not only do they improve fertility of the soil and enhance its water holding capacity but also suppress incidence of pests and diseases (Smith *et al.* 2008; FAO, 2009; Bryan *et al.* 2011). They also provide additional sources of income to the farmers, thus, increasing financial resilience to climate change. Implementing these strategies can also result in reduction in the use of chemicals and electricity or fuel for irrigation, and increase carbon sequestration through increase in plant production and improvement in soil quality, which all can contribute in mitigating climate change (FAO, 2009; Bryan *et al.* 2011).

Greenhouse farming, which is a method of agriculture contained in a built-in structure, has also been introduced to farmers in Northern Philippines to avoid interruptions from climate change- related events and to reduce pest and diseases (DA, n.d.a). This has been found to be very efficient and has increased crop production by 15 to 20 times relative to conventional farming (Ministry of Agriculture, Food and Fisheries, 2004). However, greenhouse farming also requires cooling ventilation (Mpusia, 2006), which consequently can increase demand for electricity. Farmers in Northern Philippines were also encouraged to practice homestead farming where they plant vegetables and fruit trees in their backyards. This increases their resilience to climate change by enhancing their food sufficiency and diversifying livelihood (Bernando, 2009; DA, n.d.a). This may increase the carbon sink (from fruit trees) (Bryan *et al.* 2011) but may also increase the release of GHG from the soil through land conversion and plowing (Smith *et al.* 2008) as in the case of cropping vegetables. In addition, farmers in Northern regions were also trained to use natural techniques for pest management. This results in reduction in the use of pesticides, which consequently reduces production cost (Lasco *et al.* 2011). For instance, in response to increased outbreak of pest incidence as a result of increased temperature in the Philippines, a trap barrier system (TBS) using plastic was introduced to deflect rats from growing crops, and this resulted in a 50% reduction use of chemical rodenticides (Lasco *et al.* 2011), having also the potential for reducing GHG emission.

Perhaps the most important strategy in Northern Philippines is agroforestry, which is an example of vertical crop diversification. This may include adding tree planting such as fruit trees in the same cropping area, in order to enhance income. In the Northern Philippines and across the country, agroforestry serves other functions, such as windbreaks to protect crops from strong winds, hedgerows to mark the boundary of the land or cropping area, and for contour farming to protect the slope from erosion due to water run-off (Lasco *et al*. 2011; Landicho *et al.* n.d.). Agroforestry is also being implemented in response to accelerating deforestation problem in the country, being a net importer of timber (Conservation International, n.d.). Recently, agroforestry was introduced as an adaptation strategy to climate change and a potential option for Clean Development Mechanisms (CDM) due to its mitigation potential (World Agroforestry Centre, 2012). It increases soil fertility and water conservation and reduces soil erosion and incidence of pests and diseases ((Smith *et al.* 2008; FAO, 2009; Bryan *et al.* 2011). It may also increases resilience to climate change by enhancing biodiversity, livelihood diversification, and soil and water management, which in turn increases the carbon sink and reduces carbon emissions (Smith *et al.* 2008; FAO, 2009; Bryan *et al.* 2011). It has potential to mitigate GHG by 14 MtC per year in 2010 to 28 MtC per year by 2040 in developing countries (Trines *et al.* 2006) and an ability to sequester carbon up to 389 $MgCO_2$ eq per ha in the Philippines depending on the type of trees and soil (Ilao *et al.* 2010).

5.1.2 Soil Management

Terracing is the construction of walls to create level of cropping areas along the sides of the mountains, and is used for production of upland rice and vegetables (Magcale-Macandog & Ocampo, 2005). Terraces are an old practice by the indigenous people in the Northern Philippines (Magcale-Macandog & Ocampo, 2005), however, the government is trying to extend these practices to other regions as well, to address the impacts of climate change. Terraces can enhance soil moisture and fertility and reduce soil erosion (Magcale-Macandog & Ocampo, 2005; Lasco *et al.* 2011). They make use of rainwater efficiently and enhance drainage (Magcale-Macandog & Ocampo, 2005; Lasco *et al.* 2011). By improving soil and water management, they may increase resilience to climate change during drought season, and may reduce GHG emission from irrigation. Upland rice in the Philippines has a projected mitigation potential of an average of26 MtCO_2 eq per year from 2000 to 2020 (EPA, n.d.). However, converting slopes of mountains or hills (for terracing) will also lead to release of GHG into the atmosphere from land conversion and plowing (Smith *et al.* 2008). Raising seedbeds is also another strategy used, which facilitates drainage and prevent flooding in cropping areas (Magcale-Macaondog & Ocampo, 2005). Consequently, this can reduce emission of methane. This may also be used to regenerate soil fertility in unproductive land (Magcale-Macaondog & Ocampo, 2005), thus increasing carbon sink. Farmers have also practiced protecting slope from soil erosion and water run-off by planting trees (e.g. lemon trees) alongside, with vegetables. This enhances carbon sink and provides additional sources of income (Bernando, 2009), thus increasing their financial resilience to climate change. To maintain moisture in the soil, farmers have also applied mulch to their crops (Magcale-Macaondog & Ocampo, 2005; Landicho *et al.* n.d.). This increases water efficiency through increase water retention in the soil, thereby, reducing irrigation use (Smith *et al.* 2008; FAO, 2009; Bryan *et al.* 2011). Mulch is also used in the area to increase crop yield, manage diseases and reduce soil erosion (O'Sullivan *et al.* 1985; Villanueva, 2010).

In response to increasing prices of fertilizers, farmers in Northern Philippines have also started adopting nutrient management techniques such as the Site Specific Nutrient Management (SSNM), which involves modifying fertilizer inputs such as reduction in inorganic fertilizer or increase in organic fertilizers such as compost (Bernando, 2009). A report by National Statistical Coordination Board in the Philippines suggests that fertilizers account for 30-40 percent of the total agricultural cost in the Philippines. Since the Northern Philippines composed of approximately 15% of the national agricultural land as discussed earlier, it can also be assumed that these regions utilize high fertilizer inputs in agricultural production. In the first quarter of 2008, the price of fertilizers has increased by 38 to 80 percent depending on the type of fertilizer used (e.g. urea, ammonium sulphate, and ammonium phosphate) (NSCB, 2008). Reducing inorganic fertilizer inputs will reduce emission of GHG from both consumption and manufacturing processes (IFA, 2009b). Furthermore, modifying fertilizer inputs or the type of fertilizers has significant mitigation potentials (ADB, 2009). For instance, if ammonium sulfate fertilizer is used instead of urea, 25-36% methane emission reduction will be achieved, and if urea is combined with phosphogypsum, 72% of methane emission reduction will also be achieved (ADB, 2009). However, reducing fertilizer inputs may also affect nutrient availability in the soil leading to a reduced productivity (Stockdale & Watson, 2009).

On the other hand, utilizing organic fertilizers will increase soil fertility, and organic matter in the soil, thus, increasing carbon storage in the soil, and increasing productivity (Smith *et al.* 2008). This may also be implemented as part of organic farming. By definition, organic farming is a sustainable method of agriculture, which "sustains health of soils, ecosystem and people" (IFOAM, 2009). Organic farming is also implemented in Northern Philippines to reduce production cost from avoiding chemical inputs, reduce environmental pollution and degradation, and to protect the health of farmers and consumers (Bernando, 2009; Lasco *et al.* 2011; DA, n.d.a). Organic farming may also include techniques such as crop diversification, crop rotation, use of crop covers, use of biofertilizers such as compost, reduction of pesticides inputs, and so on (Magcale-Macondog & Ocampo, 2005; Bernando 2009). Organic farming may also produce high mitigation potential. For example, a farm experiment in Germany reported a gain of 180 KgC per ha per year when organic farming was utilized compared to conventional farming, which would result in carbon losses of 120 KgC per ha per year (Niggli *et al.* 2009). Mitigation potentials from organic farming will vary depending on the type of organic fertilizers used (ADB, 2009). For example, using composted manure in the Philippines can decrease methane emission by about 64% (Ilao *et al.* 2010) while composted rice straw can reduce it by 23-30% (ADB, 2009).

5.1.3 Water Use and Management

In general, the Philippines is currently experiencing increase in frequency and intensity of drought and increase number of hot days and warm nights as summarized in Table 4. This is projected to continue in the future as a result of climate change. In addition, it is also projected that during summer season, decrease in rainfall is expected in most provinces, including Northern Philippines. Therefore to address these current and future issues, it is important especially in the Northern Philippines, being highly dependent on agriculture, to improve its irrigation systems and techniques.

In 2006, approximately 19% of the cultivated area in the country was equipped with irrigation, resulting in a lower yield (e.g. 30-40%) for areas that were not equipped (FAO, 2010a). Water reservoirs especially large-scale dams do exist, but their capacity for irrigation use is not fully achieved (Lasco *et al.* 2006; IRI, n.d.). Factors such as flaws in their designs, complexity, pumping problems, and competing uses for conflicts for water play a major role. This problem also exists in Northern Philippines.

The Philippines is one of the biggest importers of rice in the world in 2011 (IRRI, 2011). An increasing population and impacts of climate change have put a strain on water availability in the country (IRI, n.d.) affecting the productivity of irrigated rice farms (Bouman, 2001). Furthermore, 82% of the total water withdrawal in the country is used for agriculture alone and 50% of that is used for irrigation of rice production (FAO, 2010a). The Northern Philippines is responsible for approximately 47% of the total irrigated rice production in the Philippines in 2011 (BAS, 2012). Therefore, there is a great opportunity to improve irrigation systems to increase water productivity, and thus, maintain water security in these regions. Some of the identified implemented irrigation practices in Northern Philippines include modifying the irrigation systems such as switching to alternate wetting and drying (AWD) or controlled irrigation, drip irrigation, saturated soil culture (SSC) where soil is kept to saturation as close as possible, sprinkler irrigation and so on (Bouman, 2001; Lasco *et al.* 2011). These strategies are proven to increase water efficiency, which result in a reduction in irrigation use (Lasco *et al.* 2011). The bulk of the methane released into the atmosphere is produced from anaerobic decomposition of organic matter in the soil (IPCC, 1996b). Anaerobic decomposition occurs in the absence of oxygen, such as in the case of flooded rice fields (IPCC, 1996b). AWD can reduce methane emission by as much as 50% (Wassmann *et al.* 2009), while other water-efficient irrigation techniques, such as mid season drainage and shallow flooding, can reduce methane emission by 43-48% and more than 75%, respectively (EPA, n.d.). However, if water is reduced past the safety threshold (the maximum reduction in water level that will not cause negative effect on crops), productivity may be compromised especially in the case of SSC (Bouman, 2001).

Rainwater harvesting systems have also been introduced in Northern Philippines and may include small-scale irrigation projects such as Small Water Impounding Projects (SWIP), shallow tube wells (STW), small diversion dams and small farm reservoirs (SFR). These are earth dam structures constructed across a valley to collect rainwater and run-off during rainy season for later use (BSWM, n.d.). These systems are developed to provide supplemental irrigation supply to farmers, but also allow fishes to grow, thus, enhancing the livelihood of the local community (Dayo, n.d.). Recently, they are also considered as one of the adaptation responses of the country to extreme weather events such as floods and typhoons (BSWM, n.d.). From 1994 to 2010, in Northern Philippines alone, there are 2060 units of SWIPs built benefiting about 85,000 ha and 65,000 farmers, 14,423 SFRs benefiting 14,423 ha and 13,883 STWs benefiting almost 42,000 ha of farmland (Sandoval, 2011).

Similarly, micro-water managed sheds are implemented in highland areas in Northern Philippines, which serve similar functions to rainwater harvesting systems (Lasco *et al.* 2011). Aside from using water more efficiently, these sheds may serve other purposes such as flood control, recreation and inland fishery, increasing resilience to climate change and biodiversity in the area (Dayo, n.d.; Lasco *et al.* 2011). However, due to potential increase in profits, they may also result in an increase in land cultivation for agricultural use, thus reducing carbon sequestration of the soil (Smith *et al.* 2008).

Water recycling and other smaller types of rainwater collection systems are also being practiced by farmers in their households, which can provide a water source both for agricultural and household use (Bernando, 2009; Mitin, 2009). However, these rainwater harvesting systems are prone to contamination from different impurities thus degrading the quality of the water (Sarikonda, 2010).

5.1.4 Energy Use

A biofuel farm and ethanol plant have been built in Northern Philippines, which uses sugarcane as a feedstock for energy (The Bioenergy Site, n.d.). The Biofuel Act of 2006 was implemented in the Philippines, which aims to increase biodiesel and bioethanol blends by 2% and 10% respectively by 2011 (Stromberg *et al*. 2011). Bioethanol in the Philippines has a mitigation potential of 500-1200 megatons of CO_2 while biodiesel can eliminate 100-300 megatons of CO_2 (Agriculture Business Week, 2009). However, although this will displace GHG in the atmosphere and prevent additional emission from using fossil fuel, this may actually reduce resilience to climate change, as there will be competition for crop production between energy generation and food consumption. Further, crops such as sugarcane may require a tremendous amount of water compared to other crops, resulting in competition for water resources (Pittock, 2008). Bioethanol may also induce GHG emission as a result of intense irrigation use. In addition, extreme wind events are predicted to decrease biofuel feedstock production nationwide as a result of wind damages resulting in income loss (Stromberg *et al.* 2011).

A number of mitigation efforts as part of CDM projects have also been invested in partnership with industrialized countries across different regions in the Philippines. In Northern Philippines, a number of facilities for methane recovery in agriculture and agro industrial activities have been developed. CH_4, which is more potent than CO_2, is one of the important gases released into the atmosphere from storing animal manure (Steed & Hashimoto, 1994). This gas contributes to global warming, thus, recovering it can significantly reduce GHG from the atmosphere. One of the popular techniques used in recovering methane in Northern Philippines is the application of anaerobic digestion wastewater treatment to animal manure, such as in swine farm, which has potential to mitigate climate change. For instance, projects such as the Superior Hog Farm Methane Recovery and Uni-Rich Agro Industrial Corporation Methane Recovery and Electricity Generation are estimated to reduce 3,346 and 2,929 metric tons of CO_2eq per annum, respectively, (UNFCCC, n.d.j). The collected biogas is then used to generate electricity, thus, replacing consumption of fossil fuel. This can also potentially increase the profits for farmers and provide additional environmental benefits through reduction in odour from animal waste, and improved manure waste management (Landbank of the Philippines, n.d.; Lusk, 1998).

Other CDM projects that are not related to agriculture but are considered important to local communities in Northern Philippines and were also developed to address climate change includes development of renewable energy such as wind farms and hydropower plants. Since the implementation of Renewable Energy Act of 2008 in the Philippines, a tremendous boost in renewable energy development has been achieved (Global Electricity, n.d.) For example, the Northwind Bangui Bay Project was developed in Northern Philippines to promote sustainable development and mitigate climate change by displacing grid electricity generated from fossil fuels with renewable energy. This project has an estimated potential to reduce a total of 397,516 CO_2eq over the first seven years (UNFCCC, n.d.k). In addition, this wind farm increases tourism in the area, thus, providing additional sources of income to local community (Batongbacal, n.d.). Mini hydro power plants were also established to promote utilization of renewable energy and to improve the lives of local community who depends on terrace farming (Global Electricity, n.d.). The money generated from these hydropower plants were proposed to be used to conserve rice terraces in Northern Philippines that have been impacted by human activities such as deforestation, and by global warming. However, depending on the choice of technology, hydropower plants may also reduce resilience to climate change due to damaging impacts on fisheries downstream as a result of fluctuating peak hydro releases (Pittock, 2008). In addition, hydropower plants may not be as effective during drought season, which results in reduction in electricity generation causing an increase in electricity price (Pittock, 2008).

Furthermore, the Philippine government has invested in a nationwide distribution of free compact fluorescent lamp to replace incandescent light bulbs. This strategy is known as "Switch to CFL" campaign and is considered to be the first national initiative in Asia in phasing out incandescent light bulbs (IEA, 2010). It was anticipated that the impact of this project would result in savings of US$2 million as a result of reduced peak power demand of at least 2000 MW, US$500 million for the consumers, US$100 million annually on fuel cost, and 2.5 Mtons of CO_2 emissions per year (IEA, 2010). In addition to its mitigation potential, this strategy may help local community increase their resilience to climate change through reduction in energy demand especially during extreme heat events, thus, minimizing events of power outage.

5.1.5 Institutional Measures

With the help of local governments, early warning systems were developed in Northern Philippines, which are necessary for farmers in order to adjust their cropping calendar/pattern appropriately in response to the observed and projected climate change (Perez *et al.* 2007). The government also funded "cloud seeding" in the area during drought events (Mitin, 2009). This technique can be quite costly and cannot be implemented alone by farmers, requiring full support from the government (Mitin, 2009). If funding is not available, then the ability of the farmers to adapt to climate change may be at risk.

Roads from farm to market to facilitate trade especially during extreme weather events were also constructed in Northern Philippines (Mitin, 2009). This has allowed for easier and faster transfers of communication in the area (Mitin, 2009), but consequently may also lead to an increase in GHG emissions due to vehicle use. Crop insurance was also introduced in the area, which produces socio-economic benefits by helping farmers recover from financial losses due to extreme weather events and stabilizing farm incomes (PCIC, n.d.).

Perhaps one of the most important measures implemented by the government was water pricing and metering, which would encourage local farmers to switch to effective use of irrigation systems. This may enhance water conservation and decrease emission of GHG into the atmosphere (Jose & Cruz, 1999).

5.1.6 Conclusions

Overall, while a number of existing adaptation and mitigation strategies in the Northern Philippines have positive impacts on productivity, and have synergistic effects between them, possible conflicts also exist as summarized in Table 6, which may offset their efforts in mitigating climate change. Therefore, given the limited resources, the Philippines should consider prioritizing options where maximum synergistic effects between productivity, adaptation and mitigation will be achieved, which will result in a more effective and efficient allocation of resources.

5.2 Prioritization of Adaptation Options in Northern Philippines

As mentioned earlier, the Philippines being a developing country has limited resources. It may not have the necessary finances and technologies to pursue mitigation strategies. Currently, most of the mitigation efforts in the country, such as development of renewable energy technologies, are being funded by industrialized countries as part of their CDM projects. Therefore, adaptation maybe the only available approach in the country in order to address climate change.

For this reason, the second objective of this study aims only to further examine the adaptation strategies implemented in Northern Philippines as identified in the first objective. The Philippine government, despite its limited resources, continues to invest and introduce different adaptation strategies in agriculture across different regions. Therefore, it is important to assess the performance of these implemented strategies to make sure that the Philippines is allocating its resources effectively.

Due to complexity and time limitation, the most popular or common strategies in Northern Philippines based only from the literature review collected are those that are only considered for further examination. This was achieved by tallying the number of times each strategy identified from the first objective is documented in the literature. Five adaptation options to climate change in the agricultural sector have been determined to be the most common occurring farming practices in Northern Philippines. These are crop diversification, agroforestry, organic farming, water conservation and rainwater harvesting, and improved irrigation techniques. These five adaptation options were then compared qualitatively across the selected criteria by giving them ratings in their performance in reaching the overall objective: to decrease the agriculture's vulnerability to the impacts of climate change. The selected criteria are the following: productivity, effectiveness, economic efficiency, flexibility, institutional compatibility, farmer implementability and independent benefits, which are discussed in the following sections. The comparison of the five adaptation strategies across the selected criteria is summarized in Table 7.

5.2.1 Effectiveness

The more effective an adaptation strategy is in reducing the vulnerability of agriculture to the impacts of climate change, the more favourable it is. In this study, the effectiveness of an adaptation strategy to reduce agriculture's vulnerability is measured by examining its potential to reduce income loss and increase agricultural productivity under changing climatic conditions. An adaptation option that significantly reduces loss and increases agricultural productivity in the events of climate change compared to other adaptation alternatives would have a high effectiveness.

Crop diversification is moderately effective. For instance, a drought tolerant variety of rice was found to yield on average, between 25 to 37% more than a standard variety of rice undergoing controlled and natural drought conditions (Venuprasad *et al.* 2008). This can potentially help the farmers in Northern Philippines in addressing the impacts of increased temperature and increased frequency and intensity of drought events. However, maintenance breeding should also be performed as there is a potential for hybrid crops to decrease yield over time due to loss in local adaptation (Peng *et al.* 2010). In addition, although, crop diversification can increase income when substituting to stress tolerant crop varieties, adding new crop varieties does not necessarily avoid income loss, as they can still be affected by climate change (Dolan *et al.* 2001).

Agroforestry is also moderately effective. It can definitely increase yield and income under different climatic conditions as opposed to just having a monoculture cropping system or having an uncultivated land (e.g. in the case of coconut farms) (Nissen & Midmore, 2002; Bertomeu, 2003). It can also increase food sufficiency of households and farmers, especially if fruit trees are planted (DA, 2011a). As mentioned earlier, agroforestry increases soil fertility and water conservation. It can help the farmers in Northern Philippines address the impacts of increased temperature, and increased variability in precipitation such as soil erosion, increased frequency of droughts, and increased incidence of pests and diseases. However, there are also other factors that can potentially lower the effectiveness of agroforestry. These factors require consideration in order to maximize the yield from agroforestry especially when dealing with the impacts of climate change. For instance, a study by Martin and van Noordwijk (2009) in Central Philippines found that increasing the tree density results in decreasing crop yield proportional to the gain in wood volume. They also found that yield is dependent on distance between trees to allow for intercropping system and that, in the absence of fertilizer, especially in the case of degraded land, no difference was observed between the yield in agroforestry and monoculture, perhaps due to competition for nutrients (Martin & van Noordwijk, 2009).

Organic farming is also moderately effective. A study in Central Philippines suggests that during the dry season, organic rice farming can yield 38% and during rainy season it can yield 60% more than the conventional rice farming (Mendoza *et al.* 2001). This can be beneficial especially when dealing with increased number of dry days and rainy days when agricultural productivity in Northern Philippines is compromised. However, in most cases, organic farming has a slightly lower yield compared to conventional farming (Mendoza, 2004; Swedish Society for Nature Conservation, 2011). Organic farming may produce lower productivity due to reduction or complete removal of agrichemical inputs, in which case, crops become dependent on the slow nutrient cycling process in the soil (Stockdale, 2009). Various studies have confirmed this (Mendoza *et al.* 2001, Sarkar *et al.* 2003), although, the yield depends also on the crops, and the time and length of growth of the crops (FAO, 1998). If the yield does increase, it will just be comparable to the yield from conventional farming under normal conditions (Mendoza *et al.* 2001, Sarkar *et al.* 2003).

Rainwater harvesting systems are highly effective in increasing production not only through crops but also through fisheries (Cabezon & Samar, 2009). These systems are very important in Northern Philippines in addressing the impacts of increased frequency and intensity of rainfalls such as flooding, run off and soil erosion. They provide a source of irrigation for areas with limited supply of water, which allow for production of additional crops (e.g. rice) that are previously impossible (Dayo, n.d.). For instance, in one region in Northern Philippines, an additional 5,000 kg per hectare of rice and 130 kg per fisher of fish have been generated in the area (Cabezon & Samar, 2009) through installation of small water impounding systems. In another region in Northern Philippines, 100 ha of land became irrigated producing a total of 400 tons of rice per cropping season (Dayo, n.d.).

Compared to other alternatives, water-efficient irrigation techniques, which are introduced in Northern Philippines to increase water efficiency and prevent water scarcity especially during events of increased droughts, hot days and dry days, have low effectiveness in increasing agricultural productivity. A number of studies have confirmed that an increase in water savings is correlated with decrease in crop yield (Belder *et al.* 2004; Bouman & Toung, 2001; Chapagain *et al.* 2011). However, the result may also depend on the soil type and hydrology (Belder *et al*. 2004) and the technique used. For instance, an experiment in the

Philippines suggests that SSC would result in an average water savings of 23% but an average yield loss of 6%, although, this loss can increase from 10% to 40% if soil is saturated to its highest potential (Bouman & Toung, 2001). In addition, an AWD in a clay soil would result in soil cracking, thus, increasing water loss and causing further reduction in yield (Bouman & Toung, 2001).

Furthermore, an experiment in China suggests that an AWD with moderate drying has a better chance of increasing productivity by 11% and actually improving the quality of rice, while an AWD with a severe drying will reduce production by 32% relative to conventional irrigation (Zhang *et al.* 2008; Zhang *et al.* 2009). While an experiment in the USA suggests that application of sprinkler irrigation will result in water savings of 20 to 50% but a yield loss of 20 to 30% for high yield crops and a much lower yield for drought-resistant crops compared to conventional irrigation (Bouman, 2001). Decreasing water input by only about 15% to 30% may be a safe threshold to avoid yield loss (Belder *et al.* 2004).

However, another study has suggested that the reduction in yield from controlled irrigation is not statistically significant (Rejesus *et al.* 2011). It has also been recommended that in order to increase or maintain production, new agricultural land is required so that the water savings achieved from old agricultural lands using water-efficient technologies can be used to new agricultural lands (Bouman & Toung, 2001), and that better nutrient management should be applied together with water-efficient irrigation systems (Cabangon *et al.* 2011) to achieve the maximum effectiveness.

In summary, rainwater harvesting systems have the highest effectiveness compared to crop diversification, agroforestry and organic farming, which are only moderately effective. On the other hand, water-efficient irrigation techniques have the lowest effectiveness.

5.2.2 Economic Efficiency

The more economic efficient an adaptation strategy is the more favourable it is. In this study, the economic efficiency of an adaptation strategy is measured by examining the economic benefits compared to economic cost of implementing an adaptation option to address climate change. An adaptation option where economic benefits significantly outweigh the economic cost compared to other adaptation alternatives would have a high economic efficiency.

Crop diversification, which is introduced in Northern Philippines to maintain or increase production during extreme weather events such as drought, has between low to high economic efficiency depending on the crops. For instance, data gathered from the Philippines suggest that crop rotation (e.g. rice-non rice cropping) has high economic efficiency, which can vary between 25% to 90% profitability compared to not having rotation (e.g. rice-rice cropping) (Mariano, 2007). However, certain crops in the Philippines such as peanuts, tomato and hybrid corn produce negative profitability (Gonzales, 1989) and are more costly than conventional crops (e.g. garlic vs. rice) (Caluya & Acosta, 1989), while others, such as onion can yield higher profitability than rice (Marzan, 1989). A number of factors can also contribute to the economic efficiency of crop diversification. For example, fluctuating market prices affect the cost of inputs and outputs, while socio-economic factors determine whether the choice of crop will easily be accepted by consumers, thus, affecting supply and demand (Gonzales, 1989).

Agroforestry is rated as high in economic efficiency. Studies across Northern and Southern Philippines show a higher benefit/cost ratio (a ratio that compares the benefit relative to the cost and is expressed in monetary terms) relative to monoculture cropping when intercropping of trees and crops was introduced (Nissen & Midmore, 2002; Bertomeu, 2003), and a higher benefit/cost ratio from fruit trees over forest trees (Hyman, 1984). These results may also be transferable when agroforestry is implemented in response to climate change since monoculture cropping is more vulnerable to the impacts of climate change compared to agroforestry. For instance, when outbreak of pest and diseases occurs as a result of increased temperature, crops from agroforestry have better chance of surviving compared to monoculture cropping. This means that agroforestry will most likely produce better results economically than with just monoculture cropping. However, the benefit/cost ratio may also vary depending on external factors such as market prices, and demand and supply affecting net returns and cost of inputs and outputs (Nissen & Midmore, 2002; Bertomeu, 2003).

Organic farming is also high in economic efficiency relative to conventional farming due to the savings incurred from avoiding agrichemical inputs (Mendoza, 2004; Bernando, 2009). For instance, a study in the Philippines suggests that even though the yield from organic crops is slightly lower than conventional crops (3.25 tons per ha and 3.52 tons per ha, respectively), the savings from not using agrichemicals (fertilizers and pesticides), which accounts for 83% of the production cost, offsets the lower yield, thus giving a net return of 3.5 times more than the conventional farming (Mendoza, 2004). In addition, the price of organic produce worldwide is higher than conventional produce, giving more profit to the farmers (IFOAM, 2009). The economic benefits in the events of climate change is even more pronounced. For example, decreasing the use of agrichemicals will improved the quality of the soil and may minimize the impacts of run off and soil erosion from increased variability in precipitation.

The benefits and profits generated from direct and indirect impacts of rainwater harvesting systems such as increasing productivity, water efficiency, income, and livelihood of local communities and reducing cost of damage from soil erosion and flood, outweigh the relatively small cost of installation and operation across different regions in the Philippines (Cabezon & Samar, 2009). Therefore, it has also high economic efficiency.

Water-efficient irrigation techniques have also high economic efficiency. The benefits of water savings of up to 50% and reduction in irrigation use of up to 38% (Bouman, 2001; Rejesus *et al.* 2011) in the Philippines, definitely outweighs the cost of producing a relatively lower yield, especially in the Philippines where there is a threat of water scarcity, and the price for water and energy use continues to increase. In addition, there is a potential for improvement in terms of achieving an optimum threshold for improving water efficiency to maintain crop yield (Bouman, 2001). This means that in the events of climate change, water-efficient irrigation techniques could potentially be beneficial economically especially when addressing increased drought events as a result of increased variability in precipitation.

In summary, all of the adaptation options selected have high economic efficiency except for crop diversification, which can be between low to high economic efficient.

5.2.3 Flexibility

The more flexible an adaptation strategy is the more favourable it is. In this study, the flexibility of an adaptation strategy is measured by how a strategy can tolerate a wide range of climate conditions. An adaptation option than can reduce loss and agriculture's vulnerability under a wide range of climate conditions compared to other adaptation alternatives would have a high flexibility.

As mentioned earlier, crop diversification involves substitution of new species of conventional crops or addition of new varieties of crops other than the conventional crops (FAO, 2001). This may includes new hybrid of crop species that can better tolerate changes in the variability of precipitation such as drought and flood-resistant crops. These crops are found to increase agricultural productivity under extreme climate conditions (Venuprasad *et al.* 2008). Therefore, crop diversification has high flexibility.

Similarly, agroforestry has high flexibility because it can reduce agriculture's vulnerability at various climate conditions. For instance, having fruit trees enhance water conservation and soil fertility, which can better address the impacts of changing climate conditions compared to just monocropping (Smith *et al.* 2008; FAO, 2009; Bryan *et al.* 2011).

Organic farming also has high flexibility. Avoiding the use of fertilizer for cropping reduced degradation of the land over time, which consequently improves the soil quality and fertility. This will help the crops to respond better to changing climate conditions.

On the other hand, rainwater harvesting system has low flexibility. As mentioned earlier, these systems serve as flood control, thus, their functionality depends only on rainy seasons and may not be as efficient during dry or drought seasons. During dry or drought seasons, these systems may still be vulnerable to increased evapotranspiration, which can potentially decrease water availability affecting agricultural productivity.

Water-efficient irrigation techniques have also low flexibility. As mentioned earlier, these techniques only involve a change in irrigation practices such as reduction in water usage to enhance water conservation. These systems may or may not work as efficiently during a range of climate conditions as crops are still vulnerable to flooding and impacts of drought events.

Overall, crop diversification, agroforestry and organic farming are highly flexible in reducing agirculture's vulnerability at varying climatic conditions such as both in dry and rainy season. On the other hand, rainwater harvesting systems have low flexibility because their functions are dependent on rainy season.

5.2.4 Institutional Compatibility

The more compatible the local or national governments align themselves with an adaptation strategy, the more favourable it is. In this study, the institutional compatibility of an adaptation strategy is measured by examining the existing regulations or legislations that supports the adaptation strategy, and/or the willingness of the government to support development in the selected adaptation strategy to better respond to the projected climate change.

The Philippine government has provided support for implementing crop diversification. The government provides financial aid to farmers to switch to alternative crops to enhance their income and productivity. For instance, the Philippines Department of Agriculture has provided US$500,000 to tobacco farmers as a fund to perform rice cultivation as an alternative source of income (DA, 2011b). There are also institutions, such as the Philippines Rice Research Institute (PRRI), that continuously perform development of new varieties of crop species (e.g. drought or flood resistant crops)) that will better tolerate the effects of current and projected climate changes and variability.

The Philippine government also support agroforestry. For example, the DA has adopted Executive Order No. 210 also known as *"Maunland na Niyugan tugon sa kahirapan"* Project, which promotes agroforestry in coconut farms, to enhance farmer's income (DA, n.d.b). In addition the Good Roots Project, which was initiated in 1992, promoting agroforestry in

Northern Luzon, is considered to be the most successful environmental and livelihood research and development in the area (Wallace, 2009). Part of the success of this project is getting the local communities and farmers' direct involvement in the decision-making process (Wallace, 2009). Perhaps, the latest support from the Philippine government is its willingness to implement agroforestry as a possible option for CDM projects, which can potentially mitigate GHG (World Agroforestry Centre, 2012). The Philippine government is also a big supporter of organic farming and has passed a law known as RA 10068 – Organic Agriculture Act of 2010, which aims to promote organic farming nationwide (DA, 2011c) to help address the challenges of climate change. The law requires the DA to allocate at least 2% of its budget for organic agricultural programs (DA, 2011c). Further, a number of NGOs, LGUs and farmers' organizations have formed an association called Go Organic Philippines, which also aims at promoting sustainable organic agriculture in the country. Currently, one of the main challenges of organic farming in Northern Philippines is its low popularity to farmers. As a result, supporters of organic farming are also pushing for the government to increase its budget to provide support services, research and development, marketing and subsidy to farmers, which will boost the country's organic industry (Go Organic Philippines, 2012).

The government has been funding and supporting construction of small-scale irrigation projects like rainwater harvesting systems nationwide. The Bureau of Soil and Water Management under the Department of Agriculture is the main government institution responsible for developing sustainable agriculture through land and water conservation, and has funded more than US$100 million worth of these projects from 1994 to 2010 (BSWM, n.d.). In response to projected climate change, there are a number of ongoing projects in the Philippines that will ensure that planning, design and establishments of new irrigation projects will minimize susceptibility to climate risk through improved biodiversity conservation and reduced land degradation (World Bank, 2010). The Philippine government has also been promoting and adopting innovative water efficient irrigation technologies such as AWD across the country since 2001, and in 2009 under the Administrative Order No. 25, the *Guidelines for the Adoption of Water Savings Technologies (WST) in Irrigated Rice Production Systems in the Philippines* has been formulated (DA, 2009). In addition, in response to climate change, the Philippine government is also encouraging development of wind or solar pump irrigation projects in Northern Philippines and other regions aiming at promoting sustainable agriculture (BSWM, n.d.).

By definition, since all of the adaptation strategies chosen in this study have been implemented in Northern Philippines, all of the selected adaptation strategies should have high institution compatibility.

5.2.5 Farmer Implementability

The more easily it is for the farmers to implement an adaptation strategy without much dependence on external sources, the more favourable it is. In this study, the farmer implementability of an adaptation strategy is measured by examining how easily it can be understood, implemented and socially and culturally accepted. An adaptation option that can easily be implemented by farmers compared to other adaptation alternatives would have a high farmer implementability.

Since most farmers have already been practicing agroforestry even before the government started promoting it (FAO, 2010b), this suggests that this strategy is easy to understand and implement, thus, it has high farmer implementability. For instance, 90% of farmers in Abra, Northern Philippines, believe that their agricultural practices may be considered as agroforestry (FAO, 2010b). This finding is outstanding considering the importance of agroforestry in addressing the impacts of climate change.

On the other hand, without much help from the government, such as research and development on new crop varieties that will better tolerate extreme climate change and variability, provision of seeds for trial and training for proper planting techniques of new variety of crops and so on, it will be difficult for farmers to implement crop diversification, and therefore, it has a low farmer implementability (Mariano *et al.* 2007). In fact, an analysis of the national survey suggests that only an average of 11% to 15% of farmers have adopted crop diversification due to factors such as production technology, capital requirements, land suitability, and education (Mariano *et al.* 2007).

Organic farming has also low farmer implementability in Northern Philippines as the farmers cannot easily implement organic farming due to a number of critical changes from conventional farming practices that must be taken into consideration such as change in composition of inputs, timing of crop rotation, and procedure for making compost requiring training and education prior to implementation (IFOAM, 2009). Farmers may also require training and education to increase their awareness on the benefits of practicing organic farming to tackle the impacts of climate change, which can potentially make it faster and easier to be socially and culturally acceptable. Regardless, organic farming has increased its popularity nationwide in the Philippines from an area of 14133.70 ha in 2005 to 51,805.10 in 2009, an increase of approximately 366% (FiBL, 2012).

Without financial support it will also be difficult for farmers to build rainwater harvesting systems aim at addressing flooding and soil erosion from increased frequency and intensity of rainy days. Further, these systems may only be constructed in the Philippines in a land that has no tenure or "right of way" problem (BSWM, n.d.). However, the government also requires farmers to pay part of the capital cost for construction, operation and maintenance (BSWM, n.d.). Farmers are also needed to undergo training to learn operation and maintenance of these systems, and to learn cropping techniques for new crops to be introduced (BSWM, n.d.).

Water-efficient irrigation techniques, which aim at addressing drought events, have moderate farmer implementability. Some systems have low cost and once the farmers have undergone training or received information on the proper procedure, it will be easy to implement them, while other systems have a relatively high cost for installation, as in the case of sprinkler irrigation, and might require financial assistance from external sources (Bouman, 2001).

In summary, agroforestry has high farmer implementability, while crop diversification, organic farming, and rainwater harvesting systems have low, and water- efficient irrigation techniques have moderate farmer implementability.

5.2.6 Independent Benefits

The more independent benefits an adaptation strategy has, the more favourable it is. In this study, the independent benefits of an adaptation strategy are measured by examining the environmental and socio-economic benefits, other than reducing the risk of loss due to climate change. An adaptation option where environmental and socio-economic benefits are higher compared to other adaptation alternatives would have high independent benefits.

Crop diversification has moderate independent benefits. It can suppress pest outbreaks (Lin, 2011; Letourneau *et al.* 2011), which can potentially increase as a result of increased temperature. It can also increase soil fertility depending on the crops (Behera *et al.* 2007).

However, an alternative crop may also require higher fertilizer inputs than the conventional one, which, may degrade the quality of the soil over time, thus, increasing the risk of soil erosion.

Agroforestry has high independent benefits such as increasing soil organic matter and soil enrichment, thus, regenerating degraded land (Gama-Rodriguez, 2011). Other studies in the Philippines found a potential for 15% to 25% in soil conservation through agroforestry (Pattanayak & Mercer, 2002). It can also enhance biodiversity and slope and watershed protection (Lasco & Puhlin, 2006).

Organic farming has a high number of independent and socio-economic benefits by reducing productivity cost and increasing cooperation among families and farmers due to increased labour demand, energy conservation and environmental protection from avoided manufacturing and use of fertilizers or pesticides (Mendoza, 2004).

Rainwater harvesting systems have high independent benefits. By serving as a flood control measure, a flood peak discharge in an upland community in Northern Philippines can be reduced by 1.9 to 3.18 times than without having these systems (Concepcion *et al.* 2006) can be achieved. They can also serve as recreation areas increasing local tourism, and as additional sources of livelihood providing a food supply (e.g. fish) for local communities (BSWM, n.d.). They also enhance biodiversity and conserve soil by trapping sediments during run-off preventing impacts on downstream areas (Concepcion *et al.* 2006).

As mentioned earlier, water efficient irrigation techniques can save quite a bit of water and energy use from irrigation and pumping, thus, enhancing water conservation. However, this may also result in increased fertilizer use or increased land cultivation for agricultural use to compensate for the loss in yield, thus, posing more risk to environmental pollution (Rejesus *et al.* 2011). Therefore, this strategy has moderate independent benefits.

In summary, while the rest of selected adaptation options have high independent benefits, crop diversification and water- efficient irrigation techniques have only moderate independent benefits.

5.2.7 Conclusions

Table 7 shows the summary of the previous discussions. Based on this evaluation, the Philippine government can assess better which adaptation option to address climate change can provide the maximum or optimal benefits to its people and the environment, and where it can allocate its resources more effectively and successfully. This evaluation may also serve as a guide to the Philippine government in choosing the ideal adaptation option or combinations of these options to be implemented in other regions that will enable the country's agricultural industry to not only successfully adapt to climate change but also to prosper economically. For instance, agroforestry may be one of the most effective and efficient options to adapt to climate change, and may also be important if the government has also intention to attract or encourage investors from industrialized countries to implement these strategies due to its mitigation potential. Organic farming may also be a good adaptation option to climate change and may also be significant if the government is also seeking to increase its organic imports due to its increasing popularity in the market worldwide. Similarly, a combination of two or more adaptation options may be more beneficial, economically and in response to climate change, rather than just implementing one option. Ultimately, this depends on the goal that the Philippine government is trying to achieve.

Table 7. Evaluation of Adaptation Strategies in Agriculture in Northern Philippines

Criteria	Adaptation Options				
	Crop Diversification	Agroforestry	Organic Farming	Rainwater Harvesting Systems	Water Efficient Irrigation Techniques
Productivity	High	High	Low	High	Low
Effectiveness	Moderate	Moderate	Moderate	High	Low
Economic Efficiency	Low-High	High	High	High	High
Flexibility	High	High	High	Low	Low
Institutional Compatibility	High	High	High	High	High
Farmer Implementa-bility	Low	High	Low	Low	Moderate
Independent Benefits	Moderate	High	High	High	Moderate

6. Conclusions and Recommendations

This chapter is divided into three parts: general conclusions, major findings and future directions.

6.1 General Conclusions

It has been asserted that developing countries will be most impacted by the effects of climate change, whereas it is the industrialized nations that are responsible for over 80% of global GHG emissions. This fact was confirmed during the field trip in December/January 2011/2012 to the Philippines where private discussions with local experts, NGOs and farmers have confirmed that the effects of climate change are already being experienced. (T. La Vina, Dean of Ateneo School of Government; N. Sano, Philippine Climate Change Commissioner; L. Sering, Vice Chair of Philippine Climate Change Commission & B.D. Muller, Philippine climate change advisor and negotiator, personal communication, January 4, 2012; A. Abraham, EcoGov Chief of Party, personal communication, January 3, 2012).

In discussions with members of the Philippines delegation to the Durban IPCCC Conference, there was considerable dismay over the failure to reach any substantive policy decisions, especially in the failure of the developing countries to commit to acknowledge their climate debt (T. La Vina, Dean of Ateneo School of Government; N. Sano, Philippine Climate Change Commissioner; L. Sering, Vice Chair of Philippine Climate Change Commission & B.D. Muller, Philippine climate change advisor and negotiator, personal communication, January 4, 2012). Their concern was that the outcome from Durban, namely the plan to develop a “roadmap” by 2015 for implementation by 2020 does not include any binding commitment from the major GHG emitters, USA and China.

Environmental groups in the said private discussions expressed their concern that while the Philippines is especially vulnerable to the effects of climate change, the per capita GHG emissions of Filipinos is low, approximately one twentieth that of the USA. At the same time it is the major industrialized nations that are still generating the largest fraction of GHGs and in most cases increasing their emission levels.

There have been many instances of unusual, severe weather incidents that have seriously impacted different sectors in the Philippines. Being highly dependent on agriculture, the impacts in the agricultural sector can potentially threaten the economic development in the Philippines. With an increasing population already exceeding the carrying capacity of the Philippines and a high level of poverty, one can only assume that the impacts of climate change will result in significant losses and damages to the country.

While agriculture is among the major sectors that may be hit severely by climate change, it is also one of the biggest contributors of atmospheric GHG emissions. A majority of the GHG released from agriculture comes from rice cultivation releasing CH_4 into the atmosphere, which has a higher potency than CO_2 in causing global warming.

The Philippines is one of biggest importers of rice in the world, but also produces a majority of rice locally to sustain the high demand of its population. There is also an opportunity for mitigating GHG from the agricultural sector in the Philippines.

6.2 Major Findings

This study was initiated based on two main assumptions: first, the Philippines as a developing nation and especially with its large number of islands that amplifies the risks of a small island state, has limited resources to combat the effects of climate change. Second, with the option of focusing on mitigation or adaptation strategies, the latter approach maybe the only available one in the Philippines. At the same time, while there may be some mitigation policies imposed at the higher levels of government, it is vital that adaptation strategies, which are mostly implemented at the local level, should not conflict.

Given these assumptions, the study addressed two main themes: potential synergy/conflict between adaptation and mitigation, and prioritizing the most ideal adaptation strategy or combination of strategies.

In the former area, potential synergies and conflicts are found through a thorough review of all adaptation or mitigation strategies in Northern Philippines. The impacts on productivity of the identified strategies are also studied.

Some of the observed findings demonstrate synergistic effects. For instance, crop diversification has synergistic effect whereby diversifying crops can enhance sources of livelihood, thus increasing resilience to climate change, while at the same time, enhancing fertility of the soil, thus increasing its potential to sequester more CO_2. By using drought-resistant crops and other alternative crops that can survive in extreme climate conditions, crop diversification is found to increase productivity. However, crop diversification can also potentially increase GHG emissions because some crops may require greater use of fertilizers compared to a traditional one. Another example that shows synergistic effect is crop rotation whereby implementing rotation can suppress pests and diseases, thus reducing the amount of chemical use leading to a reduction in GHG emissions. At the same time, crop rotation can also reduce soil erosion and increase soil fertility leading to an increase in productivity and potential of the soil to sequester more CO_2.

On the other hand, some of the observed findings demonstrate conflicting effects. For instance, water-efficient irrigation technologies demonstrate conflicting effects whereby, a reduction in irrigation will reduce demand for water and electricity use for pumping, thus increasing mitigation potential, but at the same time, can also result in reduction in productivity, such as in the case for AWD or SSC. The reduction in productivity can potentially encourage farmers to increase their fertilizer application to compensate for the loss leading to an increase in GHG emission. Another example is the installation of biofuel and bioethanol plants whereby, although they displace the GHG in the atmosphere by reducing demand for fossil fuel, they reduce resilience to climate change due to competition for crops for food consumption or energy generation.

In the second objective, performances of the selected adaptation strategies were further evaluated across six criteria: effectiveness, economic efficiency, flexibility, institutional compatibility, farmer implementability, and independent benefits. This finding can serve as a guide to the Philippine government in assessing and choosing the ideal adaptation strategies that will provide the maximum or optimal benefits to its people and the environment prior to introduction or implementation to other regions. This may also help the Philippines allocates its resources more effectively and successfully.

For example, one of the adaptation options that the Philippine government can focus on is agroforestry. Agroforestry has a high performance in terms of productivity, economic efficiency, flexibility, institutional compatibility, farmer implementability, independent benefits, and a moderate performance on effectiveness. Agroforestry can increase crop yield and sources of livelihood of local farmers despite the varying climate conditions and hence mitigate the effects of climate change. It also has a high benefit/cost ratio relative to monoculture cropping. Agroforestry can easily be implemented by local farmers and is highly promoted in the Philippines. There is also a wide range of independent benefits from agroforestry such as increasing soil organic matter and soil enrichment, thus regenerating degraded land, enhancing biodiversity and watershed protection, maintaining soil fertility, and suppressing pests and diseases. Agroforestry may not only promote enhanced food security but can also contribute to economic development in the Philippines as it is one of the options for mitigating climate change under CDM projects.

It is also possible that a combination of two or more adaptation options may provide the maximum benefits rather than just having one, depending on the goals that the government is trying to achieve. For instance, adopting organic farming in combination with agroforestry, may also be an ideal choice to address climate change and may also be significant if the government is also seeking to increase its organic imports due to its increasing popularity in the market worldwide. Whether to improve agriculture economically or successfully adapt to climate change or both, the performance and strength of each strategy may vary. Hence, it is important for the Philippine government to prioritize the goals that it wants to achieve, beforehand, to successfully allocate its resources and choose the right adaptation option to be implemented.

In conclusion the findings of this study reinforce the significance of understanding the linkage between mitigation and adaptation, which can significantly contribute in successfully addressing the impacts of climate change. The present study has shown that the link between adaptation and mitigation strategies in the agricultural sector in Northern Philippines may not always yield synergistic effects but may also cause conflicts between them. The study has also put emphasis on prioritizing adaptation strategies in order to find the ideal adaptation option where the Philippines can focus its attention and allocate more of its resources to achieve the maximum benefits to its people and the environment, and to successfully reach its goal.

6.3 Future Directions

While the qualitative aspect of the present study can be of value, future studies might want to address a more quantitative approach, which would have the benefit of providing a larger body of data, which should facilitate the process of decision-making on prioritization of optimum strategies. For example, by performing a weighted score of the performance of the different adaptation options to the multiple criteria selected in this study, this would then generate a ranking of the various options. However, this would require a more active role for key stakeholders, especially farmers and local government units, which could be a lengthy and resource-intensive procedure.

In addition, future studies can also expand the number of adaptation strategies selected for evaluation, which can help the Philippines government to choose and decide properly which adaptation option to implement.

It is also suggested that mainstreaming adaptation and mitigation strategies across different sectors might be an important approach for future study with the possible benefits of integration that would lead to maximizing synergies or minimizing conflicts. Improving the policy-making process in the Philippines and providing recommendations is also essential to adequately manage conflicts in order to strike a balance between adaptation and mitigation strategies. However, it is also important that the national mitigation efforts that the government may choose to implement do not undermine the effects of the adaptation strategies that local farmers are practicing, vise versa, in order to achieve better results.

Cooperation and support from the developed nations would also seem to be critical to the Philippines achieving some success in combating climate change. However, this has not played a significant role to date. The reasons may include barriers to technology transfer due to conflict over intellectual property rights. It is also debatable that even if technology transfer is to be made more readily accessible, whether farmers will be able to adapt and accept these new technologies. To a large extent, the success of such initiatives will depend on the government's efforts to increase public awareness as well as providing the necessary financial support to farmers and local communities. Furthermore, it may be necessary for the Philippine government to develop strict agreements on implementation or introduction of CDM projects along with the development of feasible monitoring facilities to avoid double counting of carbon credits.

These proposed approaches should have the potential to enhance the capability of the Philippines, despite their limited resources, to address the impacts of climate change. They should also have a positive benefit on long-term sustainable development in the country.

References

Ackerman, F., & Stanton, E. (2006). *Climate change- the cost of inaction*. Retrieved from Friends of the Earth United Kingdom website: http://www.foe.co.uk/resource/reports/econ_costs_cc.pdf

Aguilar, S. (2012). UNFCCC / COP-17: Long negotiations produce a climate roadmap. *Environmental Policy and Law*, *42*(1), 15-19.

Agriculture Business Week. (2009, June 13). *Mitigating climate change through biofuels (Part 1).* Retrieved from http://www.agribusinessweek.com/mitigating-climate-change-through-biofuels-part-1

Ahlenius, H. & UNEP/GRID – Arendal. (2009). *Projected agriculture in 2080 due to climate change*. Retrieved from http://www.grida.no/graphicslib/detail/projected-agriculture-in-2080-due-to-climate-change_141b

American Institute of Physics (AIP). (2011). *Global warming timeline.* Retrieved from http://www.aip.org/history/climate/timeline

Anderegg, W., Prall, J., Harold, J., & Schneider, S. (2010). Expert credibility in climate change. *Proceedings of the National Academy of Sciences, USA, 107*(27), 12107-12109.

Asian Development Bank (ADB). (2009). *The economics of climate change in Southeast Asia: A regional review.* Mandaluyong, Philippines: Asian Development Bank. Retrieved from http://www.adb.org/Documents/Books/Economics-Climate-Change-SEA/PDF/Economics-Climate-Change.pdf

Australian Department of Climate Change and Energy Efficiency (DCCE). (2011). *Work programme to consider approaches to address loss and damage associated with climate change impacts in vulnerable developing countries.* Retrieved from http://www.climatechange.gov.au/government/initiatives/unfccc/submissions/work-programme.aspx

Azam, F. (2008, April 7). Climate change biggest challenge to human health. *The Nation.*

Behera, U. K., Sharma, A. R., & Mahapatra, I. C. (2007). Crop diversification for efficient resource management in India: Problems, prospects and policy. *Journal of Sustainable Agriculture, 30*(3), 97-127. doi:10.1300/J064v30n03_08

Batongbacal, J. L. (n.d.). *Public engagement and local benefit sharing in the northwind bangui bay project Philippines.* Retrieved from International Union for Conservation of Nature website: http://data.iucn.org/dbtw-wpd/html/eplp-070/section11.html

Belder, P., Bouman, B., Cabangon, R., Guoan, L., Quilang, E., Yuanhua, L., Spiertz, J. H. J. & Tuong, T. P. (2004). Effect of water-saving irrigation on rice yield and water use in typical lowland conditions in Asia. *Agricultural Water Management, 65*(3), 193-210. doi:10.1016/j.agwat.2003.09.002

Bernando, E. C. (2009). *Impacts of climate change and local adaptation strategies of various socioeconomic groups in Isabela, Northern Phillippines.* Retrieved from Pacific Basin Organization website: http://www.pacificbasin.org/PBC_2009_Conference/followup/presentations/Sunday/Bernardo.pdf

Bertomeu, M. G. (2003, May 19-23). Smallholder maize-timber agroforestry systems in Northern Mindanao, Philippines: Profitability and contribution to the timber industry sector. *The International Conference on Rural Livelihoods, Forest and Biodiversity.* Bonn, Germany: CIFOR.

The Bioenergy Site. (n.d.). *Ethanol Latest News.* Retrieved from http://www.thebioenergysite.com/news/category/4/ethanol/vars/country/ph

Bond, P. (2010, May 5). Climate debt owed to Africa: What to demand and how to collect? *Links International Journal of Socialist Renewal.* Retrieved from http://links.org.au/node/1675

Borick, C., Lachapelle, E., & Rabe, B. G. (2011). *Climate change compared: public opinion on climate change in the United States and Canada* (Number 39). Washington, DC, USA: The Brookings Institution.

Bouman, B. A. M. (2001). *Water -efficient management strategies in rice production.* (Report No. IRRN 26.2). Retrieved from International Rice Research Institute website: http://archive.irri.org/ipswar/publications/irrn262mini2.pdf

Bouman, B., & Tuong, T. P. (2001). Field water management to save water and increase its productivity in irrigated lowland rice. *Agricultural Water Management*, *49*(1), 11-30.

Boyd, P. W., & Law, C. S. (2001). The southern ocean iron release experiment (SOIREE): Introduction and summary: Deep sea research part II. *Topical Studies in Oceanography, 48*(11-12), 2425-2438.

Brown, D. (2011). *Going deeper on what happened in Durban: An ethical critique of Durban outcomes*. Retrieved from Penn State University, Climate Ethics website: http://rockblogs.psu.edu/climate/2011/12/going-deeper-on-what-happened-in-durban-an-ethical-critique-of-durban-outcomes.html

British Columbia Ministry of Agriculture, Food and Fisheries. (2004). *Commodity: Greenhouse*. Retrieved from http://www.al.gov.bc.ca/resmgmt/fppa/refguide/commodity/870218-17_Greenhouse.pdf

Bryan, E., Ringler C., Okoba, B., Koo, J., Herrero M., Silvestri S. (2011). *Agricultural* *management for climate change: Adaptation, greenhouse gas mitigation, and agricultural productivity*. (Report No. 01098). Retrieved from International Food Policy Research Institute website: http://www.ifpri.org/sites/default/files/publications/ifpridp01098.pdf

C40 Cities Climate Leadership Group. (2011). *About C40: sustainable action on climate change.* Retrieved from http://www.c40cities.org/about

Cabangon, R. J., Castillo, E. G., & Tuong, T. P. (2011). Chlorophyll meter-based nitrogen management of rice grown under alternate wetting and drying irrigation. *Field Crops Research, 121*(1), 136-146. doi:10.1016/j.fcr.2010.12.002

Cabezon, W. E., & Samar, E. D. (2009). *Small water impounding systems: impacts and their valuation*. Retrieved from Southeast Asian Regional Center for Graduate Study and Research in Agriculture website: http://www.searca.org/web/adss/2009/handouts/ADSS_Cabezon_27Jan2009.pdf

Caluya, M. P., & Acosta, C. G. (1989). *Comparative economic analysis of diversified crops under irrigated and rainfed conditions and their irrigated performance versus irrigated rice.* Retrieved from http://publications.iwmi.org/pdf/H006102.pdf

Central Intelligence Agency (CIA). (2012). The world factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/rp.html

Centre for Science Technology and Congress at the American Associate for the Advancement of Science. (2010). Congress examines geoengineering of climate system. *Issues in Science and Technology, 26*(2), 21-22.

Chapagain, T., Riseman, A., & Yamaji, E. (2011). Achieving more with less water: Alternate wet and dry irrigation (AWDI) as an alternative to the conventional water management practices in rice farming. *Journal of Agricultural Science, 3*(3), 3-13.

Concepcion, R. N., Contreras, S. M., Sanidad, W. B., Gesite, A. B., Nilo, G. P., Salandanan, K. A., Manalang, K. M. & de Vera, S. V. (2006). Enhancing multi-functionality of agriculture through rainwater harvesting system. *Paddy and Water Environment, 4*(4), 235-243. doi:10.1007/s10333-006-0057-3

Conservation International. (n.d.). *Climate change strategies: Quirino, Philippines*. Retrieved from http://www.conservation.org/learn/climate/strategies/field/pages/projects.aspx

Damato, A. W., Bradford, J. B., Fraver, S., & Palik, B. J. (2011). Forest management for mitigation and adaptation to climate change: Insights from long-term silviculture experiments. *Forest Ecology and Management, 262*(5), 803-816. doi:10.1016/j.foreco.2011.05.014

Dang, H. H., Michaelowa, A., & Tuan, D. D. (2003). Synergy of adaptation and mitigation strategies in the context of sustainable development: The case of Vietnam. *Climate Policy, 3*(SUPPL 1), S81-S96.

Dayo, M. (n.d.). *Small- scale irrigation systems. WRMD chronicles: looking back at the division's successful irrigation projects.* Retrieved from Philippines Bureau of Soils and Water Management website: http://www.bswm.da.gov.ph/SuccessStoryDetail.aspx?sucStoryID=1

Doaa, A. M. (2012). UNFCCC: Durban: A success or failure? *Environmental Policy and Law, 42*(2), 85-87.

Dolan, A. H., Smit, B., Skinner, M. W., Bradshaw B., Bryant, C. R. (2001). *Adaptation to* *climate change in agriculture: Evaluation of options* (Report No.26). Retrieved from University of Guelph: http://www.c-ciarn.uoguelph.ca/documents/adaptation_to.pdf

Environmental Defense Fund (EDF). (2011, November 29). *The Honourable Hilary Rodham Clinton*. Retrieved from Environmental Defense Fund (EDF) website: http://www.edf.org/sites/default/files/Clinton_CEO_Durban_letter.pdf

Espino, R. R. C., & Atienza, C. S. (n.d.). *Crop diversification in the Philippines.* Retrieved from Food and Agriculture Organization of the United Nations website: http://www.fao.org/docrep/003/x6906e/x6906e0a.htm

Food and Agriculture Organization of the United Nations (FAO). (1998). *Evaluation of the potential contribution of organic agriculture to sustainability goals.* Retrieved from ftp://ftp.fao.org/docrep/fao/003/ac116e/ac116e00.pdf

Food and Agriculture Organization of the United Nations (FAO). (2001). *Crop diversification in the Asia-Pacific Region.* Retrieved from ftp://ftp.fao.org/docrep/fao/003/x6906e/x6906e00.pdf

Food and Agriculture Organization of the United Nations (FAO). (2009, October). *Food security and agricultural mitigation in developing countries: options for capturing synergi*es. Retrieved from http://www.fao.org/docrep/012/i1318e/i1318e00.pdf

Food and Agriculture Organization of the United Nations (FAO). (2010a). *Philippines*. Retrieved from http://www.fao.org/nr/water/aquastat/countries/Philippines/index.stm

Food and Agriculture Organization of the United Nations (FAO). (2010b). APA News. *Asia-Pacific Agroforestry Newspaper*. Retrieved from http://www.fao.org/docrep/013/al409e/al409e00.pdf

Gama-Rodrigues, A. (2011). Soil organic matter, nutrient cycling and biological dinitrogen-fixation in agroforestry systems. *Agroforestry Systems*, *81*(3), 191-193. doi:10.1007/s10457-011-9372-9

Global Electricity. (n.d.). *The Philippine Ifugao- Ambangal mini- hydro project.* Retrieved from http://www.globalelectricity.org/upload/File/ifugao_publication_final.pdf

Go Organic Philippines. (2012). *Don't touch proposed budget for organic-agri, group asks lawmakers.* Retrieved from http://goorganicphils.wordpress.com

Gonzales, L. A. (1989). *The economics of diversifying into irrigated non-rice crops in the Philippines.* Retrieved from http://publications.iwmi.org/pdf/H006111.pdf

Gonzales-Intal, A., & Valera, J. B. (1989). *Successful crop diversification in irrigated rice farms: Development of a cognitive decision making model.* Retrieved from http://publications.iwmi.org/pdf/H006110.pdf

Hamin, E. M., & Gurran, N. (2009). Urban form and climate change: Balancing adaptation and mitigation in the U.S. and Australia. *Habitat International*, *33*(3), 238-245.

Hansen, J. (1981). Climate impact of increasing atmospheric carbon dioxide. *Science, 213*(4511), 957-966.

Harmeling, S. (2011). *Global climate risk index 2012: Who suffers most from extreme weather events? Weather- related loss events in 2010 and 1991-2010.* Retrieved from Germanwatch website: http://www.germanwatch.org/klima/cri.pdf

Hutton, G. (2011). The economics of health and climate change: key evidence for decision making. *Globalization and Health, 7*(18), 1-7.

Hyman, E. L. (1984). Providing public lands for smallholder agroforestry in the province of Ilocos Norte, Philippines. *The Journal of Developing Areas, 18*(2), 177-190.

Ilao, R. O., Salang, E. D., & Floresca, J. P. (2010, September 28-29). Soil carbon sequestration and greenhouse gases mitigation in selected ecosystems in the Philippines. *Proceedings of International Workshop on Evaluation and Sustainable Management on Soil Carbon Sequestration in Asian Countries*, Bogor Indonesia. pp. 139-151.

International Energy Agency (IEA). (2010). *Phase-out of incandescent lamps: Implications for international supply and demand for regulatory compliant lamps.* Retrieved from http://www.iea.org/papers/2010/phase_out.pdf

International Federation of Organic Agriculture Movements (IFOAM). (2009). *Definition of organic agriculture*. Retrieved from http://www.ifoam.org/growing_organic/definitions/doa/index.htm

International Fertilizer Industry Association (IFA). (2009a). *Fertilizers, climate change and enhancing agricultural productivity sustainably (First Edition).* Retrieved from www.fertilizer.org/ifa/content/.../1/.../2009_ifa_climate_change.pdf

International Fertilizer Industry Association (IFA). (2009b). *Fertilizers and climate change: Enhancing agricultural productivity and reducing emissions.* Retrieved from http://www.fertilizer.org/ifa/HomePage/LIBRARY/Publication-database.html/

Intergovernment Panel on Climate Change (IPCC). (1996a). *Climate change 1995: The science of climate change: Contribution of working group I to the second assessment report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom, New York, New York, USA and Melbourne, Australia: Cambridge University Press.

Intergovernment Panel on Climate Change (IPCC). (1996b). *Methane emission from rice cultivation: Flooded rice fields.* Retrieved from http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch4ref5.pdf

Intergovernment Panel on Climate Change. (2001). *Climate change 2001: Working Group 1: The Scientific Basis*. Retrieved from http://www.ipcc.ch/ipccreports/tar/wg1/029.htm

Intergovernment Panel on Climate Change (IPCC). (2007a). *Climate change 2007: Working group III: Mitigation of climate change*. Retrieved from Intergovernment Panel on Climate Change (IPCC) website: http://www.ipcc.ch/publications_and_data/ar4/wg3/en/figure-spm-6.html

Intergovernment Panel on Climate Change (IPCC). (2007b). *Climate change 2007: The physical science basis: Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, New York, USA: Cambridge University Press.

Intergovernment Panel on Climate Change (IPCC). (2007c). *Impacts, adaptations and vulnerability: Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change.* Cambridge, United Kingdom and New York, New York, USA: Cambridge University Press.

Intergovernment Panel on Climate Change (IPCC). (2007d). *Climate change 2007: Impacts, adaptation and vulnerability: Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom: Cambridge University Press.

Intergovernment Panel on Climate Change (IPCC). (2007e). *Climate change 2007: Mitigation: Contribution of working group III to the fourth assessment report of the Intergovernmental Panel on Climate Change.* Cambridge, United Kingdom and New York, New York, USA: Cambridge University Press.

Intergovernment Panel on Climate Change (IPCC). (2007f). *Synthesis report: Contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland: IPCC.

Intergovernment Panel on Climate Change (IPCC). (2011). *Carbon dioxide: Projected emissions and concentrations.* Retrieved from Intergovernment Panel on Climate Change (IPCC) website: http://www.ipcc-data.org/ddc_co2.html

International Research Institute (IRI). (n.d.). *Managing competing water uses in the Philippines: Angat Reservoir.* Retrieved from http://iri.columbia.edu/media/ProjectandPartnerships/angat.pdf

International Rice Research Institute (IRRI). (2011). *World rice statistics* [Data file]. Retrieved from http://irri.org/

Jarvis, A., Lau, C., Cook, S., Wollenberg, E., Hansen, J., Bonilla, O., & Challinor, A. (2011). An integrated adaptation and mitigation framework for developing agricultural research: Synergies and trade-offs. *Experimental Agriculture, 47*(2), 185-203. doi:10.1017/S0014479711000123

Jose, A. M., & Cruz, N. A. (2009). Climate change impacts and responses in the Philippines: water resources. *Climate Research. 12*, 77-84.

Kane, S., & Shogren, J. F. (2000). Linking adaptation and mitigation in climate change policy. *Climatic Change, 45*(1), 75-102.

Keller, A.C. (2009). *Science in environmental policy. The politics of objective advice*. Cambridge, Massachusetts, USA: MIT Press.

Klein, R. J. T., Schipper, E. L., & Dessai, S. (2005). Integrating mitigation and adaptation into climate and development policy: Three research questions. *Environmental Science & Policy, 8*(6), 579-588. doi:10.1016/j.envsci.2005.06.010

Klein, N. (2009, November 11). Climate rage. *Rolling Stone*. Retrieved from http://www.naomiklein.org/articles/2009/11/climate-rage

Kua, H., & Gunawansa, A. (2010). A multi-scale analysis of possible conflicts between climate change mitigation and adaptation initiatives in the building industry and human settlement. *Progress in Industrial Ecology, 7*(3), 219-238.

Landbank of the Philippines. (n.d.). *Profiting from pig waste: CDM financing and services available from landbank*. Retrieved from Global Methane Organization website: http:*//www.globalmethane.org/activities*

Landicho, L. D., Paelmo, R. F., Cabahug, R. D., de Luna, C. C., & Tolentino, L. L. (n.d.). *Farm-level evidence of climate change. Observations and coping mechanisms of selected agroforestry: Farmers in the Philippines*. Retrieved from Southeast Asian Network for Agroforestry Education website: http://www.seanafe.org/files/2ndconf/parallel%20session%202B_Landicho.pdf

Lasco, R. D., Cruz, R. V. O., Pulhin, J. M., & Pulhin, F. B. (2006). *Tradeoff analysis of adaptation strategies for natural resources, water resources, and local institutions in the Philippines* (AICCC Working Papers, 32). Retrieved from World Agroforestry Organization website: http://www.worldagroforestry.org/sea/Publications/files/workingpaper/WP0078-07.PDF

Lasco, R. D., & Pulhin, J. M. (2006). Environmental impacts of community-based forest management in the Philippines. *International Journal of Environment and Sustainable*

Development, 5(1), 46-56.

Lasco, R. D., Habito, C. M. D., Delfino, J. P., Pulhin, F. B., & Concepcion, R. N. (2011). *Climate change adaptation for small farmers in Southeast Asia.* Retrieved from ASB Partnership for the Tropical Forest Margins website: http://www.asb.cgiar.org/PDF webdocs/lasco-2011-ccadaptationfarmerssoutheastasia.pdf

Letourneau, D. K., Armbrecht, I., Rivera, B. S., Lerma, J. M., Carmona, E. J., Daza, M. C., Escobar, S., Galindo, V., Gutiérrez, C., López, S. D., Mejía, J. L., Rangel, A. M. A., Rangel, J. H., Rivera, L., Saavedra, C. A., Torres, A. M., & Trujillo, A. (2011). Does plant diversity benefit agroecosystems? A synthetic review. *Ecological Applications, 21*(1), 9-21.

Lin, B. B. (2011). Resilience in agriculture through crop diversification: Adaptive management for environmental change. *Bioscience, 61*(3), 183-193.

Lin, J. Y. (2012). *New structural economics: A framework for rethinking development and policy* (Report No. 66393). Retrieved from World Bank website: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2012/01/13/000356161_20120113025555/Rendered/PDF/663930PUB0EPI00nomics09780821389553.pdf

Lusk, P. (1998). *Methane recovery from animal manures: The current opportunities casebook.* Retrieved from National Renewable Energy Laboratory website: http://www.nrel.gov/docs/fy99osti/25145.pdf

Magcale-Macandog, D., & Ocampo, L. J. M. (2005). Indigenous strategies of sustainable farming systems in the highlands of Northern Philippines. *Journal of Sustainable Agriculture, 26*(2), 117.

Mariano, M. J. M., Mataia, A. B., Acda, R. D. P., & Velayo, M. D. C. (2007). Impact of crop diversification on farm income. *Philippine Journal of Crop Science, 32*(1),128.

Martin, F. S., & van Noordwijk, M. (2009). Trade-offs analysis for possible timber-based agroforestry scenarios using native trees in the Philippines. *Agroforestry Systems*, *76*(3), 555-567. doi:10.1007/s10457-009-9208-z

Marzan, E. G. (1989). *Profitability analysis of rice and onions planted during the dry season under irrigated conditions.* Retrieved from http://publications.iwmi.org/pdf/H006099.pdf

McEvoy, D., Lindley, S., & Handley, J. (2006). Adaptation and mitigation in urban areas: Synergies and conflicts. *Proceedings of the Institution of Civil Engineers: Municipal Engineer, 159*(4), 185-191.

Mendoza, T. C. (2004). Evaluating the benefits of organic farming in rice agroecosystems in the Philippines. *Journal of Sustainable Agriculture*, *24*(2), 93-93.

Mendoza, T. C., Pecadizo, L. M., & De los Santos, W. L. (2001). Comparative case study of organic, leisa and conventional rice farming systems in Quezon Province, Philippines. *Philippine Journal of Crop Science, 26*(2), 35-40.

Mines and Geosciences Bureau. (2009). *Geohazard map of the Philippines: Flood susceptibility map and landslide susceptibility map*. Retrieved from http://www.mapcentral.ph/mgb/index.cfm?maptype=Landslide&areatype=Philippines&code=Philippines&listform_prov_code=

Mitin, A. (2009). *Documentation of selected adaptation strategies to climate change in rice cultivation.* Retrieved from East Asia Rice Working Group website: http://www.eastasiarice.org/Books/Adaptation%20Strategies.pdf

Mpusia, P. T. O. (2006). *Comparison of water consumption between greenhouse and outdoor cultivation.* (Master's thesis, International Institute for Geo Information Science and

Earth Observation. Retrieved from http://www.itc.nl/library/papers_2006/msc/wrem/mpusia.pdf

Nath, P. K., & Behera, B. (2011). A critical review of impact of and adaptation to climate change in developed and developing economies. *Environment, Development and Sustainability*, *13*(1), 141-162.

National Snow and Ice Data Centre (NSIDC). (2012). *Arctic sea ice news and analysis: Frequently asked question on arctic sea ice.* Retrieved from http://nsidc.org/arcticseaicenews/faq/#north_pole

National Statistics Coordination Board (NSCB). (2008). *Price of fertilizers to increase production cost of agriculture by 0.15 percent*. Retrieved from National Statistics Coordination Board (NSCB) website: http://www.nscb.gov.ph/factsheet/pdf08/FS-200808-ES1-02.asp

Niggli, U., Fließbach, A., Hepperly, P., & Scialabba, N. (2009). *Low greenhouse gas agriculture: mitigation and adaptation potential of sustainable farming systems*. Retrieved from Food and Agriculture Organization of the United Nations website: ftp://ftp.fao.org/docrep/fao/010/ai781e/ai781e00.pdf

Nissen, T., & Midmore, D. (2002). A bioeconomic rationale for the expansion of tree planting by upland Philippine farmers. *Philippine Journal of Development, 29*(1), 85-100.

The OFDA/CRED International Disaster Database (EM-DAT). (2012). *Summarized table of natural disasters in the Philippines from 1900 to 2012* [Data file].Retrieved from http://www.emdat.be/result-country-profile

O'Sullivan, T. (1985). Farming systems and soil management: The Philippines/Australian development assistance program experience. *Soil Erosion Management. Proceedings of* *a Workshop Held at PCARRD, Los Banos, Philippines December 3-5, 1984. ACIAR Proceedings, 6*, 77-81.

Pacundar, A. & Pareno, M. (2008, October 14). *The Philippine's response to climate change.* Retrieved from Research Asia Research News website: http://www.researchsea.com/html/article.php/aid/3638/cid/6

Pattanayak, S. K., & Mercer, D. E. (2002). Indexing soil conservation: Farmer perceptions of agroforestry benefits. *Journal of Sustainable Forestry, 15*(2), 63-86.

Peng, <. c., Huang, J., Cassman, K. G., Laza, R. C., Visperas, R. M., & Khush, G. S. (2010). The importance of maintenance breeding: A case study of the first miracle rice variety-IR8. *Field Crops Research, 119*(2-3), 342-347. doi:10.1016/j.fcr.2010.08.003

Pettifor, T. (2006). Death on earth ; after years of scepticism, David Attenborough admits: Climate change is our biggest threat. *The Daily Mirror*, pp. 40.

Peralta, A. (n.d.). *Gender and financing for climate change mitigation and adaptation in the Philippines.* Retrieved from Centre for Asia Pacific Women in Politics website: http://www.capwip.org/Gender&FinancingforClimateChangeMitigation&AdaptationintthePhilippines.pdf

Perez, R. T., Espinueva, S. R., & Hernando, H. (2007). *Community- based flood early warning systems.* Retrieved from Unit for Social and Environmental Research website: http://www.sea-user.org/download_pubdoc.php?doc=3439

Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). (2011). *Climate change in the Philippines*. Retrieved from http://kidlat.pagasa.dost.gov.ph/cab/climate_change/Climate%20change%20in%20the%20Philippines%20-%20August%2025%202011.pdf

Philippines Bureau of Agricultural Statistics (BAS). (2012). *CountryStat Philippines* [Data file]. Retrieved from http://countrystat.bas.gov.ph/

Philippines Bureau of Soils and Water Management (BSWM). (n.d.). *Small scale irrigation technologies*. Quezon City, Philippines: Philippine Department of Agriculture. Retrieved from http://www.bswm.da.gov.ph/Files/PDFs/Small%20Scale%20Irrigation%20Technologies.pdf

Philippines Climate Change Commission (CCC). (n.d.). *Climate Change Commision*. Retrieved from http://climate.gov.ph/

Philippine Crop Insurance Corporation (PCIC). (n.d.). *Philippine Crop Insurance Corporation.* Retrieved from http://www.pcic.gov.ph/

Philippine Department of Agriculture (DA). (n.d.a) *Adapting to climate change: Cordillera, the Philippines*. Retrieved from http://climatechange.da.gov.ph/

Philippine Department of Agriculture (DA). (n.d.b). *Executive Order No. 210: Adopting the "Maunlad na niyugan tugon sa kahirapan" program and establishing mechanisms for its implementation*. Retrieved from http://www.da.gov.ph/agrilaws/eo/eo_210.pdf

Philippines Department of Agriculture (DA). (2009, September 11). *Guidelines for the adoption of water savings technologies (WST) in irrigated rice production systems in the Philippines.* Retrieved from http://www.da.gov.ph/n_agrilaws/AO2009/ao25.pdf

Philippine Department of Agriculture (DA). (2011a). *Competitive and Sustainable Agriculture and Fisheries Sector: Philippine Development Plan 2011- 2016*. Retrieved from Philippine Department of Agriculture (DA) website: http://www.da.gov.ph/updates/2011/pdp2011.pdf

Philippine Department of Agriculture (DA). (2011b). *Tobacco farmers get P20 million aid for palay crop cultivation.* Retrieved from http://www.da.gov.ph/n_sub.php?pass=dailynews/2011/jul/July%2018,%202011.html

Philippines Department of Agriculture (DA). (2011c, May). *Republic Act 10068: Organic Agriculture Act of 2010 and its implementing rules and regulations (IRR).* Retrieved from http://www.da.gov.ph/updates/2011/Organic%20Agriculture%20Act%20oOrganic%20Act%20of%202010.pdf

Philippines Department of Environment and Natural Resources (DENR). (2010). *The Philippines strategy on climate change adaptation 2010- 2020.*

Pittock, J. (2008). Climate change and energy: The water dilemma. *Water*, *21,*13-16.

Rejesus, R. M., Palis, F. G., Rodriguez, D. G. P., Lampayan, R. M., & Bouman, B. A. M. (2011). Impact of the alternate wetting and drying (AWD) water-saving irrigation technique: Evidence from rice producers in the Philippines. *Food Policy*, *36*(2), 280-288. doi:10.1016/j.foodpol.2010.11.026

Research Institute of Organic Agriculture (FiBL). (2012). *Data tables from the FiBL-IFOAM survey on organic agriculture worldwide* [Data file]. Retrieved from http://www.organic-world.net/statistics-data-tables.html?&L=0

Resnik, D. B., & Vallero, D. A. (2011). *Geoengineering: An idea whose time has come?* Retrieved from http://www.omicsonline.org/2157-7617/2157-7617-S1-001.pdf

Rincon, M. F. G., & Virtucio, F. K. Jr. (2008). *Climate change in the Philippines: a contribution the country environmental analysis.* Retrieved from World Bank website:

http://siteresources.WorldBank.org/INTPHILIPPINES/Resources/PhilippineCEACC1July.pdf

Rosenfeld, D. (2007). New insights to cloud seeding for enhancing precipitation and for hail suppression. *Journal of Weather Modification, 39*, 61-69.

Rosenzweig, C., & Tubiello, F. (2007). Adaptation and mitigation strategies in agriculture: An analysis of potential synergies. *Mitigation and Adaptation Strategies for Global Change, 12*(5), 855-873. doi:10.1007/s11027-007-9103-8

The Royal Society. (2009, September). *Geoengineering the climate: Science, governance and uncertainty*. Retrieved from The Royal Society website: http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2009/8693.pdf

Sandoval, T. S. (2011). BSWM helps sustainable agriculture. *Greenfields Magazine, 11*. Retrieved from http://www.bswm.da.gov.ph/NewsDetail.aspx?newsID=26

Sarikonda, S. (2010). *Analysis and quality monitoring of roof-harvested rainwater: Potable water supply in developing areas.* (Master's thesis, Southern University).

Sarkar, S., Singh, S. R., & Singh, R. P. (2003). The effect of organic and inorganic fertilizers on soil physical condition and the productivity of a rice-lentil cropping sequence in India. *The Journal of Agricultural Science, 140*(4), 419-425.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenback, M., & Smith, J. (2008). Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal*

Society of London, Series B: Biological Sciences, 363(1492), 789-813. doi:10.1098/rstb.2007.2184

Smith, P., & Olesen, J. E. (2010). Synergies between the mitigation of, and adaptation to, climate change in agriculture. *The Journal of Agricultural Science, 148*(5), 543-552. doi:10.1017/S0021859610000341

Somorin, O. A., Brown, H. C. P., Visseren-Hamakers, I. J., Sonwa, D. J., Arts, B., & Nkem, J. (2011). The congo basin forests in a changing climate: Policy discourses on adaptation and mitigation (REDD+). *Global Environmental Change. 22*(1), 288-298.

Speth, J. G. (1992, October 27). *Building a post-Rio North-South compact: The role of the USA and Japan*. Retrieved from United Nations University website: http://archive.unu.edu/unupress/lecture2.html

Steed, J. J., & Hashimoto, A. G. (1994). Methane emissions from typical manure management systems. *Bioresource Technology, 50*(2), 123-130.

Stern, N. (2007). The Stern review: The economics of climate change. *Business and the Environment, 18*(2), 1-1-4.

Stockdale, E. A., & Watson, C. A. (2009). Biological indicators of soil quality in organic farming systems. *Renewable Agriculture and Food Systems, 24*(4), 308-318. doi:10.1017/S1742170509990172

Stromberg, P. M., Esteban, M., & Gasparatos, A. (2011). Climate change effects on mitigation measures: The case of extreme wind events and Philippines' biofuel plan. *Environmental Science and Policy, 14*(8), 1079-1090. doi:10.1016/j.envsci.2011.06.004

Swart, R., & Raes, F. (2007). Making integration of adaptation and mitigation work: Mainstreaming into sustainable development policies? *Climate Policy, 7*(4), 288-303.

Swedish Society for Nature Conservation. (2011). *Organic farming in the Philippines.* Retrieved from http://www.naturskyddsforeningen.se/upload/Foreningsdokument/Rapporter/engelska/Organic%20farming%20in%20the%20Philippines.pdf

Tans, P., & Keeling R. (2012). *Trends in atmospheric carbon dioxide.* Retrieved from USA Department of Commerce: National Oceanic and Atmospheric Administration website: http://www.esrl.noaa.gov/gmd/ccgg/trends/

Trines, E., Höhne, N., Jung, M., Skutsch, M., Petsonk, A., Silva-Chavez G., Smith, P., Nabuurs, D. J., Verweig, P., & Schlamadinger, B. (2006). *Integrating agriculture, forestry and other land-use in future climate regimes. Bilthoven: Netherlands Programme on Scientific Assessment and Policy Analysis* (Report No. 500102002). Retrieved from National Institute for Public Health and the Environment website: http://www.rivm.nl/bibliotheek/rapporten/500102002.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.a). *Status of ratification of the kyoto protocol*. Retrieved from http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.b). *Kyoto protocol*. Retrieved from http://unfccc.int/kyoto_protocol/items/2830.php

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.c*). Feeling the heat: Climate science and the basis of the convention.* Retrieved from http://unfccc.int/essential_background/the_science/items/6064.php

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.d). *Background on the UNFCCC: The international response to climate change*. Retrieved from http://unfccc.int/essential_background/items/6031.php

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.e). *United Nations Framework Convention on Climate Change.* Retrieved from http://unfccc.int/essential_background/convention/background/items/1350.php

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.f). *Article 3: Principles*. Retrieved from http://unfccc.int/essential_background/convention/background/items/1355.php

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.g). *Mechanisms under the Kyoto Protocol: Emissions Trading, the Clean Development Mechanism and Joint Implementation.* Retrieved from http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.h). *Kyoto protocol reference manual: On accounting of emissions and assigned amount*. Retrieved from http://unfccc.int/resource/docs/publications/08_unfccc_kp_ref_manual.pdf

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.i). *Green climate fund*. Retrieved from http://unfccc.int/cooperation_and_support/financial_mechanism/green_climate_fund/items/5869.php

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.j). *Project 1208: Superior hog farms methane recovery*. Retrieved from http://cdm.unfccc.int/Projects/DB/DNV-CUK1182371201.93/view

United Nations Framework Convention on Climate Change (UNFCCC). (n.d.k). *Project 0453: Northwind bangui bay project: Crediting period renewal request*. Retrieved from http://cdm.unfccc.int/Projects/DB/DNV-CUK1149535405.35/view

United Nations Framework Convention on Climate Change (UNFCCC). (1994). *Emissions summary for Philippines.* Retrieved from http://unfccc.int/files/ghg_data/ghg_data_unfccc/ghg_profiles/application/pdf/phl_ghg_profile.pdf

United Nations Framework Convention on Climate Change (UNFCCC). (2007). *Climate change: Impacts, vulnerabilities and adaptation in developing countries.* Retrieved from http://unfccc.int/resource/docs/publications/impacts.pdf

United Nations Framework Convention on Climate Change (UNFCCC). (2009a). *Conference of the Parties Serving as the Meeting of the Parties to the Kyoto Protocol - Fifth Session* (Report No. FCCC/KP/CMP/2009/12). Retrieved from http://unfccc.int/resource/docs/2009/cmp5/eng/12.pdf

United Nations Framework Convention on Climate Change (UNFCCC). (2009b, November). *Fact sheet: The need for mitigation.* Retrieved from http://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_mitigation.pdf

United Nations Framework Convention on Climate Change (UNFCCC). (2011, December). *Durban Climate Change Conference – November/December 2011*. Retrieved from http://unfccc.int/meetings/durban_nov_2011/meeting/6245/php/view/press.php

United Nations Office for the Coordination of Humanitarian Affairs (OCHA). (2011). *The Philippines*. Retrieved from http://www.unocha.org/where-we-work/Philippines

United States Conference of Mayors. (2008). *About the center - Mayors climate protection center*. Retrieved from The United States Conference of Mayors website: http://www.usmayors.org/climateprotection/about.htm

United States Environmental Protection Agency (EPA). (2010). *Methane and nitrous oxide emission from natural r esources.* Retrieved from http://www.epa.gov/outreach/pdfs/Methane-and-Nitrous-Oxide-Emissions-From-Natural-Sources.pdf

United States Environmental Protection Agency (EPA). (n.d.). *Global mitigation of non-CO_2 greenhouse gases.* Retrieved from http://www.epa.gov/climatechange/economics/downloads/GM_SectionV_Agriculture.pdf

Vaughan, N. E., & Lenton, T. M. (2011). A review of climate geoengineering proposals. *Climatic Change, 109*(3-4), 745-790. doi: 10.1007/s10584-011-0027-7

Venuprasad, R., Cruz, M., Amante, M., Magbanua, R., Kumar, A., & Atlin, G. N. (2008). Response to two cycles of divergent selection for grain yield under drought stress in four rice breeding populations. *Field Crops Research, 107*(3), 232-244. doi:10.1016/j.fcr.2008.02.004

Villanueva, L. M. (2010). Disease management in strawberry production: The Philippine experience. *Phytopathology*, *100*(6) S130-S130.

Virgoe, J. (2009). International governance of a possible geoengineering intervention to combat climate change. *Climatic Change, 95*(1-2), 103-119. doi: 10.1007/s10584-008-9523-9

Wallace, B. J. (2009). Critical reflections: Confessions from the director of a 15-year agroforestry research and development project in the Philippines. *Human Organization, 68*(1), 55-63.

Walsh, C. L., Dawson, R. J., Hall, J. W., Barr, S. L., Batty, M., Bristow, A. L., Carney, S., Dagoumas, A. S., Ford, A. C., Harpham, C., Tight, M. R., Watters, H., & Zanni, A. M. (2011). Assessment of climate change mitigation and adaptation in cities. *Proceedings of the Institution of Civil Engineers: Urban Design and Planning, 164*(2), 75-84.

Wassmann, R., Hosen, Y., & Sumfleth, K. (2009). *Agriculture and Climate Change: An Agenda for Negotiation in Copenhagen: Reducing Methane Emissions from Irrigated Rice.* Washington D.C., USA: International Food Policy Research Institute: Retrieved from International Food Policy Research Institute website: http://www.ifpri.org/sites/default/files/publications/focus16_03.pdf

Wikitravel. (2013). *Philippines*. Retrieved from http://wikitravel.org/en/Philippines

World Agroforestry Centre. (2012). *Climate change adaptation through agroforestry*. Retrieved from World Agroforestry Centre website: http://www.worldagroforestry.org/af2/node/115?q=node/264

Worl Bank (WB). (2010). *A strategic approach to climate change in the Philippines.* Retrieved from http://siteresources.worldbank.org/INTPHILIPPINES/Resources/PH_CC_Strategy_April_19_2010.pdf

World Bank (WB). (2012). *Philippines*. Retrieved from http://www.World Bank.org/en/country/Philippines

World Health Organization (WHO). (2008). *Climate Change*. Retrieved from http://who.int/heli/risks/climate/climatechange/en/

World Resources Institute (WRI). (2011). *Global greenhouse gas emissions* [Data file]. Retrieved from http://www.google.ca/publicdata/explore?ds=cjsdgb406s3np_&ctype=l&met_y=emissions&hl=en&dl=en

World Vision. (2008). *Disaster monitor: Philippines*. Retrieved from http://wvasiapacific.org/downloads/factsheets/Philippines_web.pdf

Yusuf, A. A., & Francisco, H. (2009). *Climate change vulnerability mapping for Southeast Asia*. South Bridge Court, Singapore: Economy and Environment Program for Southeast Asia (EEPSEA): Retrieved from International Development Research Centre website: http://web.idrc.ca/uploads/user-S/12324196651Mapping_Report.pdf

Zhang, H., Zhang, S., Yang, J., Zhang, J., & Wang, Z. (2008). Postanthesis moderate wetting drying improves both quality and quantity of rice yield. *Agronomy Journal, 100*(3), 726-734.

Zhang, H., Xue, Y., Wang, Z., Yang, J., & Zhang, J. (2009). An alternate wetting and moderate soil drying regime improves root and shoot growth in rice. *Crop Science, 49*(6), 2246-2260.

Glossary

A1B Scenario: One of the long-term emissions scenarios developed by Intergovernment Panel on Climate Change (IPCC) to predict climate change and to be used in analysis of possible mitigation to climate change. This scenario describes a world with rapid economic growth but with a balance across different sources of energy supply.

Annex 1: Includes industrialized countries that were also member of Organization for Economic Cooperation and Development (OECD) in 1992, and countries with economies in transition

Non-Annex 1: Includes mostly developing countries

Organization for Economic Co-operation and Development (OECD): An organization consisting of countries aiming at facilitating economic growth, world trade and financial stability