Strategies of Adaptation and Mitigation for Coping with Climate Change: From Aspects of Taiwan Agriculture

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Summary: This paper highlights some of the aspects of the current understanding of climate change and their vast influences on agricultural production, and then describes present research activities relevant to the impacts of climate change on crop productivity and food security and their responsive studies in Taiwan, with the research programs focusing on strategies of adaptation and mitigation to cope with climate change. The aim is to provide a national-scale overview of several relevant strategies and their respective adaptive and mitigating measures, and the purpose is to provide specific topics for sharing and exchange of viewpoints in aid for the future research directions and options.

Key words: climate change impact, agricultural production, crop productivity, food security.

1. Introduction

Quite a few number of studies conducted over the past years for many locations across the world in many different countries show solid physical evidence of a changing climate. The increased temperatures, erratic precipitation patterns, greater extent and frequency of extreme weather events, sea level rise and elevated carbon dioxide concentrations are among the noted signs observed by scientists and the general republic as well. However, even today, more than thirty years of intensive research on the issue, it is still uncertain about the potential impacts of climate change on agriculture. There is the uncertainty in climate projections as well as the quantitative assessments of extreme events and risks in biotic and abiotic stresses raised from climate change on agricultural production in regional and global scales (Reilly 1996; Gornall et al. 2010). There is also high uncertainty in the extent to which the direct effects of carbon dioxide rise on plant physiology will interact with climate change in affecting crops productivity (Gornall et al. 2010). Different methodologies also produce diverse results of the impacts of climate change on crop yields and agricultural production. There are many likely effects of climate change, positive and negative. Where apparent scientific consensus exists, as climate change continues, negative effects are likely to go beyond advantages. The changes in the socio-economic circumstances, advancement of agricultural technologies, and provision of natural resources over the next decades will also bring about a great influence on current trends and future possibilities.

Agriculture is a sector strongly influenced by weather and climate (IPCC 2001; Lobell et al. 2008; Battisti and Naylor 2009). Climate change can potentially threaten established ways of farming systems and environment that supports functions and productivity of farming outputs. Nevertheless, without acknowledging a rapid change in climate, experienced farmers are often flexible in dealing with weather and yearly variability, developing a certain degree of adaptation practices to the local climate. From the perspective of national and regional levels, however, strategic planning and systematic measures are required to make thoughtful decisions and substantial progress providing opportunities for improvements to ensure food security for all in the future. For example, by reducing greenhouse gas (GHG) emissions with a global effort, the impacts of anthropogenic climate change could be brought down to a certain degree. Implementation of suitable farming practices for agricultural and food production with specific adaptive strategies, it is possible to improve tolerance ability and capability for crops to maintain the productivity.

2. Climate Change Scenario

The scientific evidence for climate-warming trends is unequivocal and is attributed mainly to human activities over the past century (GCC 2015). As declared by IPCC (2007), there are four signs for the presence of a climate change scenario, including higher temperatures, changing precipitation patterns, more extreme weather events and sea level rise.

A number of independent measures all illustrate a similar compelling observation indicating a global warming trend, with most of this warming occurring since the 1970s (US NRC 2006; Peterson and Baringer 2009). By reviewing a large number of literature records, Dore (2005) concluded that there is increased variance of precipitation everywhere, wet areas become wetter while dry and arid areas become more so. As to weather extremes, in addition to increasing numbers of intense rainfall events, the record high and low temperature events have been found to increase in the USA since 1950 (NOAA 2015). The claimed global sea level rise is inevitable under current warming trend. It rose nearly 17 centimeters in the last hundred years, but was double in the last decade (Church and White 2006). More recently, further physical evidence have been observed to tell a rapid changes in climate, such as warmer oceans, increased ocean acidity, melting glaciers, less snowpack, thawing permafrost, and more droughts, etc. (Sabine et al. 2004; Levitus et al. 2009; Polyak et al. 2009; Derksen and Brown 2012; World Glacier Monitoring Service 2015).

Climate change will interact at all levels with other phenomena in global environmental and natural resource concerns, such as pollution, health hazards and disaster risk, as well as sectoral operational activities and functions, such as agriculture. Therefore, if we take no notice of their serious adverse circumstances, their combined impacts may be compounded in future.

3. Impacts of Climate Change on Agriculture and Integrated Approach to Strategic Planning

3.1. Impacts of Climate Change on Agriculture

Climate change affects agriculture in a number of ways, through changes in the aforementioned physical evidence, atmospheric carbon dioxide and ground-level ozone concentrations directly and changes in pests and diseases, available resources, appropriate technologies and socio-environment influences indirectly. In fact, climate change and agriculture are interrelated, because the output from climate change often becomes the input for agricultural process, and vice versa (IPCC 2007). Both of processes take place on a regional or global level, but will affect agricultural production and ecological integrity at local and national levels.

As reported in numerous studies, climate change has the potential to change significantly the productivity and operation of agriculture at most locations, some may become much less productive while others may benefit to a significant extent (Lobell et al. 2008; Battisti and Naylor 2009). Societies can respond to climate change by adapting to its negative effects and by reducing GHG emissions as a mitigation strategy to counterbalance climate change. Above all else, identification and assessment of the degree to which agricultural/farming system is susceptible to and unable to cope with the impacts of climate change is the most important. That is, to recognize vulnerability of physical, social and economic aspects that agricultural/farming system is exposed to climate change and its sensitivity and adaptive capacity (IPCC 2001). Basically, the greater the exposure or sensitivity, the greater is the vulnerability, while the greater the adaptive capacity, the lesser is the vulnerability. In terms of strategies of adaptation and mitigation, adaptation can reduce sensitivity to climate change while mitigation can reduce the exposure to climate change.

From a broader perspective, climate change restrains nation's abilities to reach sustainable development of agriculture, which can reduce vulnerability to climate change. Agriculture is not only the sector providing a driving force for climate change through the GHG emissions, but also as a major land user and fossil fuel consumer to contribute to the elevation of GHGs that thought to cause climate change. Practices such as rice production and the raising of livestock are factors to produce methane, fertilizer application liberates nitrous oxide, and deforestation makes CO_2 releases. Any improper management of these agricultural processes would be causes to the increase in GHGs. The ways to adapt and mitigate are becoming more important and urgent.

3.2. Integrated Approach to deal with Impacts of Climate Change

Effects of climate change have broad implications and impacts on agriculture stimulate innovative studies and the deployment of new technologies, as that made in Taiwan. The profound consequences of climate change require integrated approaches to deal and cope with. To reduce vulnerability to the impacts of an extreme weather event at local and national levels, such as drought, heat wave, flood and frost, frequently an integrated approach rather than one single measure is needed for a better solution. More extensive adaptation strategy with a series of multiple measures is needed for difficult conditions even at local level. However, any approach or option has its barriers, limits and costs, whereas available resources and financial support are among the drivers to be concerned for adopting the selected pick.

4. An Integrated Agricultural Thematic Research Project Implemented in Taiwan to Cope with Climate Change and Food Security

4.1. Origin and Purpose

Apart from energy conservation and environmental protection, climate change and food security are two issues connected with cause-effect relationship and are closely linked to the sustainable production of food for the growing population. Both are also hot topics recently gathering much attention from all sides. In Taiwan, a four-year integrated agricultural thematic research project, join together with multidisciplinary experts and scientists across institutions and governmental agencies nationwide, was formed to respond some key aspects of climate change and food security for an intensive study in the period of 2012-2015. The project, entitled "Agricultural innovation studies for coping with climate change and food security", including six strategies/themes and a variety of measures, is carried out with a wide range of research programs. This project is designated to develop feasible practices that can be used to meet multiple local demands for reducing impacts on agricultural production from climate change and sustaining agricultural productivity to secure food sufficiency.

The cross-domain research project looks at on strategies of adaptation and mitigation as well as applicable measures as the available options for implementation in the country. The strategies from both perspectives of adaptation and mitigation are focused on whether they are fitted to the situations in Taiwan, with emphasis on their feasibility and applicability. In real practice settings, however, integrating an array of feasible actions in broader development plans can make implementation and overcome identified problems easier. As that pointed out by Smit (1993), while identifying many specific technological options, it is necessary to place the focal points on their cost and ease of adoption.

4.2. Project Context

A variety of issues have been considered in the context of the project, including responsive mechanisms for food security, indigenous vegetables as supplement to food supply, germplasm tolerance and cultivation practices to abiotic stresses, animal feed recipe to reduce GHG emissions, eco-friendly cropping systems for mitigation, rehabilitation of farming system, and adaptive measures for climate changes. Topics such as energy use efficiency, energy conservation techniques, protected cultivation, and international cooperation have also been attracted much attention. Altogether these considerations indicate the need to develop capacity and capability for local requirements and to evaluate potential options fit for changing conditions. The studies on the strategies of adaptation and mitigation are grouped in the following section.

4.3. Strategies and Measures

Strategy 1: Food security responsive mechanisms & strategies

– Building and networking databases related to food security;
– Planning administrative policies for utilization and management of resources for food production;
– Re-constructing food safety risk management system and its responsive mechanisms; and
– Developing matching and supporting measures for food self-sufficiency policies.

Strategy 2: Crop and animal tolerance enhancement programs to stresses

– Improving crop tolerance to abiotic stresses and its utilization;
– Exploiting new uses of local food crops varieties;
– Scheming countermeasures for local unique wildlife to cope with climate change; and
– Designing multiple feed ingredients, quality formulae and feeding systems for livestock.

Strategy 3: Eco-friendly cropping systems and indigenous vegetables utilization

– Integrating eco-friendly rotation systems for specific locations;
– Optimizing prevention and recovery techniques to reduce crops damage from stresses;
– Bettering storage and transport methods to reduce losses of harvested produce;
– Framing and networking databases containing information related to rehabilitation of farming systems; and
– Utilizing indigenous vegetables.

Strategy 4: Agricultural environment adaptation and management

– Combining cultivation practice and nutrient management techniques before and after extreme weather events to reduce losses;
– Adjusting farming practice and crop/animal variety to reduce emission of greenhouse gases;
– Increasing soil carbon storage with improved crop and land management;
– Formulating adaptive strategies for industry to deal with disasters and safeguard its infrastructure; and
– Monitoring changes in oceanographic environment and offshore fishery resources and establishing early warning capability.

Strategy 5: Energy conservation techniques and new energy sources for agriculture

– Upgrading energy conservation efficiency for agricultural equipment;
– Applying renewable energy in agricultural and food production;

– Improving sensing devices and key elements for protected cultivation; and
– Ameliorating techniques used for crops production under protected agriculture.

Strategy 6: International cooperation and collaboration
– Strengthening introduction of germplasm, advanced technology and management system;
– Reinforcing international cooperation and collaboration; and
– Promoting participation in international agricultural meetings and activities.

5. Concluding Remarks

The studies on the above strategies and measures in the project have come out of many interesting results. Some of the strategies are beneficial regardless of direction and extent of climate changes, while some will be evaluated their outcomes during the coming years. Like climate and weather conditions, goals and objectives among locations and growers vary considerably. Building the capacity and capability to respond to a stimulus of abiotic or biotic stress is fundamental to successful strategy. Identifying some strategies to reduce potential vulnerability, disclosure changes after applying options, and evaluate outputs from given inputs are crucial for an integrated approach to cope with climate change. Thus, even without having clear projections of climate change and accurate assessments of weather extremes, it is possible to reduce risks and impacts from a changing climate.

There is proved evidence that interactions and compromises exist between adaptation and mitigation options, yet neither one can prevent from negative effects of climate change alone. An integral of multiple strategies can substantially reduce risks and vulnerabilities from climate change (IPCC, 2007, 2014). Moreover, as indicated in many other studies and this one, the ways to adapt or mitigate are dynamic and are influenced by mixed adverse conditions bring up in combination of climate and non-climate events. Those have prepared sound strategic frameworks and action plans will have more options available for a dynamic response to the impacts and obtain better opportunity to ease the adverse effects from climate change. Similarly, no single technology or measure can provide answer to all questions in any case and location. Strategies at local or national level should at least include key technologies, measures, limits and opportunities, with addition of costs, outputs and barriers. With that, they become the real feasible and applicable options for implementation. Further, the experience from implementation in various cases and locations helps to illustrate the advantages and disadvantages for a given option, assisting assessment and evaluation of the significance of its practices.

One last very important point to mention is that diseases, pests and weeds would undergo the same acceleration as cultivated crops, and would also benefit from carbonaceous fertilization. Many C3 weeds are likely to compete even more than now against C4 crops. Increased humidity combined with higher temperatures could favor the development of some fungal diseases and insects. These are aspects need to be more vigorously explored in the future.

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