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IS CLIMATE CHANGING IN MINDANAO?

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Introduction

Twenty years ago, climate change was only a peripheral concern of a handful of people mostly made up of scientists and environmentalists. It was actually broached much earlier by a Swedish chemist named Svante Arrhenius who in 1896 proposed that changes in carbon dioxide (CO_2) concentrations could affect surface temperatures (Arrhenius, 1896). He hypothesized then that a doubling of CO_2 levels could increase surface temperature by as much as 5 °C. Current prognoses by the Intergovernmental Panel on Climate Change (IPCC), an international body of several hundred scientists and researchers, put this so-called climate sensitivity factor between 1.5 to 4.5 degrees (IPCC, 2001). Present levels of CO_2 have not yet doubled since the time of Arrhenius who at that time conjectured that it would take about 3000 yrs for CO_2 to double from its concentration then, given the emission rates of his time. With today's current pace of global growth however, CO_2 is expected to double pre-industrial age levels within the century. The latest IPCC climate forecast for the 21st century states that global surface temperatures are expected to rise by about 1.4 to 5.8 °C (IPCC, 2001)

Such an increase in temperature, if it were to happen, would be unprecedented in the last 400,000 yrs of climate history. The prognosis is supported by hundreds of climate simulations run on sophisticated global circulation models (GCM's) that have been made to work on various CO_2 level scenarios in the 21st century (IPCC, 2000). Here it is important to note that CO_2 levels are nonetheless projected to increase relentlessly into this century, at levels likewise never seen by the planet in the last 400,000 yrs. It is a dangerous experiment we are conducting, something we cannot replicate in the clinical confines of a laboratory.

The consequences of this human interference with the natural chemistry of our atmosphere can be manifold and complex. One possible consequence, in the best of outcomes, is that the temperature increase will be minor, due to offsets and equilibrating mechanisms of our planet. Or, in the worst case possible, it can be fatal for the planet, with nonlinear feedback mechanisms working in concert and activating the most dangerous scenario of all which is the "runaway greenhouse effect," a mechanism which is hypothesized to have caused the fate of our sister planet Venus. At present, Venus is unbearably hot at about 900 °C; whatever water it had is theorized to have been completely evaporated three to four billion years ago (Powell and Bluck, 2002).

It is therefore helpful that climate change has lately been in the forefront of media and political concerns. Mr Tony Blair's focus on Africa and climate change for the G8, along with Mr Al Gore's film, "An Inconvenient Truth," and countless initiatives all over the globe have helped galvanize public opinion on the matter. But concerted global action, which this serious environmental issue demands, is still wanting.

Most of the difficulties can be found in the fact that economic growth is still tightly coupled to carbon, the main element of our fossil fuel-based energy resources. Unless growth is decoupled from carbon, putting a simple cap on carbon emissions (in command-and-control fashion or in spite of market-based mechanisms such as emissions trading) may decelerate or stall economies in the near term. Policy questions have also focused on timing since alternative or renewable energy technologies are still far from the mainstream. Must we reduce carbon emissions now when it is expensive (such as what happens when we retrofit or replace power plants that have life cycle terms of several decades) or can we still afford to reduce later when these renewable carbon-free technologies are already viable and in place?

While scientists have been sounding the alarm, asking for an immediate 60% global reduction in carbon emissions relative to 1990 levels in order to stabilize atmospheric CO_2 concentrations, the reality on the ground has been more complex. What we have come up instead is the Kyoto Protocol which for now stipulates a negotiated 5.2 % decrease in CO_2 emissions among developed countries by the first commitment period of 2008-2012. The strategy of graduated emission cuts in subsequent commitment periods only indicates that we have abandoned the 60% mitigation imperative of science and have taken realpolitik into account, along with the gamble that a staggered approach to reducing carbon emissions perhaps may not lead to fatal planetary consequences.

Climate change is no longer therefore a simple scientific and environmental problem (Villarin, 2001). Such an issue which spans the entire planet and which must straddle the worlds of the geosciences as well as those of global economics and geopolitics, can indeed be intimidating and overwhelming. The aim of this essay is to familiarize the educated layperson or nonscientist with climate change by looking at the science, impacts, and policy aspects of this urgent environmental issue. An attempt has likewise been made to localize the global climate issue by exploring changes in rainfall patterns particularly in Mindanao in the last 50 yrs and their possible impact on crop production and freshwater resources. Such a diagnosis is by no means a forecast of things to come. It can however be an indispensable indicator that change indeed is afoot.

Climate Science 101

Weather vs Climate

Think sea breeze. Think of the afternoon waves that are noticeably higher than those in the morning. As noon wears off, the wind comes from the sea and moves farther inland. In the morning, the wind reverses direction and moves seaward. Like clockwork, the oscillatory constancy of the seabreeze circulation is an instance of air masses moving due to land-sea temperature contrasts. In the morning, the sea is warmer than land, thus convecting air upward over the warm sea. The upward movement pulls in cooler air from the shore, thus creating a wind system. In the afternoon, the process reverses itself, when the land is warmer than the water, thus pushing warm, buoyant air over land upward. This upward movement then pulls air from the sea toward land. The seaward-landward wind rhythm is due to night and day, brought about by solar radiation, the daily rotation of the earth, and the different energy absorbing capacities of land and sea.

The time scale of the oscillation (i.e. 24 hrs) makes the seabreeze circulation a weather phenomenon. It is not strictly speaking a climate event, since climate, in its simplest definition, is the average of weather. Weather is all about wind and water movements in the atmosphere that have time scales ranging from hours to just several days. Given typical wind speeds in the troposphere (the lower 10 km of the atmosphere), this means that the spatial scale of weather events is also limited (from tens to hundreds of kilometers).

Now, think seasons. Think *amihan* and *habagat*, the monsoons. In the months of June to August, the large-scale wind generally moves from the southwest to northeast (*habagat*). From December to February, cooler air moves from the northeast to southwest (*amihan*). Again, like clockwork, this oscillatory system owes its rhythm to land-water contrasts between the huge Asian landmass and the different ocean systems surrounding the mainland. In the summer months, warm continental air masses circulate around an extensive low pressure area over land and eventually rise, thus pulling in moist air from the equatorial regions. The monsoon rains accompany this large-scale ascent of moist air. In the winter, cool and therefore less buoyant continental air descends, creating a high pressure system over the Asian mainland, which in turn pushes cooler air toward the tropics. This large-scale wind system, lasting several months, is due to the revolution of the earth around the sun, the tilt of the earth's axis, and the contrast again in the energy absorbing capacities of land and water. The four seasons of the temperate regions are also due to these orbital factors and land-water contrast.

The time scale of the oscillation makes the monsoon circulation a climate phenomenon. It is no longer simply weather. The change happens over several months, spanning thousands of kilometers.

The difference between weather and climate is also the reason why it is possible to forecast climate beyond the normal time scales of weather. While it may not be possible to forecast rainfall on a particular day next week, it is possible to predict what the average temperature will be for the month of January next year. What makes this possible is that climate fluctuations over times scales longer than those of weather are not as dramatic or variable. The predictability of climate relies on the earth's planetary orbit and the way the planet's surface responds to the seasonal forcing of the sun.

The warmth of radiation

These oscillatory patterns in climate are due to the rotational and orbital movements of the earth around the sun. If one were to average out all these patterns over a long time (say 10 to 1000 yrs), the effect would be to take out these seasonal periodicities. The long-term average temperature of the earth, for example, when calculated as a running 10-year mean of the temperature record, no longer exhibits these seasonal variations. This temperature baseline of sorts is equivalent to what you would obtain if the earth were kept stationary relative to the sun.

Now think of the earth as not orbiting the sun at all. Given its distance from the sun (about 150 million km), would it be possible to predict the average global temperature at the surface of the earth? Simple calculations based on the sun's radiative energy, the earth-sun distance, and the size of the earth tell us that the average surface temperature should be about –18 °C, too cold for water to be liquid and thus for life as we know it to evolve. But in reality, earth's surface temperature is not that low. It is about +16 °C. What accounts for this discrepancy?

Chemistry explains the difference. It turns out that if the earth were devoid of an atmosphere, our planet should indeed be shivering in sub-freezing temperatures. It is the atmosphere, in particular certain gases called greenhouse gases (GHGs) that keep the earth from plunging to sub-zero levels. The way these gases add warmth to our planet's surface is by radiative transfer, i.e. the absorption and radiation of electromagnetic waves, particularly thermal infrared waves. By virtue of its temperature, the earth releases most of its energy (or warmth) into space in the form of infrared waves. In the absence of greenhouse gases, notably water vapor and carbon dioxide which are good absorbers of infrared, all those "heat" waves would flow unimpeded into space, thus leaving us cold on the surface. Instead, these GHGs absorb some of the outgoing infrared waves and re-radiate a portion back to earth and the rest to space. The greenhouse effect therefore is a natural benign mechanism that has been keeping us warm in space, operating for as long as we have had an atmosphere.

The metaphor "greenhouse" is used to refer to the warming effect of a greenhouse. This image is at times debated since the warming effect of a greenhouse (which is an enclosure for plants) is not simply due to radiative transfer but to the stifling of convective air currents in an enclosure, much in the same way a parked car's interior is warmed eventually in the sun.

Climate complexity

The clockwork mechanisms observed in our climate give a notion of fidelity and balance. The monsoons come annually with anticipated regularity. Even weather gives us this sense of balance when, for example, a scorching sunny morning gives way to clouds and rain in the afternoon. The afternoon rain effectively cools the warm surface eventually. There are "wrenches" in this climate machine, however, that throw these regularities out of sync. Three of these wrenches are described below.

The first of these wrenches or complicating factors is the presence of varying scales of motion in the atmosphere. For instance, the seabreeze circulation would have behaved like clockwork if it were the only process happening on the beach. But such a local phenomenon is never isolated. When combined with the large-scale monsoon winds, the seabreeze circulation can be suppressed or enhanced. The monsoon itself is modulated by larger inter-annual (i.e. year-to-year) disturbances such as the El Niño Southern Oscillation (ENSO). The latter arises from complex air-sea interactions off the Peruvian coast that cause the Eastern Pacific to warm up and pull the rain clouds away from the Western Pacific. ENSO and its twin La Niña are inter-annual climate phenomena that lead us to infer that it is not just the yearly orbit of the earth around the sun that is the main determinant of climate. The ocean circulation itself, which stores the sun's energy, contains cycles that have periods that can vary from days to decades (Philander, 1989). It is the ocean therefore that modulates the seasons, and differentiates one *habagat* or one autumn from the next. When these cycles are superimposed on one another, the result is a complex picture of climate composed of various harmonic frequencies and amplitudes.

The other "wrench" in the climate engine is human intervention. This interference happens in at least two ways. Take land use change. When natural vegetation is removed due to agricultural expansion, human habitation, or industrial production, the reflectivity of the earth's surface (or albedo) is modified. The balance of moisture in the air due to the evapotranspiration of plants is also changed. These have the effect of changing the net incoming solar radiation and the formation of clouds. Higher temperatures can happen as a result of modifying the natural surface of the earth. This is what happens, for instance, in city centers where the urban heat island effect can raise temperatures several degrees higher than the surrounding rural areas (Cruz and Villarin, 2003; Cruz and Villarin, 2005).

In addition to this small-scale human effect of urbanization, large-scale modification of the earth's surface can likewise trigger irreversible damage to the landscape in the form of deserts or artificially induced parched areas (see for instance the United Nations Convention to Combat Desertification, at http://www.unccd.int/).

The second way in which human interference in climate can happen is through the alteration of the atmosphere's chemistry and natural greenhouse function. Climate change, as understood nowadays, is technically defined to be the change that is brought about by this kind of human interference in the natural chemistry of the atmosphere. The pumping of human-sourced carbon from earth to the atmosphere is cause for alarm since the atmospheric levels we are seeing now are unprecedented in the last 400,000 yrs (IPCC, 2001). In spite of this, it has been argued that the capacity of carbon and other GHGs to warm the earth's surface (i.e. "radiative forcing") is insignificant compared to that of water vapor, the most vital GHG, or the oceans. While this may be so, there is another wrench in the climate engine that warns us that small things need not have small effects.

The third wrench is nonlinearity in the response of the earth's surface to the constant forcing of the sun. A linear system is a simple system that unidirectionally proceeds from cause to effect. In a nonlinear system, there is feedback from effect to cause, which can compound the subsequent effect thus enabling the effect to amplify/accelerate or attenuate/decelerate over time. Chaos in natural systems is an example of nonlinearity. Small changes in initial conditions can lead to widely diverging consequences in the end due to nonlinearity. In the case of climate, there are possible feedback mechanisms that can amplify the relatively small radiative signal coming from the rise of atmospheric carbon levels.

One such feedback mechanism is the temperature-water vapor interaction. Simply put, as atmospheric carbon triggers the rise in temperature, water vapor levels rise as a result of evaporation. Unless this water vapor saturates and condenses to become clouds, more water vapor in the air means more outgoing infrared waves trapped and reradiated back to earth, which means warmer surface temperatures leading to ever increasing water vapor. Another feedback mechanism is the so-called ice albedo effect: as ice melts and decreases in surface area, more solar radiation is absorbed rather than reflected back into space. This leads to melting more ice, which results in the earth taking in more of the incoming radiation and warmth, which then proceeds to melt more ice. A third feedback mechanism is the ocean-CO_2 interaction, in which a warmer ocean will release more CO_2, much in the same way a warm softdrink loses its fizz and carbonation when carbon bubbles out of the liquid. More CO_2 released from the oceans means ever warming oceans, which then release more of its resident CO_2 into the atmosphere.

These wrenches have a way of compounding the effect of small disturbances. As mentioned above, in the best of outcomes, they can also offset or cancel each other out, thus leading to minimal increases in surface temperature. In the worst of cases, these complicating factors can work together, activating a runaway greenhouse effect that is so called precisely because nonlinearities have made it near to impossible to rein in the effect by controlling the cause that ignited the problem in the first place.

Impacts

Physical and social impacts

The impacts of climate change can be categorized into two classes, namely, physical and social. On the physical level, changes in surface temperature are projected to be accompanied by changes in rainfall, sea level, wind, the monsoons, frequency and intensity of extreme weather and climate events such as typhoons and ENSO, and the like. Without being quantitative, one can infer, for example, that increasing the thermal contrast between land and sea could intensify the sea breeze and monsoonal circulations described earlier. Warmer surface temperatures could affect plant photosynthesis and respiration rates, which in turn could affect the moisture balance of the atmosphere. The point is that increases in temperature due to rising GHG levels will be tied in with other physical changes as well.

These changes are difficult to predict since these effects cannot be treated in isolation processwise or geographically. There are interlocking nonlinear processes that bind all these effects in time and space. Moreover, it does not help that our understanding of the underlying physics, chemistry, and biology of the atmosphere and ocean is still incomplete. Three of the biggest unknown variables that continue to hobble climate science are clouds, the oceans, and the role of the biosphere in climate modification. The complex climate response of these variables also indicates that the physical impacts of a globally warmer world will be geographically differentiated.

Notwithstanding these scientific uncertainties, the physical impact on various human or socio-economic sectors will not be insignificant. Many of our social sectors, including culture and religion, are climate driven. There will be social impacts arising from changes in agriculture, energy, freshwater supply, forest and coastal resources, public health, and the like. Predicting what these climate impacts will be on the human community is even more complicated than forecasting the physical climate in this century. Integrated assessment models (IAMs) are an attempt to look at the interplay of the physical and social impacts associated with a globally warmer world.

As an example of the interplay between the physical and social, the discussion that follows below delves into the possible climate risk associated with changing rainfall in Mindanao. These are the results of a diagnostic exercise that attempts to detect the historical change in rainfall in the second half of the last century. Because it is diagnostic, no predictions are made. Present IPCC assessments indicate that part of the warming of the last 50 yrs can be attributed to human influence (IPCC, 2001). Physical changes observed in the last 50 yrs including those that have occurred in the Philippines may therefore be associated with the onset of climate change.

Is rainfall changing in Mindanao?

The short answer is yes. This brief yet difficult question leads to other corollary questions. If so, then where in Mindanao is it changing? How is it changing? Is the change significant? If so, what social sectors will be affected?

To answer all these, a method is applied to compare rainfall patterns over two 25-year time slices, namely, 1951-1975 and 1976-2000. Rainfall data are taken from the 0.5 x 0.5 degree gridded rainfall database of Mitchell *et al.* (2003), which can be downloaded from the Tyndall Center for Climate Change Research (http://www.cru.uea.ac.uk/~timm/grid/CRU_TS_2_0.html).

Probabilities of significance of the changes are calculated using the bootstrap resampling method (Storch and Zwiers, 1999). To determine the impact of these changes on the two important social sectors of croplands and freshwater resources, these rainfall change patterns are overlaid with maps of agricultural crop production and major river water basins in Mindanao.

The results of the analysis of rainfall change are shown in Figure 1. Contours of rainfall change (in mm) indicate that rainfall over the northern coast of Mindanao has generally increased over the decades, with the northeast section particularly receiving most of the rainfall increase. On the other hand, rainfall over the southern regions has been decreasing over the years, with most of the decrease happening in the south central parts of the island.

The hatch marks that have been overlaid with the contours indicate probabilities of significance since not all change can be considered equally consequential. For example, these probability patterns indicate that the most of the rainfall increase over Northern Mindanao is unlikely (10-33% certainty), which means that rainfall could have just as easily swung in the opposite direction. Most of the significant change is in the Surigao del Norte area, where rainfall seems to have increased considerably over the years. In terms of decreasing rainfall, most of the significant change seems to span the regions of Maguindanao, Sultan Kudarat, South Cotabato, and the Davao provinces. Decreased rainfall is apparently more pronounced over those provinces that include the south central coastal regions of Mindanao.

To determine the impact of rainfall change over major croplands, agricultural land use data are mapped and overlaid with the rainfall patterns. Cropland information was obtained from the global land use dataset of the Center for Sustainability and the Global Environment (http://www.sage.wisc.edu/iamdata/grid.php) and from other related studies (Ramankutty and Foley, 1998; Foley *et al.*, 2003; Leff, 2003). The result is shown in Figure 2. The high impact areas seem to be over the cultivated and managed areas of south central Mindanao including the areas over the northern coast of Davao Gulf. Department of Agriculture data indicate that production crops which are planted there are mostly coconut, coffee, mango, banana, and pineapple (Department of Agriculture, at http://www.da.gov.ph/mindanao/index.html). While resilience to water stress varies from crop to crop, it would still be important to consider the probable influence of rainfall change on crop productivity in these high impact regions. Since the rural population is largely dependent on agricultural livelihood, it is not difficult to see how rainfall change can affect the other social development sectors in these areas as well.

The geographic impact of rainfall change on freshwater resources can be determined by intersecting the watershed areas with rainfall change patterns. Figure 3 shows the major river basins of Cotabato and Agusan that are flanked by the various mountain ranges in Mindanao. Overlaying this map with rainfall change yields Figure 4. Qualitatively, in terms of rainfall coverage, one can immediately see that the Cotabato river basin is in greater danger of water stress than the

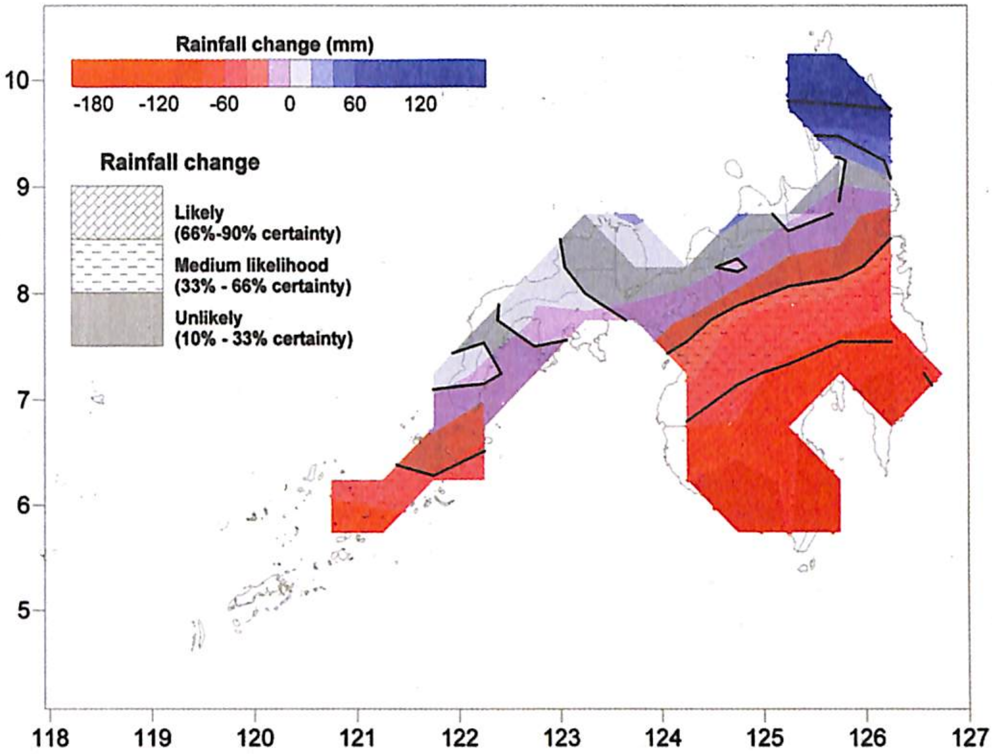

Figure 1. Rainfall change and probabilities of significance of the change.

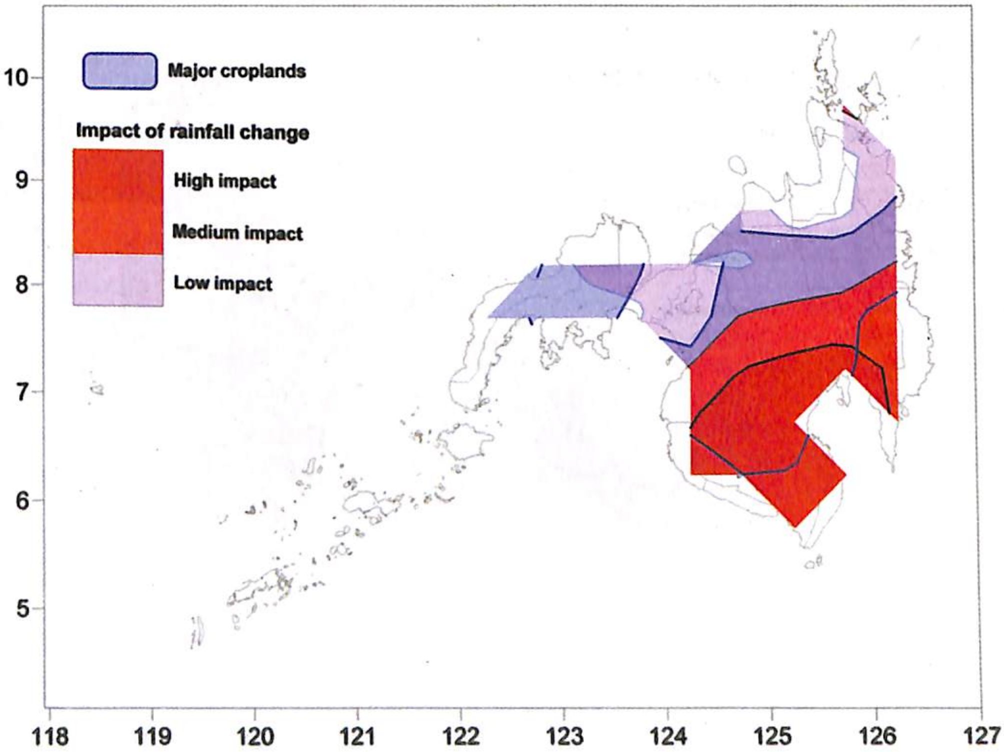

Figure 2. Rainfall impact on major croplands in Mindanao.

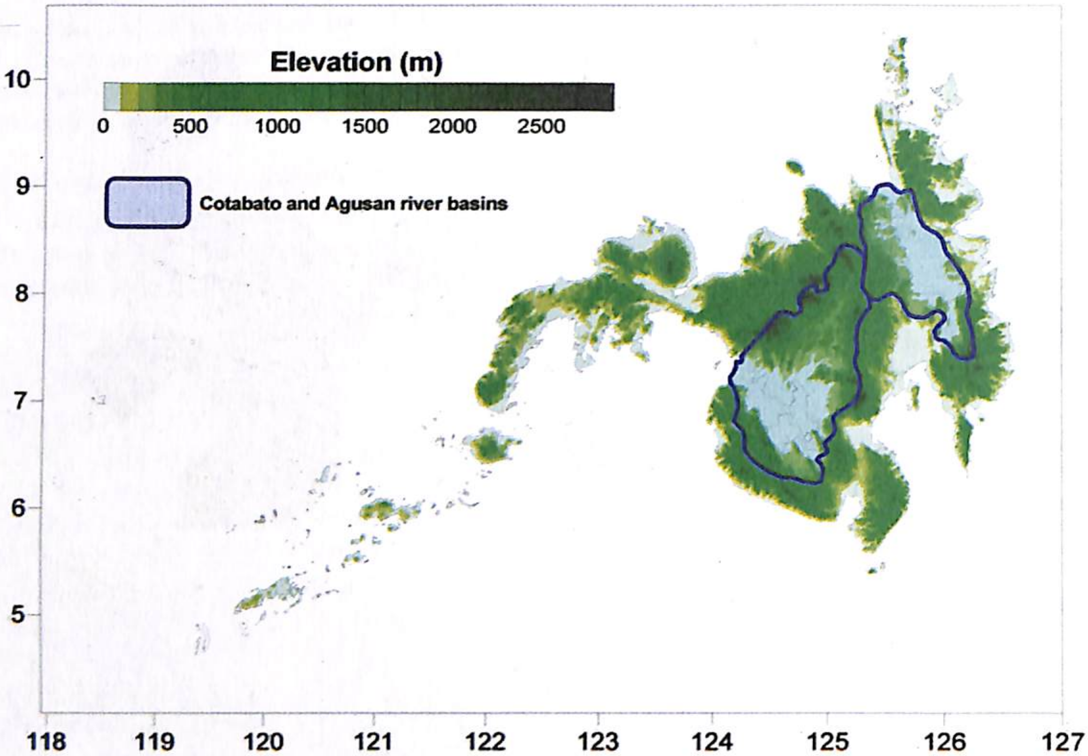

Figure 3. Major river basins in Mindanao.

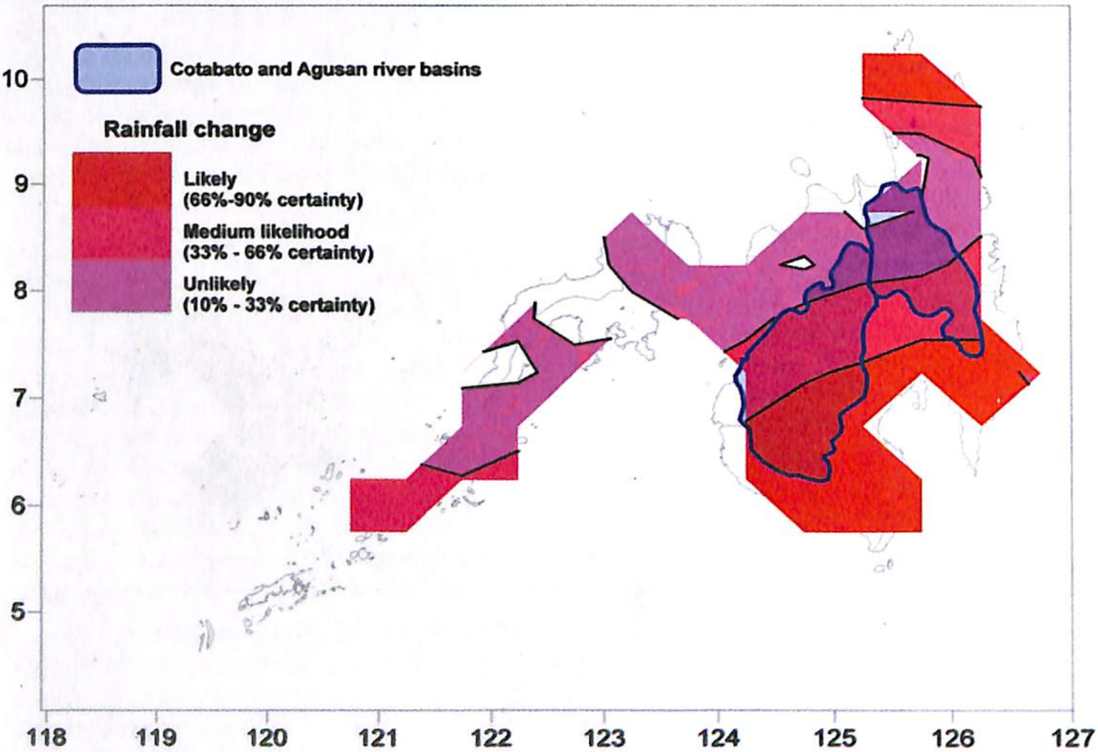

Figure 4. Rainfall impact on freshwater resources in Mindanao.

Agusan. Since freshwater resources are used for domestic consumption and irrigation, appreciable decreases in the supply of this resource will have important implications for public health, agricultural livelihood, rural to urban migration, peace and order, and other matters of social concern in these areas.

In sum, one physical impact of globally higher temperatures in the second half of the last century on the island of Mindanao is the regional pattern of local changes in rainfall. Most of the significant increase has been in the northeast while most of the rainfall decrease has been in the south central areas of the island. The socio-economic sectors that can be affected by this physical change are cropland and freshwater resources. The impacts in these sectors are more pronounced in the south central areas of Mindanao.

The next question that needs to be asked immediately is whether rainfall will continue to change in this century. Large-scale, low-resolution model results from GCM simulations indicate that surface temperatures in Mindanao are projected to increase the fastest relative to the other regions of the country by the 2080s (Castillo and Villarin, 2003). Climatological rainfall predictions are less reliable. That surface temperatures are projected to continue rising well into this century at rates faster than those observed in the last 50 yrs is already cause for concern despite the difficulty in predicting rainfall patterns. It is not wise to merely extrapolate from the patterns detected in the last 50 yrs. But it may be more dangerous to merely assume that rainfall change will not be significant as surface temperatures relentlessly rise and carbon is released in business-as-usual fashion.

Response

The global response to climate change is twofold, namely, mitigation and adaptation. In the former, the aim is to stabilize CO_2 concentrations in the atmosphere by reducing emissions at the source and/or increasing carbon uptake by the terrestrial biosphere. In adaptation, the aim is to manage the disaster risk associated with the adverse impacts of climate change. These two response strategies are not mutually exclusive although global negotiations have often been wedged by an unfortunate North-South divide between mitigation and adaptation.

Mitigation

Mitigation focuses action on the five major sectors that are responsible for the release of GHGs into the air. These are: energy (and transport), industry, agriculture, waste, land use change and forestry (LUCF). The most important of these is energy, especially in developed countries and emerging economies. For developing countries, LUCF and agriculture can be major sources of their GHG emissions (Villarin *et al.*, 1999).

As mentioned earlier, the Kyoto Protocol is the world's first attempt at a negotiated carbon emissions cap on developed countries. The first commitment period (2008-2012) involved these countries because of their significant historical contribution to the problem. The UN Convention on Climate Change also makes an important point about equity and the historically differentiated responsibilities of the Parties. The second commitment period is now being negotiated and it is not yet clear whether big developing countries such as China, Brazil, and India will be included.

It is important to note here that since climate change is a global commons problem, reducing emissions in a particular place will not result in direct local climate benefit to that place. That is, reducing carbon emissions in Cagayan de Oro will not "save" the local climate of Northern Mindanao. Solving climate change is not the same as cleaning up a river or conserving topsoil. There are co-benefits however that can be locally gained in the effort to lessen carbon emissions, such as the improvement of air quality or the economic savings tied up with energy efficiency. Moreover, action on locally specific environmental issues (e.g. reforestation, river rehabilitation, waste recycling, etc) can have the global benefit of helping to stabilize CO_2 concentrations in the atmosphere.

Adaptation

There are those who see adaptation as the desperate response of people and communities who have all but given up on the problem of climate change. They see adaptation simplistically as a reactive measure that does not help people confront and solve the root problem directly, which is the progressive increase in atmospheric carbon. They would rather that the world focus on mitigation before it is too late.

Of course, even that simple question ("when is too late too late?") is something that is not readily answered even by science. The 60% immediate reduction in carbon emissions that science has been advocating to stabilize atmospheric carbon levels is arguably far from practicable. The unrelenting upsurge of carbon levels in this century, together with the prognosis that capping carbon emissions will not lead immediately to stabilization even in this century, have led many Parties (especially those from the developing world) to adopt climate risk management strategies and measures. Thus, while adaptation may be construed as an act of desperation. it may nonetheless be unwise to assume that adverse change will be insignificant or easily reversible in the face of increasing surface temperatures and rising carbon emissions. Adaptation can also help strengthen the mitigation capacity of the Parties since mitigation will eventually need to marshal low-carbon or carbon-free technologies which are dependent on renewable resources (such as water, sun, and wind) that are under threat in a globally warmer world.

As an example therefore of an adaptation strategy that addresses potentially significant rainfall change in Mindanao in this century, the following measures are worth pursuing as soon as possible:

- Rainwater impoundment systems
- Forest protection (especially in critical watersheds)
- Irrigation systems
- River and coastal front rehabilitation and replenishment
- Aquifer protection
- Water conservation and efficiency (supply and demand side management, including wastewater treatment, reuse, and recycling)
- Crop diversification programs
- Land use management (especially in the allocation of urban, agricultural, and industrial areas since these different types of land use have implications on water consumption and drainage)
- Drought and flood management (including early warning systems, disaster risk management programs, etc.)

A number of these response measures are interlocking actions that can reinforce each other. These also have collateral benefits in other environmental issues. For example, forest protection will prevent river siltation, thus helping river and coastal front rehabilitation. Coastal front rehabilitation will protect aquifers from saltwater intrusion and will have co-beneficial impacts on aquaculture and marine biodiversity.

It would also help to engage the academe in the disciplines and research that are sorely needed for Mindanao to adapt to climate change. Some of these important programs and research topics are:

- Networked environmental database and near real-time monitoring systems
- Impact modeling systems (high performance computing, parallel structures)
- Research on drought- and/or flood-resistant crops and crop diversification
- Input on land use planning (policy advice on getting people out of harm's way, water resource management, geographic information systems)
- Capacity building for climate risk management (including information-education-communication, risk assessment and reduction)
- Academic programs on environmental sciences, hydrogeology, geomatics, environmental economics, energy development, urban planning, etc.

It is in the very nature of the global problem of climate change that no one sector alone will be able to solve this issue. The various social sectors of government, the private sector, and civil society will need to be mobilized on both local and international scales to address this urgent problem. As such it is giving rise to a new type of environmental and development governance. Climate change may be a formidable problem, but despite the attendant uncertainties and complexities, there are co-benefits to be gained from responsible action. The many interlocking, inter-dependent environmental measures (including disaster risk management and carbon mitigation) are no-regrets actions that have positive impacts on the life of our communities. Most important of all, the climate change issue is making us come together as a global community, training us to cultivate a new compassion for the global commons and the generations of the future.

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