International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Climatic Change Impact on Corn Productivity in the Philippines

Arnold R. Salvacion[a]*

[a] *Department of Community and Environmental Resource Planning, College of Human Ecology University of the Philippines Los Baños, College 4031, Laguna, Philippines*
[a]*Email: arsalvacion@up.edu.ph*

Abstract

Agriculture crop production system is considered one of the sectors that will be highly affected by projected climate change because of the fact that climate influences not only the agricultural crop itself but as well as the different production activities and processes (e.g. land preparation, fertilization, harvest, pest and disease occurrence, etc.). The main focus on climate change impact assessment is its effect on crop productivity as it directly translates to possible food supply problem. Possible effects of the projected climate change on corn productivity in the Philippines were assessed under different climate change scenarios (A1, A2, B1, and B2) for different time periods (i.e. 2020, 2050, and 2080) using the developed methodological framework through the use of different research tool such as the geographic information system, stochastic weather data generator (SIMMETEO), and crop simulation model (CERES-Maize). Climatic change will surely affect corn productivity in the country. The extent of the impact depends on the location and cropping season. Assessment showed that wet season cropping is negatively affected by climate change. This was observed across different climate change scenarios and time periods. Decreasing yield trend during wet season was also observed from year 2020 to 2080.

Keywords: climate change; Philippines; corn; crop simulation model; GIS;

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* Corresponding author.
E-mail address: arsalvacion@up.edu.ph

1. Introduction

Climate change is one of the major issues nowadays because of the threat it poses to environment and on biological existence [1,2]. The issue of climate change is global, long-term, and involves complex interactions between different factors and processes such as climate, environment, economic, political, institutional, social, and technological processes [3]. Hence, national governments, international institutions, and research agencies are putting their efforts on studying and addressing the possible impacts of climate change [4].

Climate change is defined as a statistically significant variation in either the mean state of the climate or in its, variability, persisting for an extended period (typically decades or longer), which may be due to natural internal processes or external forcing, persistent anthropogenic changes in the composition of atmosphere or in land use [5–7].

Being a third world country with an agriculture-based economy, the Philippines is expected to be highly affected by the possible impact of climate change [8,9]. The limited access of the country to vital resources and its lesser ability to adapt and cope with disasters brought about by climate changes is expected to exacerbate the impact. In addition, the lack of infrastructures, limited disaster planning and response capability, and low levels of economic diversification could further aggravate such problem [9,10].

Agricultural crop production system is very sensitive to short-term changes in weather and to seasonal, annual and longer term variations in climate [6,11, 12]. The crop itself is highly affected by climate. Crop growth and development, as well as different physiological processes are highly influenced by climate [6,11,12]. Conversely, occurrence of pest and different crop diseases are also attributed to climate [13]. Land preparation, date of sowing, irrigation, fertilization, harvesting, and other farms activities are also affected by climate. Climate change is expected to affect crop yield, total volume of production and the spatial distribution or location of the major crop production regions [11,12,14].

Corn is considered the second most important cereal crops in the Philippines [15]. It is also among the field crops that will be directly hit by climate change. The anticipated impact of climate change on corn will not only affect it production system but also the different social and economic activities related to this crop. Shortage in supply of corn due to yield decrease will surely affect not only the country’s food production system but also the different livelihood and economic activities in which this crop is the primary inputs and center of trade activities. Thus, it is imperative to quantify the extent of climate change impact on corn in the country.

Advances in science and technology have facilitated interdisciplinary approach in assessing the impact of climate change [7,16]. Among the scientific advances, crop modeling and simulation, and geographic information system are the tools identified by United Nations Framework Convention on Climate Change (UNFCC) to evaluate impacts, vulnerability, and adaptation to climate change [4]. A long list of examples on the use of crop simulation models and geographic information system can be found on the compendium report of the UNFCC [4].

2. Materials and Methods

2.1. Climate Change Scenarios

Nakicenovic and his colleagues [17] pointed out that in order to address the complexity and uncertainty of future challenges, scenarios are among the tools that can be used. This principle was applied even earlier by IPCC [18] by creating sets of emission scenarios or storylines that will serve as basis for General Circulation Models (GCM's) in simulating possible climate characteristics that can be used for climate change analysis, including climate modeling and the assessment of impacts, adaptation, and mitigation climate change impact assessment [17,19]. The Special Report on Emission Scenarios (SRES) contained four (4) different scenarios which were generated from new baseline line information developed by the IPCC, in 1998, through an international and interdisciplinary modeling effort involving six modeling groups [17]. These scenarios were the A1, A2, B1, and B2 scenarios. According to Nakicenovic and his colleagues [17], these scenarios cover a wide range of the main demographic, economic, and technological driving forces of greenhouse gas (GHG) and sulfur emissions and are representative of literature. However, climate initiatives are not included in these scenarios in accordance with the UNFCC Framework or the emission targets of the Kyoto Protocol [17]. Table 1 contains the characteristics of the different scenarios as described in Nakicenovic and his colleagues and his colleagues [17] and as summarized by Xiong and his colleagues [19]

Table 1: Characteristics of different climate change scenarios [17,19].

Climate Change Scenario	Characteristics
A1 mid	Increasing globalization/convergence; rapid global economic growth; materialist/consumerist; rapid uniform technological innovation
A2 High	Heterogeneous world; rapid regional economic growth; materialist/consumerist; diverse technological innovation
B1 low	Increasing global co-operation/convergence; environmental priority; clean and efficient technologies
B2 mid	Heterogeneous world/local emphasis; environmental priority; clean and efficient technologies

The study utilized the downscaled climate change scenarios published by Hulme and Sheard [20] for the Philippines based on the climate change scenarios set by the IPCC in 1998 and which was also used in the production of SRES by the IPCC [17]. Four (4) climate change scenarios were included on the report of Hulme and Sheard (1999) namely: (1) A1 mid; (2) A2 high; (3) B1 low; and (4) B2 mid. Each scenario (Table 2) contains figures of the future climatic changes for the Philippines in the years 2020, 2050, and 2080. However, the study only considered the increase in atmospheric CO2 concentration and the increase in atmospheric temperature since these two factors directly influence crop productivity. In addition, change on rainfall was not also considered because of incomplete data for rainfall provided in the report of Hulme and Sheard [20].

Table 2a: Projected future increase in temperature (°C) for the Philippines**.**

Climate Change Scenarios	Year		
	2020	2050	2080
A1 mid	1.0	1.8	2.3
A2 High	1.4	2.6	3.9
B1 low	0.6	0.9	1.2
B2 mid	0.9	1.5	2.0

Source: Hulme and Sheard [20].

Table 2b: Projected future carbon dioxide concentration (ppm) in the Philippines.

Climate Change Scenarios	Year		
	2020	2050	2080
A1 mid	448	555	646
A2 High	440	559	721
B1 low	421	479	532
B2 mid	429	492	561

Source: Hulme and Sheard [20].

2.2. Climate Change Impact Assessment

The study quantified the potential impact of climate change on corn productivity using crop simulation model, CERES-Maize [21]; weather generator, SIMMETEO [22]; and geographic information system.

A set of procedures (Fig. 1) was followed starting with weather data pre-processing, interpolation of weather variables for input in crop simulation modeling, crop simulation and modeling, until the computation of yield statistics (i.e. mean and relative yield changes) to estimate the potential impact of climate change on corn. In addition, percentage of provinces with decreased corn yield was computed to determine the extent of climate change impact on the whole country.

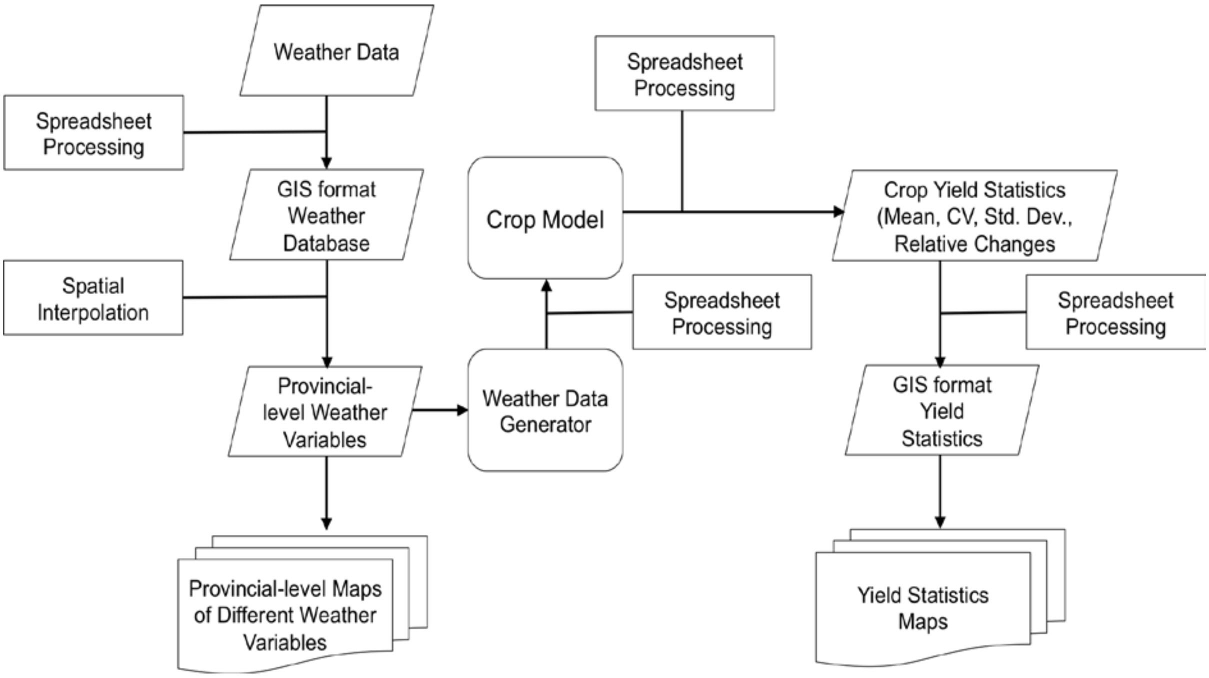

Figure 1: Methodological framework for climate change impact estimation using GIS, stochastic weather data generator, and crop simulation models

2.2.1. Input Data

Weather Data. Climatic normal refers to arithmetic mean of the observed climate values for a given location over a specified time period (30 years) which are used to describe the climatic characteristics of that location. Climatic normal were obtained from the Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) for a total of forty-two (42) weather stations (Fig. 2). The data include station location (longitude and latitude), rainfall, rain event, maximum temperature, and minimum temperature. Solar radiation for each weather station was estimated using maximum and minimum temperature through Allen's model [23].

Soil Data. Soil data is also an important input data on crop model. Crop model uses information such as soil texture, soil pH, and profile depth to calculate for soil and nutrient balance which also serve as basis for the overall computation of crop growth and development. In this study, soil input data was derived from soil profile data collected by Lansigan and his colleagues [24] on major corn growing areas in the Philippines

Crop Data. The corn variety used in the simulations was IPB911 (corn). The crop parameter for this variety was adapted from Lansigan and his colleagues [24].

Crop Management Data. Crop management information such as planting method and planting density were based on common practices on corn production system. Planting date was based on the common planting window in the country for both wet (June to July) and dry (November to December) cropping season.

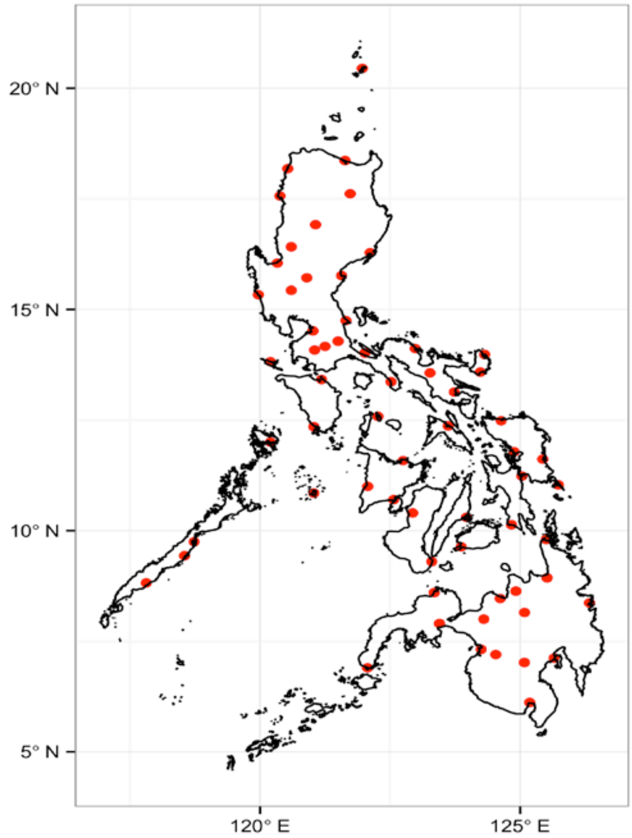

Figure 2: Geographic location of weather stations (red dots) in the Philippines (Data Source: PAGASA).

3. Results

Simulation analysis showed corn productivity was highly affected by the projected climatic change. A decrease in corn yield can be observed across the country under the different climate change scenarios (i.e. A1, A2, B1, and B2) for the three (3) time periods (i.e. 2020, 2050, and 2080) both for wet and dry season cropping. However, between the two cropping season, wet season cropping is more negatively affected by climatic change. In addition, decreasing trend of corn yield during the wet cropping season was observed for the year 2020 to 2080.

3.1. Wet Cropping Season

Simulation results showed that corn yield during wet season cropping in the country is negatively affected by the change in weather condition due to climate change. As shown on Table 3, large number of provinces will experience decrease in yield under the four (4) climate change scenarios (i.e. A1, A2, B1, and B2) on all time periods (i.e. 2020, 2050, and 2080). A higher decrease in wet season cropping corn yield can be observed for 2080 time period (Fig. 3). Furthermore, an increasing decrease in corn yield under different climate change scenario can be observed from year 2020 to 2080. Figure 4 shows map of the change in corn yield during wet season cropping across different climate change scenarios for the three time periods (i.e. 2020, 2050, and 2080).

3.2. Dry Season Cropping

Results from simulation showed decrease in corn yield among provinces under the different climate scenarios for the three (3) time periods are lesser during the dry cropping season (Table 4). In addition, contrasting change (decrease and increase) in yield was observed during the dry cropping season across scenarios and time periods (Fig.5). On the average the decrease in corn yield observed on some provinces were offset by the increase in corn yield observed in other provinces. Figure 6 shows the map of the change in corn yield during dry season cropping across different climate change scenarios for the three time periods.

Table 3: Percentage (%) of provinces with decrease in corn yield under different climate change scenario during wet season (WS) cropping

Climate Change Scenarios	Percentage (%) of Provinces with Decrease in Yield		
	2020	**2050**	**2080**
A1 mid	95	96	96
A2 High	97	97	99
B1 low	95	97	96
B2 mid	91	972	97

Table 4: Percentage (%) of provinces with decrease in corn yield under different climate change scenario during dry season (DS) cropping

Climate Change Scenarios	Percentage (%) of Provinces with Decrease in Yield		
	2020	**2050**	**2080**
A1 mid	85	81	78
A2 High	21	90	95
B1 low	6	72	78
B2 mid	31	86	83

4. Discussion

The observed decrease in corn yield as influenced by climate change in this assessment is consistent with the results of other simulation studies. In 1996, Buan and his colleagues [25], observed consistent decrease in corn yield under different climate change scenarios projected by different regional climate models. In the same year, Jinghua and Erda [26] observed the same trend of yield reduction on yield in major corn growing areas in China. In the United States, Brown and Rosenberg [27] simulated an average of 6% reduction in corn yield due on the major corn growing areas in the country due to climatic change scenarios from global circulation models. Tubiello and his colleagues [28]also observed corn yield decrease in the United States using different climate change scenarios from regional circulation models.

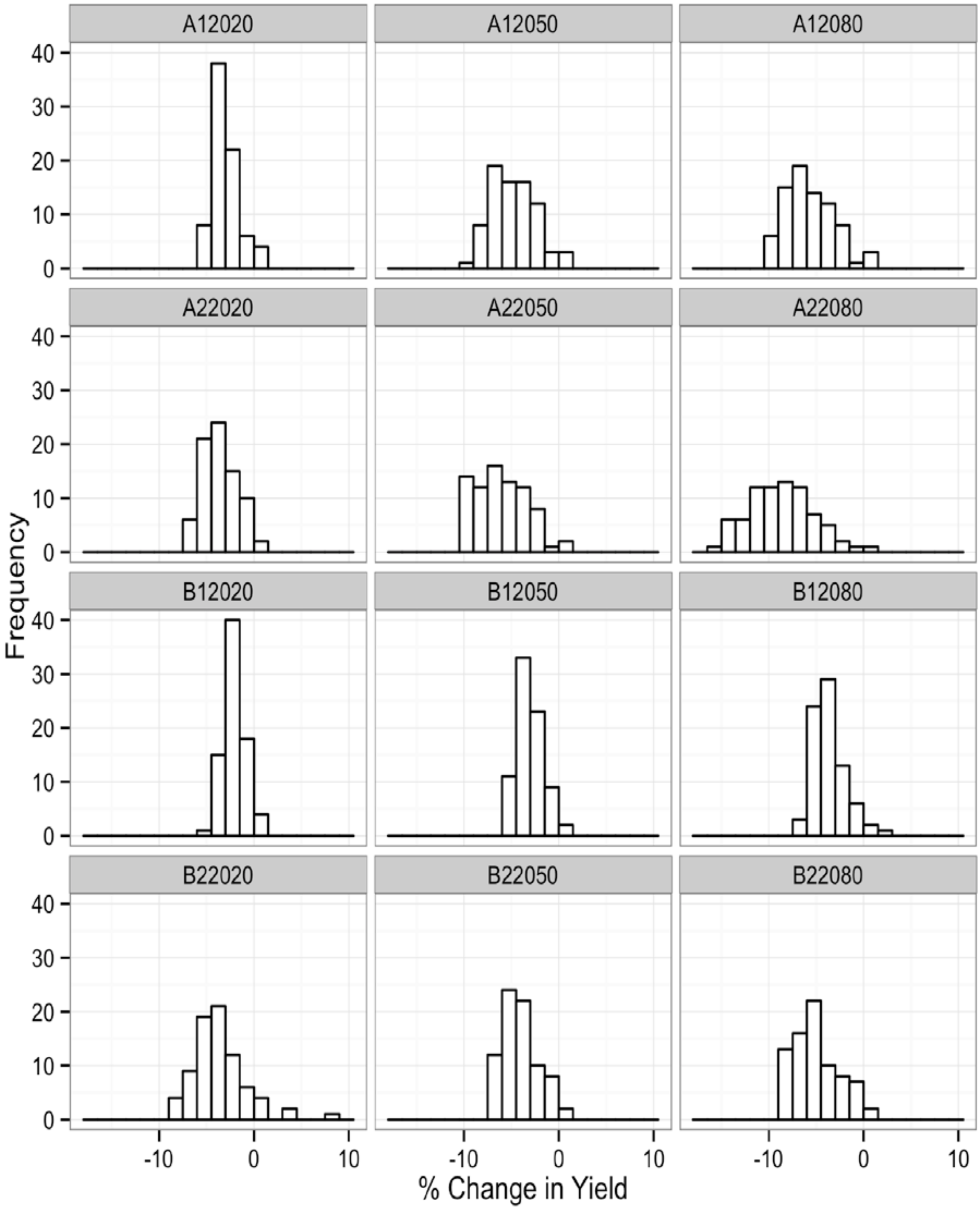

Figure 3: Histogram of yield change under different climate scenarios and time periods during wet season cropping.

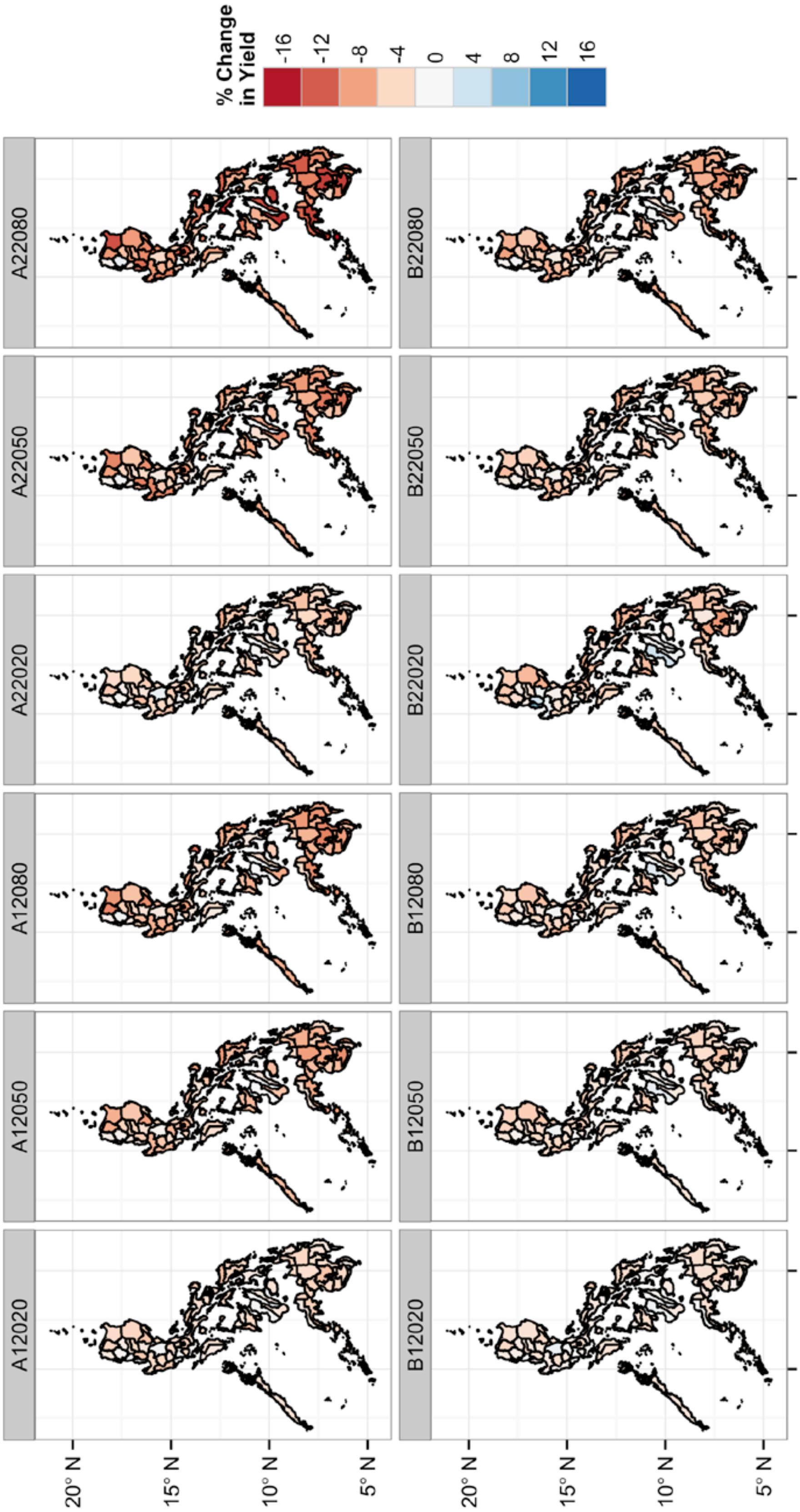

Figure 4: Map of corn yield change (%) under different climate scenarios during wet season cropping.

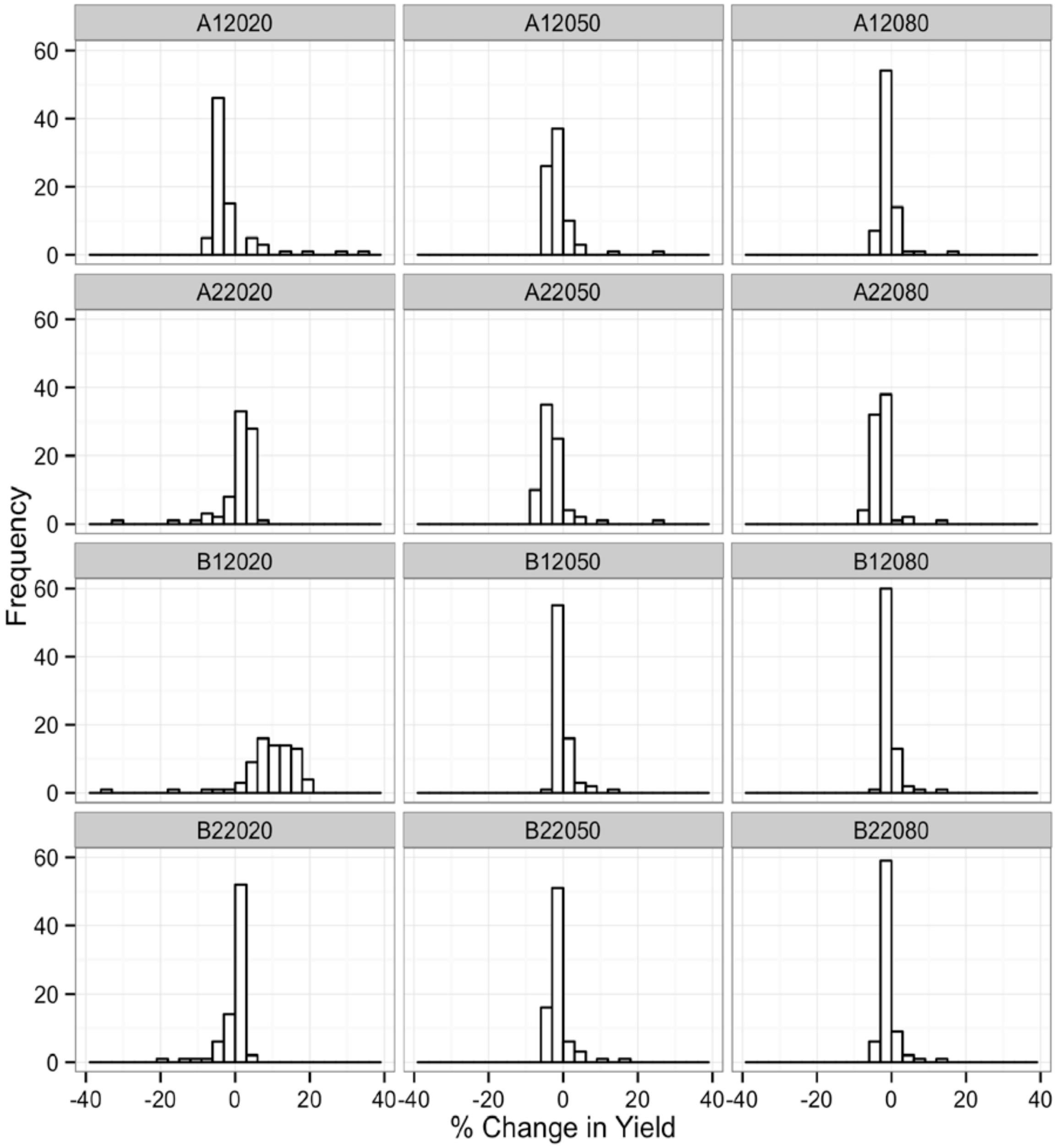

Figure 5: Histogram of yield change under different climate scenarios and time periods during dry season cropping.

The observed decrease on corn yield based on simulation studies were attributed to the increase in temperature which reduces growth and grain filling period [26,28]. Increase in temperature affect the thermal time response functions that determine the rate of crop development [29–31]. Early maturity due to increase in temperature leads to less biomass accumulation which cause reduction in yield [27,31]. Heat stress during flowering can also induce sterility problem [26]. On the other hand, based on the review of Ziska and Bunce [32], elevated CO_2 can have little or no effect on C4 crops like corn.

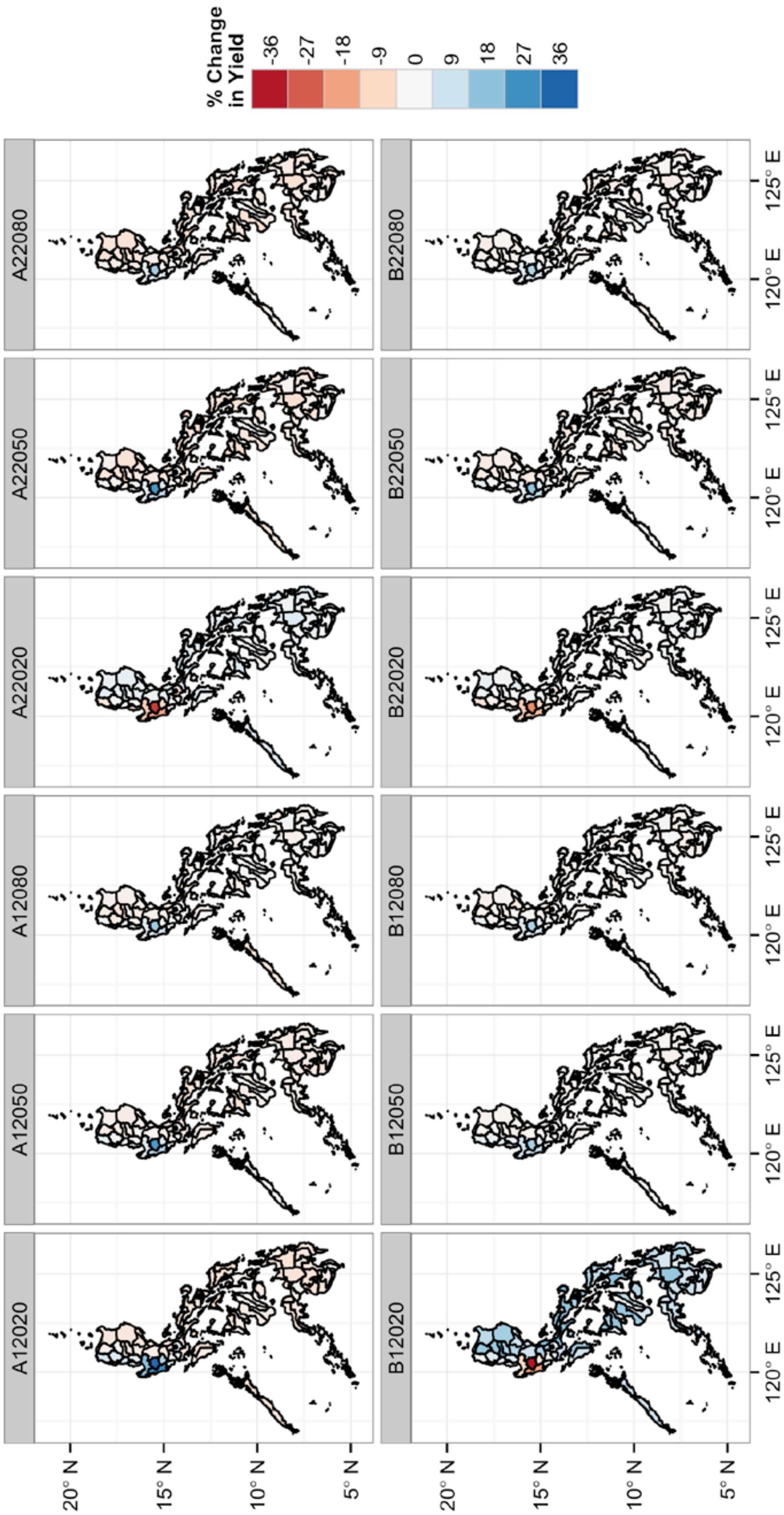

Figure 6: Map of corn yield change (%) under different climate scenarios during dry season cropping.

5. Conclusion and Recommendation

Climatic change will surely affect corn productivity in the country. The extent of the impact depends on the location and cropping season. On the average, the projected climate change will negatively impact corn productivity in the country. In the absence of policy and production adaptation measures the country will surely face problem in the supply of corn produce. Different policy and adaptation measure such as crop insurance, improvement of irrigation system, dissemination of climate information, breeding of improve varieties, adjustment of cropping calendar, and improvement of current cropping system can reduce if not totally eliminate the negative impact of climate change on corn productivity in the country [32].

This study also shows a methodological framework on how to carry out climate change impact assessment by combining different systems research tools such as GIS, stochastic weather data generator, and crop simulation models. This methodological framework can also be applied for other modeling studies such as hydrologic, soil erosion, bio-economic, and environmental risk assessment.

On the other hand, it is highly recommended to explore and assess the impact of rainfall, occurrence of pest and diseases, as well as changing land suitability brought about by changing climate. Furthermore, adding economic facet (i.e. prices, market demand, etc.) on the analysis to economic can provide a more robust quantification on impact of climate change on the corn production system.

Acknowledgement

The author would like to thank the Department of Science and Technology (DOST) and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) through the Accelerated S&T Human Resource Development Program (ASTHRDP) for providing the financial support during the author's study.

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