# Implication of climate change increased intensity typhoons on land use strategy: case of biofuels in the Philippines

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**Abstract**

Much of the debate on biofuels has centred on its role in mitigating climate change, reducing dependency on imported fuel, and providing rural employment and income opportunities. However, much less is known about the effects that climate change might have on the production of the biofuels themselves. In the present study the authors try to establish if this effect is significant and the order of magnitude that it will have. In particular, this report focuses on the expected increase in the intensity of typhoons, due to climate change, resulting in higher wind speeds which may damage biofuel feedstock production. The focus is on the Philippines, which is implementing an ambitious biofuel plan and which currently has a high exposure to typhoons. A Monte Carlo simulation is conducted, based on historical typhoon data and planned biofuel production, in order to assess the effect of strong winds in 80 of the country's regions. The simulation suggests a

decrease in the capability to produce biofuel feedstock, particularly in the northern areas of the country. As a result, an adaptation measure may be to plant biofuel feedstock in areas which are less threatened by high winds. However, the resulting land use change may cause high carbon emissions if suitable production locations and methods are not used.

## 1. Introduction

Biofuel production has been promoted as a way to reduce societies' dependency on fossil fuels, which are some of the main drivers of climate change. Besides mitigating climate change, in some countries biofuels are seen as an alternative for reducing dependency on imported oil and a way to promote employment and economic growth. Recently, however, the interest in biofuels has changed and discussion has shifted to their negative impacts on global food production and prices. The Philippines is currently implementing an ambitious program of biofuel feedstock production with the aim to reduce dependency on imported fuel, mitigate greenhouse gas emissions and increase rural employment and incomes. The 1992 United Nations Framework Convention on Climate Change (UNFCCC) highlights the important role of new technologies in reducing greenhouse gas emissions. The United Nations Intergovernmental Panel on Climate Change (IPCC) in its fourth Assessment Report also highlights the crucial role that mitigation technologies, especially those associated with increased energy efficiency, will have in addressing climate change.[1] For the period beyond 2012, at which time the Kyoto protocol will expire, there are several potential future climate change regimes currently under discussion, and further intense debate is expected during the 2009 UNFCCC Conference of Parties (COP) in Copenhagen. Part of this debate will no doubt be centred around the future role of biofuels in mitigating climate change.

[1] Intergovernmental Panel on Climate Change (IPCC, 2007), *Summary for Policymakers of the Synthesis of the IPCC Fourth Assessment Report*.

However, climate change vulnerability may currently not be sufficiently factored in. The Philippines is frequently battered by tropical typhoons and from 1975 to 2002 the annual average damage to agriculture was 3.047 billion pesos. One of the fears of global warming is that it might result in an increase in the frequency and intensity of tropical cyclones due to the warming of the surface of the sea,[2], a trend that has been confirmed by a thirty-year satellite record of tropical cyclones.[3] An analysis of the trends in the upper quintiles of cyclone maximum wind speeds found a significant upward trend for wind speed quintiles above the 70th percentile.[4] However, some authors have disputed the accuracy of satellite-based pattern recognition.[5] The fact is that tropical cyclones can have devastating effects, especially in poor countries, such as in the case of the 1970 Bangladesh cyclone where between 300,000 and 500,000 people killed.[6] More recently in 2005, the U.S. hurricane Katrina caused major damages and left more than 1,800 people dead, triggering a debate about whether such tragic events will occur more frequently in the future. However, tropical cyclones occur most frequently in the western north Pacific Area, which accounts for approximately one-third of all typhoons in the world.[7] In 2006, typhoon Durian left 800 people dead in the Philippines alone.[8] However, serious damage from typhoons is not limited to less developed countries. In August 2009, Typhoon Morakot struck Taiwan, leaving hundreds dead, and many buried alive or trapped by mudslides and floods. Taiwan, one of the better developed nations of the region, struggled to deal with the catastrophe, and

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[2] Nordhaus, W. D. (2006), *The Economics of Hurricanes in the United States. Boston*, Annual Meetings of the American Economic Association.

[3] Webster, P. J., G. J. Holland, et al. (2005), *Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment*. Science 309(5742): 1844-1846.

[4] Elsner, J. B., Kossin, J.P. and Jagger, T.H. (2008). The increasing intensity of the strongest tropical cyclones. Nature 455, 92-94.

[5] See of example Landsea, C. W., B. A. Harper, et al. (2006). Can We Detect Trends in Extreme Tropical Cyclones? Science 313(5786): 452 – 454.

[6] Landsea, C. W., B. A. Harper, et al. (2006). Can We Detect Trends in Extreme Tropical Cyclones? Science 313(5786): 452 – 454.

[7] Imamura, F. And Van To, D. (1997). Flood and Typhoon Disasters in Viet Nam in the Half Century Since 1950. Journal of Natural Hazards **15**: 71-87.

[8] See Munich Re (2009). Natural disasters 1980-2008, 10 costliest typhoons ordered by insured losses. http://www.munichre.com/ Retrieved 28th April 2009.

had to call for international aid. President Ma Ying-Jeou came under heavy criticism for failing to act fast enough.[9]

However, attempting to analyse the economic damage due to tropical cyclones is not an easy task. Generally speaking the damage can be divided into two components, the direct damage relating to the physical destruction, and the indirect damage due to the loss of productive time during the tropical cyclone passage. Hallegatte (2008) explains how the indirect costs include "business interruption in the event aftermath, production losses during the reconstruction period, and service losses in the housing sector". Other such losses could include increases in energy prices, loss of workers income or increases in insurance premiums following the passage of major events, and Hallegatte (2008) explains how the total socio-economic damage can be much larger than direct economic impacts. Very little research has so far gone into estimating the indirect economic damage of tropical cyclones and Hallegatte (2007) points out how additional research is necessary to understand these indirect impacts. This effect includes for example the loss in economic productivity due to downtime in the public transportation system, important industries and commerce. Particularly, urban areas can be greatly affected by the passage of a tropical cyclone, with their inhabitants leaving work early and shuttering houses and shops before its arrival and taking shelter until it has passed. Hallegate (2008) found that the total losses due to a disaster affecting the area of Louisiana in the USA increase nonlinearly with respect to direct losses when the latter exceed $50 billion (for instance when direct losses exceed $200bn, total losses are twice as large as direct losses). The model given by this author attempts to reproduce the disruption in production that takes place after the event, and is useful to model the effects of high intensity events. However, in many countries in the Asia-Pacific region, the majority of the tropical cyclone related downtime is due to low-intensity but high-frequency events, where the downtime is directly related to the duration of the event. As the tropical cyclones grow larger, the number of hours that a given area of

[9] BBC News. Taiwan leader in typhoon apology. 15 August 2009. http://news.bbc.co.uk/2/hi/asia-pacific/8202821.stm

a country will be affected by them will increase in the future. Esteban et al. (2009, two papers) thus analysed the effect of downtime on the economy due to an increase in the size of future tropical cyclones. They concluded that these events could deduct 0.7% of the annual GDP of the Taiwanese economy by 2085, and that additional investments would be required in Japanese Port infrastructure to remove potential bottlenecks in the export of goods.

Forecasting this direct damage is quite a difficult undertaking, due to the non-linearity of wind damage, different storm lifetimes and the rarity of large tropical cyclones (Nordhaus, 2006). Howard et al. (1972) calculate that damage in the Atlantic coast of the United States rises by between the power of 4.36 and 6.7. Nordhaus (2006) calculates that damage in the Atlantic coast of the United States rises with the eighth power of the maximum storm wind speed, although this seems high compared to what is calculated by other researchers. Later, Pielke (2007) decided to present damage as being proportional to the $3^{rd}$, $6^{th}$ and $9^{th}$ power of wind speed, in order to bind all the sets of probable possibilities. Hallegatte (2007) carried out an assessment of hurricane damage in the east coast of the USA, and found how a 10% increase in potential intensity can cause a 54% increase in the mean normalized economic losses. This author used a damage function where the damage is related to the $3^{rd}$ power of the wind speed and an extra parameter $\alpha(s)$ that measures the local vulnerability at each point *s* along the coast.

In this paper we assess the viability of domestic biofuel feedstock production in the light of an expected increase in typhoon intensity due to climate change. Essentially, we tried to develop damage curves for different types of crops, and using a Monte Carlo simulation the damage that a future potential increase in tropical cyclone intensity might bring is compared to a scenario in which there is no increase in tropical cyclone intensity.

## 2. Climate change: increased tropical cyclone intensity in the Asian-Pacific

### *2.1 Tropical cyclones*

A tropical cyclone is a storm system characterised by a large low-pressure centre surrounded by numerous thunderstorms, which result in strong winds and heavy rain. The driving mechanism behind them is the heat released when moist air rises, resulting in condensation of the water vapour contained in this moist air. The head mechanism that drives them makes them different from other types of cyclonic windstorms, such as European windstorms, as they originate in the vicinity of the equator, about 10° away from it. The reason for this is that they require a certain amount of Coriolis force (which is an acceleration given by the Earth's rotation), which does not exist at the equator. Equally, as they feed on warm moist air, they cannot form in the colder northern latitudes, as shown in Figure 1. Depending on its location, a tropical cyclone is referred to by a variety of names such as hurricane (America), typhoon (Asia Pacific), or cyclone (Indian Ocean).

Tropical cyclones are generally associated with high winds and torrential rain, but they can also produce high waves and damaging storm surges (where the sea level rises due to the lower atmospheric pressure and wind forcing). They develop over large bodies of warm water, and lose their strength if they move over land, which is the reason why coastal regions can receive significant damage while inland regions are relatively safer. Although their effects on human settlements can be catastrophic at times, tropical cyclones can also relieve drought conditions.

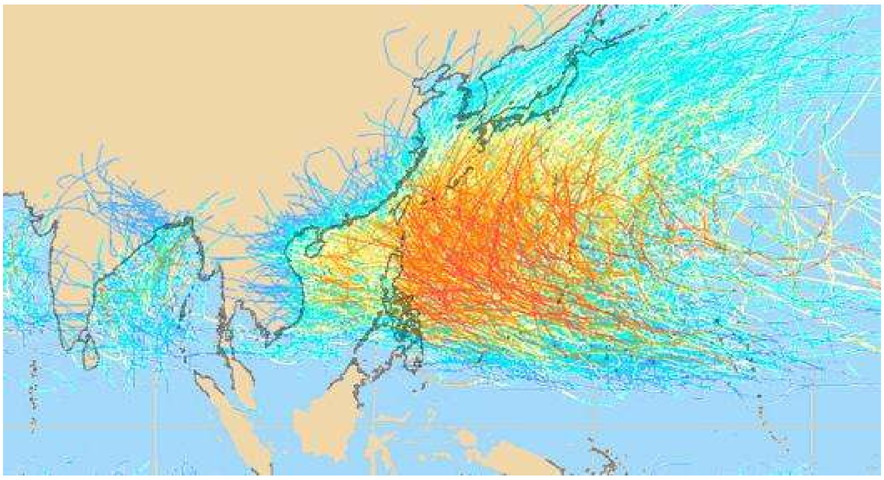

**Figure 1: Typhoon tracks in the Asia-Pacific Region**[10]

### *2.2 Influence of climate change on tropical cyclones*

To try to understand how tropical cyclones are likely to be affected by an increase in global temperatures, a number of climate models using powerful supercomputers have been carried out, as highlighted in the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).[11] That report shows that, although there is general agreement that tropical cyclones are likely to increase in intensity, there is no consensus yet on the future frequency of these events.

One example of a simulation of the increase in tropical cyclone intensity is the work of Knutson and Tuleya.[12] These authors carried out 1,300 five-day idealised simulations using a high-resolution version of the Geophysical Fluid Dynamics Laboratory (GFDL) R30 hurricane prediction system. These simulations were carried out for a Surface Sea

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[10] The image was produced by Wikipedia users and released into the public domain. http://en.wikipedia.org/wiki/File:Tropical_cyclones_1945_2006_wikicolor.png

[11] Giorgi, F. and Co-authors (2001). Regional climate information-Evaluation and projections. Climate Change 2001: The Scientific Basis. J.T. Houghton et al.: 583-638.

[12] Knutson, T. R., R. E. Tuleya, et al. (2001). Impact of CO2-Induced Warming on Hurricane Intensities as Simulated in a Hurricane Model with Ocean Coupling. Journal of Climate 14: 2458-2468

Temperature (SST) change of between +0.8° to +2.4°C, which assume a linear +1% compounded yearly increase in $CO_2$ over a period of eighty years up to the year 2085, in order to calculate the SST. This +1 per cent yearly increase means that $CO_2$ levels would reach 2.2 times the control value (that of 2004) by the year 2085. These authors acknowledge how other radiative forcing agents besides greenhouse gases may have important effects on the global climate, but quantification of their past and possible future forcing remains even more unclear than for greenhouse gases.

However Surface Sea Temperature is not the only factor that affects the intensity of tropical cyclones. Other factors such as vertical wind shear can also play a crucial role, although how to correctly apply this is at present still under discussion. For this reason, Knutson and Tuleya chose not to include this effect, as they take the view that it is possible to obtain useful information on the relative distribution of intensities from knowledge of the potential intensity alone.[13]

Knutson and Tuleya computed and presented histograms for the maximum surface wind speed for four different types of hurricane simulation (see Figure 2). The histograms depict an increase in both storm intensity and near-storm precipitation rates related to the increase in Surface Sea Temperature. It should be emphasized, however, that there is large uncertainty about future changes in tropical cyclone intensity, as highlighted in Pielke, who reports that nine of the leading scholars on tropical cyclones and climate change give estimates ranging from a zero to 36 per cent increase in tropical cyclone intensity by the year 2100.[14]

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[13] See: Emanuel, K., Sundararajan, R., Williams, J. (2008). Hurricanes and Global Warming. Results from Downscaling IPCC AR4 Simulations. Bulletin of American Meteorological Society, 89, 3, 347-367, DOI:10.1175/BAMS-89-3-347; Chan, J. C. L. (2006). Comment on "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment". Science, 311, 1713; Vecchi, G. A., Swanson K. L., Soden, B. J. (2008): Whither Hurricane Activity? Science, 322, DOI:10.1126/science.1164396.

[14] Pielke Jr., R. A. (2007). Future Economic Damage from Tropical Cyclones. Sensitivities to Societal and Climate Changes, Philosophical Transactions of the Royal Society, DOI:10.1098/rsta.2007.2086.Pielke., R. A. and Landsea C. W., (1998). Normalized Hurricane Damages in the United States: 1925-95. Weather and Forecasting, 13, 621-631.

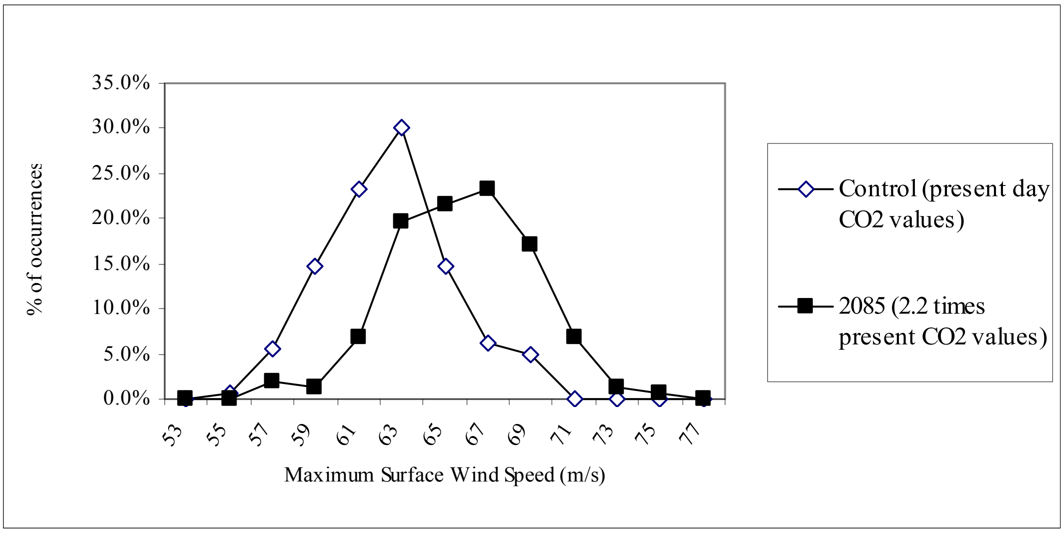


**Figure 2: Resolved inner-grid convection hurricane intensity simulation, Knutson and Tuleya (2004)**

### *3.3 Effect of an increase in typhoon size and intensity in the Asia-Pacific Region*

A future increase in tropical cyclone intensity will also result in an increase in the size of these phenomena, as there is a direct relation between the maximum wind speed and the size of these events.[15] A series of Monte Carlo based geographical simulation of the future expected increase in tropical cyclone impacts using the method of Esteban et al. (2009) were carried out at the UNU-IAS for various countries in the Asia-Pacific Region.[16] This type of simulation is able to estimate that the annual indirect damage to the Japanese economy due to downtime during tropical cyclone passage could amount to 0.15 per cent of

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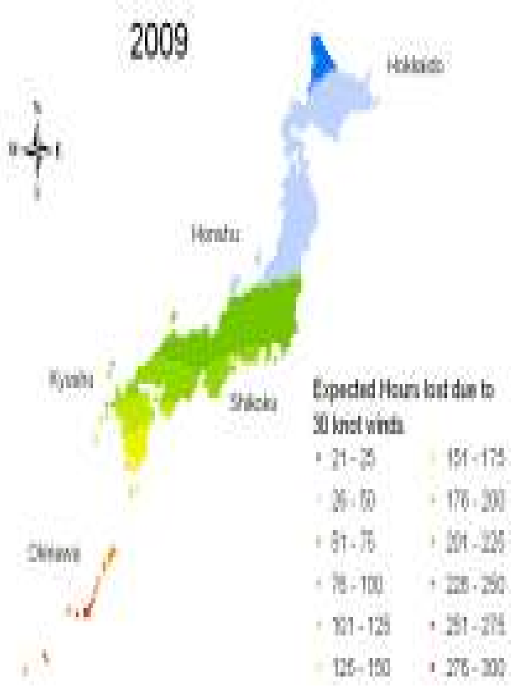
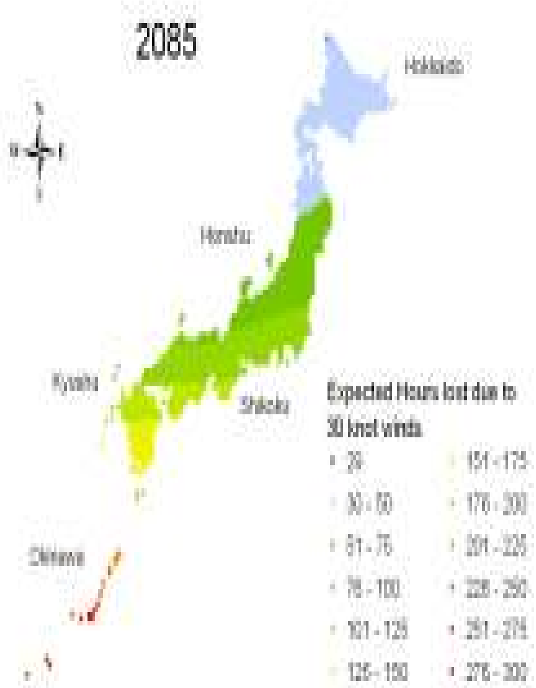
[15] Esteban, M., Webersik, C., Shibayama, T. (2009?) "*Methodology for the Estimation of the Increase in Time Loss Due to Future Increase in Tropical Cyclone Intensity in Japan*", Journal of Climatic Change DOI 10.1007/s10584-009-9725-9, http://www.springerlink.com/content/u568p666t2h04075/

[16] Esteban M., Webersik, C., Shibayama, T. (2009) "*Estimation of the economic costs of non adapting Japanese port infrastructure to a potential increase in tropical cyclone intensity*", IARU International Scientific Congress on Climate Change, Copenhagen, Denmark, March 2009. *IOP Conf. Ser.: Earth Environ. Sci.* **6** Volume 6 (2009) 322003 (1pp). http://www.iop.org/EJ/article/-search=64728466.2/1755-1315/6/32/322003/ees9_6_322003.pdf?request-id=e1e6c993-9c38-4eb3-b502-97a107b1d9c3

Japanese Gross Domestic Product (GDP) in the year 2085 (based on 1990 GDP figures).[17] If this were to happen to the Japanese economy as it is today, it would mean a loss of more than ¥687 billion (US$7 billion, or the equivalent of US$60 per capita) every year from typhoons alone. Not only that, but the areas affected by tropical cyclones will shift northwards (see Figures 3 and 4), though most of the economic losses will be concentrated in the Eastern coastal areas of the main island of Japan where the economic activity is the highest. This includes most of the major cities, such as Tokyo, Yokohama, Nagoya, Kobe and Osaka (Figures 4, 5 and 6).[18] Although the overall loss due to potential future increase of typhoons in Japan in the year 2085 is a small percentage of the Japanese overall economy, it is only one part of the overall loss figures. First-order physical losses are likely to increase as well, and they make up a much larger proportion of the total overall losses.

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17 Ibid

18 Esteban, M., Webersik, C., Shibayama, T. (2009?) "*Methodology for the Estimation of the Increase in Time Loss Due to Future Increase in Tropical Cyclone Intensity in Japan*", Journal of Climatic Change DOI 10.1007/s10584-009-9725-9, http://www.springerlink.com/content/u568p666t2h04075/

**Figure 3 and 4: Expected hours lost due to 30 knot winds in 2009 and 2085, Japan**[19]

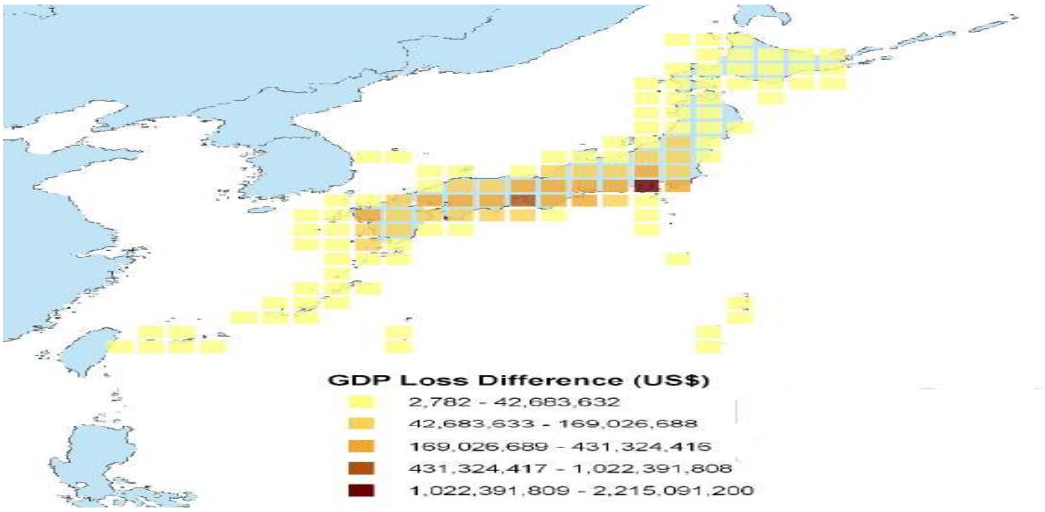


**Figure 5: Expected difference in GDP due to climate change in the year 2085, Japan**[20]

Other countries in the area also suffer the effects of tropical cyclones, particularly Taiwan and the Philippines. For the case of Taiwan, most of the typhoons that make landfall have an east-west trajectory. However, the mountain ranges that run along the centre of Taiwan, from north to south of the country act as a natural barrier and offer a great deal of protection to the communities located to the west of them. This protection effect is likely to continue in the future with the east coast, and north and south parts of the country affected far more than the west coast. The potential future increase in tropical cyclone intensity is likely to further aggravate this effect, and Figures 6 and 7 shows a comparison of the average expected number of hours lost in various Taiwanese cities between 2009 and 2085.[21]

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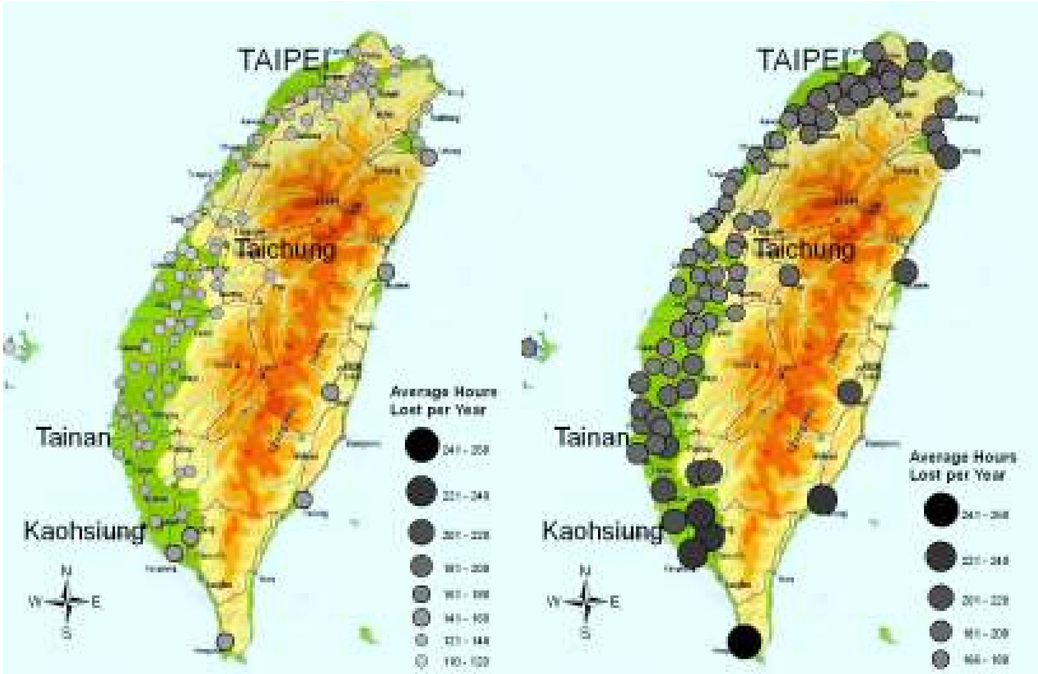
[19] *Ibid.*

[20] Webersik, C., Esteban, M., Shibayama, T. (2009?) "*The Economic Impact of Future Increase in Tropical Cyclones in Japan",* Journal of Natural Hazards (under review)

[21] Esteban, M., Webersik, C. and Shibayama, T. (2009?) "*Effect of a Global Warming Induced Increase in Typhoon Intensity in Urban Productivity in Taiwan*", Journal of Sustainability Science Journal of Sustainability Science, Vol 4, Number 2, pp 151-163.




**Figures 6 and 7: Average expected hours lost per year per urban centre in 2009 and in 2085, Taiwan**

Currently, on average 1.5 per cent of the entire productive time of the country each year is lost due to tropical cyclones, though this number can be expected to rise to between 1.7 per cent and 2.2 per cent by 2085. This represents an almost 50 per cent increase in the amount of downtime each year for the case of Scenario B, and is thus significant. In GDP terms, assuming that the current GDP already includes the average effect of the current average tropical cyclone downtime, the increase in downtime could cut between 0.26 per cent and 0.7 per cent of the Taiwanese economy by 2085, assuming no population growth.

To be noted is that this work only describes the indirect damage of an increase in tropical cyclone size. Direct damage is a subject which has received very little attention in the Asia-Pacific Region, though very little attention has been paid to direct damage in this part of the world. Hence the significance of the present work, that will try to determine the direct damage to one particular industry following the same philosophy as for the previously explained case studies. The Philippines is also frequently battered by tropical typhoons and from 1975 to 2002 the annual average damage to agriculture was more than 50 million USD[22]. This clearly highlights, further highlighting the significance of the current work.

## 3. Implications of increased typhoon intensity on biofuels production: the case of Philippines

### *3.1 Overview of the Philippines*

The Philippines is an archipelago nation located in Southeast Asia to the south of Taiwan and to the northeast of the island of Borneo. The nation suffers from high levels of poverty - in 2003 it was estimated that 30% of its population of more than 97 million people lived below the poverty line. However, its economy has been growing at a considerable rate in recent years.[23] Goldman Sachs has included the Philippines in what it has dubbed the "N-11" or Next Eleven; a group of emerging economies, which it estimates "could potentially have a BRIC-like impact in rivalling the G7" (BRIC refers to Brazil, Russia, India and China).[24]

The Philippines is comprised of three main island groups (Luzon, Visayas and Mindanao), which are divided into a total of seventeen regions (Figure 8). Only the Autonomous Region in Muslim Mindanao has political autonomy.

While there is little variation in temperatures from the north of the country to the south, the Philippines is a mountainous nation and that can cause vast differences in temperature.

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[22] Greenpeace (2006). Philippines loses billions to climate change.http://www.greenpeace.org/seasia/en/press/releases/philippines-loses-billions-to?mode=send, accessed on 15th June 2009.

[23] Central Intelligence Agency. The World Factbook: East & Southeast Asia, Philippines. July 30, 2009. https://www.cia.gov/library/publications/the-world-factbook/geos/rp.html

[24] Goldman Sachs. Global Economics Paper No: 153, The N-11: More Than an Acronym. March 28, 2007.

Baguio City for example, located at 1,500 meters above sea level in the Cordillera Administrative Region has a mean annual temperature of 18.3 degrees Celsius, 8.3 degrees cooler than the national average. Conversely, there is little difference between the temperature at sea level of northern Luzon and southern Mindanao.

Rainfall patterns, however, do vary throughout the country. While much of western Luzon and western Visayas have pronounced wet and dry seasons, many areas of Mindanao, central Visayas and eastern Luzon have fairly even rainfall. Mindanao has the added benefit of being hit by very few typhoons. This is because almost all of Mindanao, as well as the southern areas of the Central Visayas Region fall below 10°N. As described in Chapter 3, there is not usually sufficient Coriolis force within 10° of the equator to generate a tropical cyclone. However, it is estimated nevertheless that the northern portions of Mindanao and the southern portions of the Central Visayas Region will be increasingly affected by typhoons due to climate change.[25]

### *3.2 The Philippine Biofuel Plan*

The Philippines is currently implementing an ambitious programme of biofuel feedstock production. However, as shown in the previous section, climate change vulnerability may currently not be sufficiently accounted for in this national plan. The Philippines is frequently battered by tropical typhoons and from 1975 to 2002, the annual average damage to agriculture was 3.047 billion pesos.[26] Based on the Philippines' legislated targets on gasoline by 2011, a simulation of the affected area for each crop and expected agricultural damage for each region of the country is computed for various years in the period 2010-

[25] Philippine Atmospheric, Geophysical & Astronomical Services Administration (PAGASA). Climate of the Philippines. http://www.pagasa.dost.gov.ph/

[26] Greenpeace (2006). Philippines loses billions to climate change.http://www.greenpeace.org/seasia/en/press/releases/philippines-loses-billions-to?mode=send, accessed on 15th June 2009.

2050. Additionally, the indirect economic effect that loss of time has on interruptions in the biofuel crop production cycle is also included in the simulation.

In 2006, the Biofuels Act was ratified, mandating a minimum one per cent biodiesel blend and five per cent bioethanol blend by volume in all diesel and gasoline fuels by 2009, respectively, which are distributed and sold in the country. President Gloria Macapagal-Arroyo signed the Bill into law on 12 January 2007.[27] The plan is to further raise the requirements to a minimum two per cent biodiesel blend and ten per cent bioethanol blend in gasoline by 2011, respectively. For bioethanol, this amounts to an estimated 269 million litres in 2009 and 594 million litres in 2011.[28]

The Philippines' biofuel plan aims to enhance energy security by reducing exposure to peaks and fluctuations in oil prices. Another motivation is rural development: the country has excess capacity in production of some food crops which can be used as first generation biofuels feedstock. A third motivation is climate change mitigation. This is arguably the lowest priority since the Philippines does not currently have binding international targets to reduce greenhouse gas emissions.

The Philippines is one of the first countries in the Asia-Pacific Region to mandate biofuel use. The biofuels plan is part of the Philippine's Energy Independence Agenda, aiming at sixty per cent energy self-sufficiency by 2010.

Together with China and Thailand, the Philippines is the only other country in the Asia-Pacific Region to produce ethanol in significant volumes. While sugarcane is the main feedstock for ethanol production in the Philippines, the plan is to diversify into other feedstocks such as cassava, coconut, sweet potato and potentially corn, sweet sorghum and

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[27] Philippine Department of Energy website, http://www.doe.gov.ph/AF/Biofuels.htm, accessed on 13th July 2009.

[28] EIA 2008. Country Analysis Briefs: Philippines. US Energy Information Administration. http://www.eia.doe.gov/emeu/cabs/Philippines/pdf.pdf, 5th June 2009; The Philippine's Department of agriculture: http://daweb.da.gov.ph, accessed on 15 June 2009.

palm oil. Philippines is a net importer of ethanol from China, Thailand, Brazil, Australia, and India, but currently the government plans to build 10 additional ethanol plants to improve its productive capacity.[29]

### *3.3 Simulation of tropical cyclone damage on biofuel production in the Philippines in 2050*

The economic impact of tropical cyclones on biofuel production in the Philippines depends on several factors, such as the location of economic activity, number and intensity of storms. Moreover, geographical characteristics, including topography and island areas, have implications for vulnerability to tropical cyclones. In the Philippines, like in other countries, agricultural output varies geographically, with different regions producing different volumes and types of crops. Hence the economic impact of typhoons on biofuel production will differ depending on the type and location of biofuel feedstock cultivation and the wind speed in each area.[30] Thus, the simulations used a disaggregated computational approach to measure the economic loss caused by storms under a climate change scenario for the year 2050.[31] The year 2050 was chosen because it represents the middle year between 2014, i.e. the year of the biofuel feedstock production volume used here, and the year for which simulation results of increased tropical cyclone intensity are given by Knutson and Tuleya.[32] In reality, tropical cyclones are believed to follow a cyclical pattern, and thus the

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[29] EIA 2008. Country Analysis Briefs: Philippines. US Energy Information Administration. http://www.eia.doe.gov/emeu/cabs/Philippines/pdf.pdf, 5th June 2009.

[30] Tropical cyclones are limited in space and time and thus do not affect areas equally. The model assumes that a tropical cyclone that reaches wind speeds of more than 30 knots (55.56 km/h) will disrupt many human activities related to agriculture. According to the Beaufort wind force scale a moderate gale (over 27knots) makes it difficult to walk against the wind. Anything over 34 knots (“fresh gale”) causes twigs to be broken and cars to veer on the road, and would result in a Gale warning in places like the U.K. and U.S.A. From this point on normal economic activity and transport are usually disrupted, including for biofuel feedstock production.

[31] The method used simulates the wind speed and size of typhoon in the long term in year 2085 and the results in 2050 are actually obtained by interpolation

[32] 2014 is used as reference for biofuel feedstock production because this is the latest year for which production estimates have been found.

2050 values should be seen as an illustration of the average tropical cyclone impact in the 'mid-term' rather than for the exact year 2050. Extrapolation of the short-term increase in intensity instead of mid-term impact of tropical cyclones is not advisable with the current methodology since the values would be less reliable.

The simulation is based on the Philippines' legislated target of a minimum two per cent biodiesel blend and ten per cent bioethanol blend in gasoline by 2011, respectively.[33] With this in mind, a simulation of the affected area for each crop, and expected agricultural damage for each region of the country is computed for two different typhoon climate change scenarios.

### *3.4 Data sources*

The tropical cyclone data was obtained from the website of the Japan Meteorological Agency, which provides best track data for tropical cyclones in the western North Pacific and South China Sea between 1951 and 2008. Sugarcane and cassava are included among the target feedstocks of the Philippine biofuel policy[34]. Although this program includes other crops such as coconut and camote (sweet potato), the production for biofuels production by 2014 is small compared to that of sugar cane or cassava. This means that they are unlikely to greatly contribute to the biofuel program and were hence ignored in the present study. Biofuel production data for sugarcane and cassava were derived from the Philippines' National Academy of Science and Technology's prediction of the tonnage required to meet the country's legislated biofuel targets.[35] In order to enable the calculation of the geographical distribution of the damage to the crops, the national per crop tonnage in

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[33] Act 9367, Congress of the Philippines. http://www.senate.gov.ph/republic_acts/ra%209367.pdf, accessed on 16th Aug, 2009

[34] Javier, E.Q. (2008) The Philippine Biofuel Program. Paper presented at the 2008 Philippine Energy Summit, Jan.

[35] Javier, E.Q. (2008) The Philippine Biofuel Program. Paper presented at the 2008 Philippine Energy Summit, Jan.

2014 was distributed across the provinces according to their production levels as per 2007, for each of the four crops. Data was obtained from the Philippine Bureau of Agricultural Statistics.[36]

### *3.5 Tropical Cyclone Damage Functions for biofuel feedstock*

Determining the wind damage to feedstock crops is a complex task. Moreover, the impact of maximum wind speeds on damage is non-linear, and physical damage increases sharply with maximum winds. However, the duration and occurrence differs greatly from storm to storm. Another effect of tropical cyclones is a localized increase in rain fall. Depending on the amount, intensity and force of rain fall, there are both positive and negative effects which partially cancel out each other. Hence for the purpose of this study the focus is on the wind effect and not rain.

Moreover, catastrophic crop damage is likely to occur beyond a certain threshold of wind speed that is reached by only a few very strong storms. The low historical occurrence of such tropical cyclones poses a challenge for the researcher to specify a wind-crop damage function. Guard and Lander (1999) analysed damage due to tropical cyclones in various basins, and the wind-damage relationships, which they incorporated into a description of the Saffir-Simpson Tropical Cyclone Scale.[37] In their work, each tropical cyclone size is given a descriptive damage for a certain wind speed.

The simulation takes into account the future wind speed and area coverage of typhoons. It is also adjusted for the length of the growing season of each crop, and therefore damage is

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[36] Future biofuel production may be located in areas different to the agricultural production areas in the year 2007. However, we hold that it is likely that future production will take place in the same or closely adjacent areas which are equally affected by the typhoons; http://countrystat.bas.gov.ph/, accessed 15th June 2009. Due to the difficulty to find predicted biofuel production requirements for camote, the national tonnage produced in the year 2007 for this crop was used, instead of the biofuel feedstock tonnage.

[37] Guard, C. and Lander, M. A. (1999). A Scale Relating Tropical Cyclone Wind Speed to Potential Damage for the Tropical Pacific Ocean Region: A User's Manual. WERI Technical Report 86.

only done to the fraction of the total annual production that can be considered to be planted at the time of the typhoon. In order to obtain information that is accurate for the case of the Philippines, this information is sourced from experts on Philippine agriculture as well as from the Philippine Department of Agriculture.[38] Cassava can be harvested after six months but needs nine to twelve months to produce maximum yields. However, in order to produce conservative results and because the damage function is not certain, conservative values for the length of the growing season were used. For the case of sugar cane the growing season is around 12-14 months, and the present study uses a 12 month growing season as a simplification.

### *3.6. Effect of future typhoons on biofuel production*

Table 1 shows the preliminary results of the expected losses of sugarcane biofuel feedstock as well as some other feedstocks, due to typhoon winds at the national level. For example, for the case of sugarcane (Figure 8), in the Negros Region, for example, sugarcane biofuel feedstock production in 2014 is projected to reach 3,096,710 tonnes (as illustrated by the lower of the two largest circles). Without an increase in typhoon intensity (control scenario), the losses due to typhoons would be 10,597 tonnes, which amounts to a 0.34 per cent loss to production volume ratio. However in 2050, with the projected future increase in typhoon intensity and calculated on the same production volume, the losses would reach 17,482 tonnes, or a 0.56 per cent loss ratio. This amounts to a 65 per cent increase in losses due to typhoons. Batangas is another major production centre of sugarcane (illustrated by the higher of the two largest circles) and there the loss ratio will increase by 98 per cent from an initial already high loss ratio of 1.28 per cent. Sugarcane production in Philippine is already operating with excess capacity in many regions meaning that competitive profit margins are zero. Thus, the productivity loss due to a future potential increase in typhoon intensity could have a negative economic effect on biofuel production.

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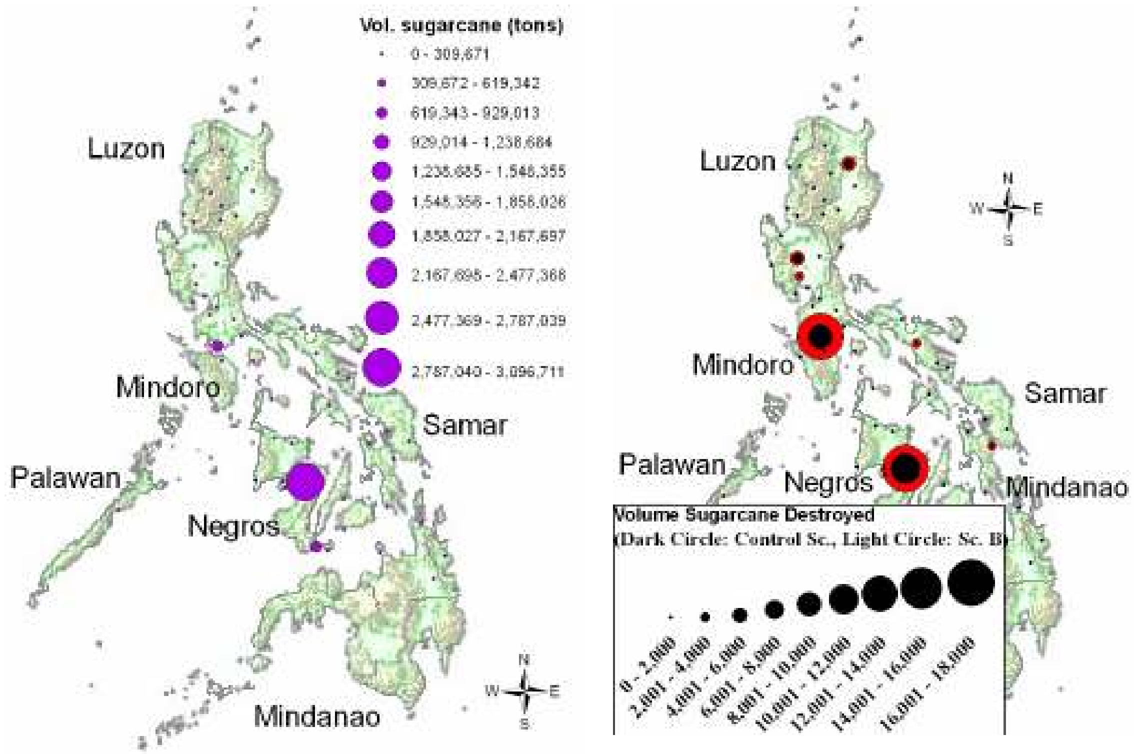
[38] http://www.bar.gov.ph/, accessed on 14$^{th}$ July 2009

**Table 1: Biofuel feedstock production and losses in two climate change scenarios, Philippines (tonnes)**

| Biofuel feedstock | Production 2014 | Loss 2050: (control scenario) | Loss 2050 (climate change scenario) | Increase in loss ratio 2050 |
|---|---|---|---|---|
| Sugarcane | 6,848,535 | 33,625 | 47,969 | 42.66% |
| Cassava | 3,315,720 | 29,901 | 38,790 | 29.73% |




**Figures 7 and 8: Sugar cane production in the Philippines and destroyed volumes for climate and control scenarios (black circle is control scenario and red circle shows climate change, in tonnes)**

## 4. Discussion

There is now broad scientific evidence that climate change is a serious issue and that it could dramatically affect human economic systems. The Stern Report claims that "the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more" (Stern 2006). The results of the present simulation can be seen as an attempt to move from the general approach followed by the Stern Report into a more detailed assessment one aspect of a country's economy, in this case that of biofuel production in the Philippines.

Climate models form an important tool to investigate the potential change in tropical cyclones. They contain hypotheses relating to how the climate system works, and yield fairly different results depending on these assumptions. The model of Esteban et al. (2009) uses the results provided by Knutson and Tuleya (2004) to develop a methodology to evaluate the future economic consequences of an increase in tropical cyclone intensity. This method has a number of shortcomings, and is unable to take into account possible changes in tropical cyclone paths. By relying on historical tropical cyclones it has no way to predict what future changes in global climate will have on typhoon routes or frequencies, and hence these follow closely the events of the last 20 years. It would be possible to alter these routes and frequencies using the work of other authors, but at present research on this issue is still inconclusive. Thus, the assumption of keeping the routes and frequencies the same can be seen as the default starting point of any simulation to determine the productivity and economic consequences of tropical cyclones, as highlighted by Esteban et al. (2009).

The implications of the research is that although biofuels can help reduce the country's exposure to price fluctuations and peaks in imported oil, the potential increase in typhoon intensity highlights production risks that must be addressed in the development strategy. In the future we aim to be able to draw conclusions about the implications that local weather events have on the national planning for where to locate biofuel production.

These findings have implications for the biofuel strategies in other feedstock producing countries: governments as opposed to markets have high capability for coordinated action to address future strong uncertainty. One case is climate change events, which as the analysis suggests requires multilevel governance at the local, national and international level in order to make the best use of scientific information while considering country specific differences in climate vulnerability. This is especially the case in energy policy due to its path dependency with investment outputs being both long term and sometimes bringing irreversible consequences such as in the choice of biofuel feedstock with potentially detrimental ecological effects.

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Finally, it should be highlighted that the present work should be interpreted as an indicative assessment of the likely consequences of an increase in tropical cyclone intensity. Direct damage is far more complex than as outlines in the present model. Furthermore, the present model only encompasses one aspect of damage, that of damage to the production of biofuel. Infrastructure, housing and human casualties are often a consequence of these events, and will also have direct implications on a country's economy.

## 5. Conclusion

This paper provided the results of an analysis on the impact that increased typhoon intensity may have on biofuel production. The simulation results have indicated that, in the case of Philippines, the biofuel provision may be an ecosystem service with a declining overall productivity in the mid-term. The reason is that climate change may cause more intensive typhoon winds, both damaging the crop and interrupting the production chain. However, because wind damage is highly localised, one adaptation measure may be planting biofuel feedstock in localities less affected by wind speed. A second, indirect, effect may then emerge: adaptation may cause the current land conversion of forest areas in the southern Philippines to accelerate, requiring careful analysis regarding the net effect on other ecosystem services such as climate control.

Because climate change mitigation strategies are unlikely to dramatically reduce the effects of typhoons in the short to mid-term, one implication of this study may be that climate change may reduce the effectiveness of the mitigation strategies such as biofuel production, in certain localities.

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