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Time Series Analysis of Heat Index: Bases for Determining Extent of Damages in the Rice Farming Industry in Metro Bataan

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Abstract**—** The main purpose of this research was, initially, to have a Mathematics-based analysis for determining the extent of damages in the agricultural sector of Metro Bataan from 2015 to 2019. However, during data gathering, the researchers were informed that the needed official data were not available because they were not collected by the government agency concerned. Thus, instead, the researchers established a math model for observed and predicted heat index for the province. The respondents were 40 farmers, with farms ranging from half-hectare to 15 hectares. The research made use of a combination of quantitative and qualitative methods. Two sets of data were collected: [1] heat index data in two nearby provinces through data provided by the Climate and Agrometeorological Data Section from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (CADS-PAGASA) and [2] local information from questionnaires, individual face-to-face interviews and an online interview which became the basis for the case study of the farmers. From 2015 to 2019, the heat index in Bataan was not officially recorded by the PAGASA. Because of this, the researchers had to rely on the heat index data for two other Region 3 provinces, specifically Iba, Zambales, and Clark area, Pampanga. The researchers computed the estimated and assumed heat index in Bataan by getting the mean of the heat indexes in Iba and Clark. This was used to derive a math model for forecasting heat index in the future. This model hopes to aid government and non-government agencies in planning and organizing efficient responses to farms affected by extreme heat. This research can be used as a springboard for more accurate and more extensive calculations in future research on agriculture. From available quantitative data, the exact effects of the heat index in Metro Bataan cannot be pinpointed. However, more in-depth qualitative data were obtained from farmers through the mentioned questionnaires and interviews. The vast majority of respondents experienced a decline in the amount and the quality of their harvest, and they claim that it was because of extreme temperatures. In the case of two respondents, the quantity of harvest was not negatively affected due to the availability of efficient diesel water pumps. The research also reveals the advantages of being affiliated with government agencies that provide relevant assistance to farmers. It also offers insights to farmers and government agencies to design and implement mitigating actions to make agriculture in the province of Bataan more climate-resilient and more sustainable.

Keywords**—** heat index, climate change, damage prediction model.

I. INTRODUCTION

The world is experiencing extreme weather conditions nowadays due to climate change. Typhoons, floodings, and droughts are now beyond the usual that people have seen in the previous decades. All aspects of human life have been drastically affected, but agriculture has borne the brunt of extreme weather. Rainy seasons unleash a remarkable volume of water that floods farms. On the other hand, the summer season brings scorching temperature that withers crops. The heat index, which is a combination of temperature and relative humidity, has been taking its toll on agriculture. This has a domino effect on the economic situation of the farmers, as well as on their emotional and mental well-being. On a larger scale, agricultural conditions have an immense impact on the progress of a country and of the world in general. The Philippines is a tropical country that experiences warm and humid conditions almost throughout the year. It has a land area of 30 million hectares, 47% of which or 14 million hectares are used for agricultural purposes. Because of this, the country is heavily impacted by the heat index. On the other hand, Bataan is one of the 81 provinces in the Philippines, and it is located on the island of Luzon. Although it is fast becoming a highly industrialized and commercialized area, Bataan still has a considerable agricultural industry that must be protected. The Philippines, including provincial governments, should prepare ways and means to react on the situation as it happens. By being aware of the different scenarios brought about by extreme heat index, prevention against possible devastation can highly be implemented. Crops may be protected and their impact on humans may be lessened.

The result of this project may be utilized not only by the farming industry but by government agencies and

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businesses as well. Rice farmers may devise plans to meet the problems even before they arrive. Moreover, government and non-government agencies may already formulate science-based processes to lessen the heat index. Thus, the effects of climate change may be mitigated.

Theoretical Framework and Related Studies

In this research, the input includes the following: farmers' demographic profiles in terms of sex, age, and educational attainment. Agricultural stability which refers to the condition and accessibility of the land, the severity of heat-related problems and adaptation strategies which are actions that farmers took to resolve their problems. Process refers to the methods the researchers used to gather and analyze information. Surveys through questionnaires and interviews were done to collect the qualitative data, while time series analysis was used to obtain quantitative data on damages. The researchers made use of the various statistical information from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Department of Agriculture (DA), Department of Science and Technology (DOST), Department of Trade and Industry (DTI), National Disaster Risk Reduction Management Center (NDDRMC) and Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARD).

The most important output of this research is a Math model for observed and predicted heat index in Bataan. Moreover, this study provides an in-depth group case study of the farmers in the province, which is hoped to give important insights to LGUs and lawmakers. The research also enhanced the capacity of Bataan Peninsula State University to conduct agriculture-related research and to contribute positively to the farming sector. The overall output shall contribute to the development of the agricultural roadmap of Bataan and the rest of the region.

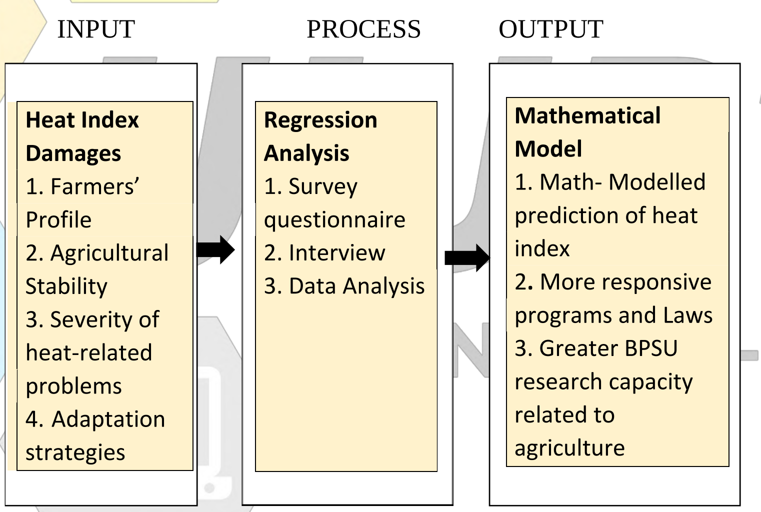

Fig. 1 *Conceptual Paradigm of the Study*

Prior researches have been done to determine the impact of climate variability on agricultural yields. In a peer-reviewed journal by Stuecker and Malte entitled "Climate variability impacts on rice production in the Philippines" (2018), it was stated that crop production depends on genetics, agronomics, and climate. The authors explored the impact of climate variability on rice yield and production in the Philippines from 1987 to 2016 under different circumstances. The results showed that climate impacts on rice production are strongly seasonally modulated and differ considerably by region. From the study, it was found that while temperature variability is of limited importance in the Philippines nowadays, future climate projection suggests that by the end of the century temperatures might regularly exceed known limits to rice production if warming is unabated. Authors also believed that skillful seasonal prediction will likely become increasingly crucial to provide the necessary information to guide agriculture management in mitigating the compounding impacts of soil moisture variability and temperature stress.

A study entitled "The effects of climate extremes on global agricultural yields" by Elizabeth Vogel, published in Environmental Research Letters Volume 14 Number 5 (2019), analyzed the impacts of climate extremes on yield anomalies of maize, spring wheat, rice, and soybeans at the global scale using sub-national yield data through the application of a machine-learning algorithm. The researchers found out that growing season climate factors including mean climate, as well as climate extremes, explain 20% - 49% of the variance of yield anomalies (the range describes the differences between crop types), with 18% - 43% of the explained variance attributable to climate extremes depending on the crop type. The researchers used a non-parametric, nonlinear machine- learning algorithm to examine the historical and current impacts of climate extremes during the growing season on crop yields, using reported agricultural statistics at high spatial resolution. The study focused on the importance of considering the impacts of climate extremes on the global food system and how agriculture can adapt to changes in extreme events to meet future food demands. Several researches focused on high temperature as a climate variability or extreme negatively affecting crop growth and quality have also been published. The Rice Science Journal Volume 26, Issue 1, entitled "Research Progress on Heat Stress of Rice at Flowering Stage" (2019) discussed that global warming has caused the frequent occurrence of heat stress at the flowering stage which is the most sensitive stage to high temperatures of single-season rice in the Yangtze River region of China. The heat stress resulted in a decline of spikelet fertility and yield in rice. Based on this research, the most effective measures of preventing heat stress are avoiding high temperatures, planting suitable cultivars, and adjusting of sowing date. The study also suggested that irrigation is an effective real-time cultivation measure to decrease the canopy temperature during the rice flowering stage. To achieve optimal heat stress management efficiencies, the study recommended improvements in high-temperature monitor and warning systems. Other recommendations from the research include a further study on exploration of heat injury differences among different rice variety types and innovation of rice-planting methods according to planting system changes in rice planting regions with extreme heat stress.

A group of Chinese researchers also conducted a research study entitled "Effects of short-term heat stress at booting age on rice-grain quality" (Zhen et.al, 2019) under Crop and Pasture Science. It stated that extreme heat stress has devastating effects on the quality of the grain produced. Study results showed that high temperatures of 35°C to 39°C for 4 to 6 days significantly reduce the grain size and chalky grain rate. The researchers also found out that short-term stress at the booting stage deteriorates most grain-quality traits, posing a potential risk to rice quality. The impacts on grain quality could be well quantified by the combined effects of the intensity and duration of heat stress at the booting stage.

Application of mathematical modeling in agricultural systems

In the Encyclopedia of Life Support System (EOLSS) Volume II: Mathematical Models of Agricultural Supply, O.D. Sirotenko and V.A. Romanenkov (2006) state that research applying mathematical modeling in modern agriculture had been very useful and important to specify the strict limits in the adopted farming system. The researchers quoted those mathematical methods of resource utilization started from the end of World War II, with several methods arising quickly following the introduction of the simple method from the first mathematical programming using linear programming. When complex dynamical problems in research emerged, mathematical modeling also evolved to include several methods from the differential equation to numerical simulations. In some studies requiring optimal resource allocation, higher mathematical programming was developed wherein parameters in economic-mathematical model (resources, technical-economic coefficients, and coefficients of the objective function) are deterministic, a priori known quantities. Agriculture faculty Christopher B.S. Teh, Ph.D from Universiti Putra Malaysia, wrote a book on mathematical modeling entitled "Introduction to Mathematical Modelling of Crop Growth: How the Equations are Derived and Assembled into a Computer Model," (2006). The author discussed the uses and characteristics of different mathematical modeling, with emphasis on the use of simple and complex models depending on the interests and purpose of the study. If the study requires rough estimation, the book suggests that it would be advisable to use simple mathematical modeling. Meanwhile, if the study requires high accuracy and deals with critical conditions, the use of a complex and accurate model is mandatory. The book also describes the importance of mathematics in agriculture, as well as the use of mathematical modeling in agriculture particularly in the growth and yield of a crop.

In the study by a group of Taiwanese researchers Dr. Yi-Chien Wu, Su-Jein Chang, and Huu-Sheng Lur, entitled "Effects of field high temperature on grain yield and quality of a subtropical type of Japonica rice - Pon-Lai rice" (2016), statistical analysis was utilized to develop the correlation between the temperature and data

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regarding grain yield or quality, with a derived linear or binomial formula according to adjusted R-square. P-value and significance were analyzed by statistical software The 'R' (R Development Core Team, 2007). P values of each formula were defined as significant correlation if the P-value < 0.05, highly significant correlation if the P-value < 0.01, and extremely significant correlation if the P-value < 0.001. The result of the research indicated that there were many cultivation periods or cultivation districts with cool to high-temperature conditions. Correlations between temperature conditions (including accumulated temperature) and yield or quality traits (including fertility, grain, weight, perfect grain, chalky grain, grain shape, and flour viscosity traits) were established as a mathematical model of linear or binomial formula.

Another research study from a group of Chinese students from the College of Engineering, Nanjing Agricultural University, headed by Kunjie Chen, entitled "Mathematical Modelling and Optimization of Low-Temperature Drying on Quality Aspects of Rough Rice" (2020) on Hindawi - Journal of Food Quality, used a mathematical quadratic model to determine the extent at which certain variables influence the quality of rice. Response surface methodology (RSM) with a central composite design was employed to study the effects of variables such as temperature (x_1), time (x_2), and air velocity (x_3), and the responses such as head rice yield (HRY), hardness, lightness, and cooking time. The results revealed that the variables had a significant influence on responses, with temperature having the greatest influence on the quality aspects of rough rice, followed by time and velocity.

The study by multi-awarded Professor Takeshi Horie from Japan who worked as a researcher in different research institutions and laboratories, entitled "Global warming and rice production in Asia: Modelling, impact, prediction and adaptation," (2019) developed a process-based mechanistic rice model named SIMRIW (Simulation Model for Rice-Weather Relationships) to predict growth and yields of irrigated rice based on physiological and physical processes of rice response to climate. The data used for SIMRIW were obtained from experimental work with the use of a newly developed Temperature Gradient Chamber (TCG). This research aimed to predict the effects of projected global warming on Asian rice production, as well as to find ways for adaptive rice production technologies.

As discussed, several pieces of literature have been published to show the impact of climate change and resulting heat stress on crop growth and quality through the use of mathematical modeling. In this research, the same methodology would be utilized to project the extent of damages caused by heat index in the region's rice farming industry.

III. METHODOLOGY

The study utilized the mixed method of qualitative and quantitative research. The quantitative method of research established the time series analysis of the heat index for the years 2015-2019, the harvest for each year, and the extent of the effect on the farm industry in terms of production. This established the deviation in the farming activities of the farmers covered within the time series analysis. The study also employed simple regression analysis to correlate the extent of damage and heat index. On the other hand, the qualitative part of the research focused on the quality of farming activities from the preparation of land for farming up to harvest season. Data were obtained through printed questionnaires, online questionnaires, face-to-face interviews, and a Google Meet interview. Information about each respondent is presented as a briefcase study.

The population of the study comprised 40 farmers in Metro Bataan, with farms suitable for rice planting and accessible to any kind of transportation and with an irrigation system. All are engaged in farming all year round for the last five years, and their farmlands are situated in the 11 municipalities and 1 city in Metro Bataan.

Fig. 2 *Map of Bataan, Philippines*

The target population for this study are the farmers who had been actively engaged in the farming industry for the period of 2015-2019, consistent with the period covered in the time series analysis. The 40 farmers who formed part of the study were selected using purposive sampling that fell into the criteria mentioned above. All the 11 municipalities and the component city are represented in the questionnaire responses. Since purposive sampling was used, the sample of 40 farmers was limited to the farmlands that qualified based on the criteria above. One farmland in each municipality and the city of Balanga was selected as per the given criteria.

The study covered farmlands in Metro Bataan actively engaged in the rice farming industry from 2015 to 2019. Because of the challenges in finding respondents at the time of the pandemic, respondents in this study own varying sizes of farms: from half-hectare to 15 hectares.

At the time of data gathering, it was not feasible to find respondents with similar farm sizes. In the interviews which were used as a basis for the case studies, there were no respondents from five municipalities: Samal, Pilar, Bagac, and Limay.

Another limitation of the study is the lack of official data about the heat index in Bataan from 2015 to 2019. DOST started collecting such data only in 2021. In the previous years, the said agency only gathered heat index data for Iba Zambales and Clark Pampanga. When this study was only in the proposal phase, the researchers assumed that the needed data were available.

This was not the case, as they found out only during data-gathering. Thus, some adjustments had to be made. The researchers computed an estimated and assumed heat index for Bataan based on the data for Iba and Clark. Because of this limitation, it was not feasible to make a valid math model that could determine damages based on the heat index. Instead, the researchers formulated a math model for predicting heat index in Metro Bataan.

The variables that were investigated are the size of the farmlands, accessibility to transportation, presence of irrigation system, amount of harvest, the extent of damage which can be quantified by volumes with their corresponding cost, the inclusion of time, and heat index.

This study made use of interview and questionnaire methods to gather relevant data from the farmers. Four farmers answered the questionnaire sent through Google form, while 36 answered the printed versions. Documentary records and statistics from available public resources were also utilized.

The researchers, with the aid of the compiled related literature, prepared questions that were given to the farmers via interview sessions to establish the farming activities of the farmers within the time frame of the study. This established if there were some deviations in the farming activities of the farmers every year, as well as to establish difficulties encountered due to heat change.

The questionnaire was also used to determine the quantity of harvest per year and the perceived extent of damage in terms of harvest loss because of heat. It was also able to develop documentary analyses on-farm productivities in Bataan.

The study made use of the mixed method for data analysis. The qualitative part established deviation in the farm activities due to heat, while the quantitative part predicted the heat index in Metro Bataan through a simple time series analysis on the heat index, A mathematical model was also developed from the data and statistical analyses.

IV. RESULTS AND DISCUSSION

Table 1. *Demographic Profile of the respondents with respect to sex*

Sex	Frequency	Percentage
Male	28	70.0
Female	12	30.0
Total	40	100

Table 1 shows that the greater proportion of the respondents are male, with 70%. This is the typical make-up of the agricultural owners and workers in the Philippines. Female workers on the farm are those classified as a single/solo parent or whose husbands were working in other places.

Table 2. *Demographic Profile of the respondents with respect to Age*

Age	**Frequency**	**Percentage**
35-45 years old	4	10.0
46-56 years old	16	40.0
57-67 years old	15	37.5
Above 68 years old	5	12.5
Total	40	100
Mean Age	56.78	Almost in their Senior Years

Table 2 shows that 40% of the respondents are aged 46-56 years old, closely followed by 37.5% are in the age bracket 57.67 years old and the least number of farmers with 4% are in the age bracket of 35-45 years old.

The computed mean age for farmers is 56.78 years old indicating that the farmers in Metro Bataan are nearing their senior years. The result of the study implies that the young generations of today were not interested anymore in farming.

The result may also implicate that the farmers in Bataan motivated their siblings to choose other career paths except for farming. It has been noted that some farmers said that they sent their children to school so that they will never become farmers in their future lives

Table 3. *Demographic Profile of the respondents with respect to educational attainment*

Educational Attainment	**Frequency**	**Percentage**
Elementary	8	20.0
Secondary	11	27.5
Vocational	8	20.0
Tertiary	13	32.5
Total	40	100

Table 3 shows the educational attainment of farm owners and tenants, with 32.5% reaching the collegiate level. Twenty percent reached the elementary level only.

Agricultural Stability

Table 4 shows that the majority of the farms, 60%, are located in lowland areas, and 60% of the respondents own only one to two hectares, which means that most of them are small-time farmers. Forty-five percent have spent more than two decades on farming.

Table 4 also illustrates that 97.5% can do cropping twice a year while cropping three times annually used to be sustainable and doable in the past. This means a reduction in harvest quantity and profits.

Table 4. *Descriptive analysis of the respondent's assessment on the agricultural stability*

Location	**Frequency**	**Percentage**
Lowland	24	60.0
Upland	16	40.0
Total	40	100
Size of Farmland	**Frequency**	**Percentage**
Less than 1 hectare	8	20.0
1-2 hectares	24	60.0
More than 2 hectares	8	20.0

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Total	40	100
No. of Years in Rice Farming Industry	**Frequency**	**Percentage**
5-10 years	12	30.0
11-20 years	10	25.0
21 years and above	18	45.0
Total	40	100
No. of Cropping in a Year	**Frequency**	**Percentage**
1	0	0
2	39	97.5
3	1	2.5
Total	40	100

Table 5 shows that majority of the farms are near commercial or business areas, with a distance of one thousand meters or less (a total of 75%). Also, 92.5 percent are accessible by transportation.

***Table 5.** Descriptive analysis of the respondent's assessment of the agricultural stability in terms of farm accessibility*

A. Distance from the farmland to business land	Frequency	Percentage
Less than 500 meters	18	45.0
501-1000 meters	12	30.0
More than 1000 meters	10	25.0
Total	40	100
B. Accessibility to transportation	**Frequency**	**Percentage**
Yes	37	92.5
No	3	7.5
Total	40	100

Estimated and Assumed Heat Index in Metro Bataan from 2015 to 2019

In the absence of official data on the heat index in Metro Bataan from 2015 to 2019, the researchers computed an estimate and assumption of such index by getting the mean heat index of Clark, Pampanga, and Iba Zambales, as provided by the DOST.

The basis is the proximity of these areas to Bataan. Clark is 82.7 kilometers from Bataan while Iba is 132.8 kilometers away from the province.

Table 6 shows that in 2015, 2016, and 2017, the assumed heat index level in Bataan was at the "dangerous" level for the longer part of the year: seven months, nine-month, and eight months respectively.

For the remaining parts, the index was at an "extreme caution" level. In 2018 and 2019, the assumed heat index was at three months and five months respectively.

The rest was at the "extreme caution" level. Therefore, the assumed heat index in Bataan was never at the "safe" level from 2015 to 2019.

It never even reached the "caution" level which is the least threatening category according to PAGASA.

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Table 6. *Estimated and Assumed Heat Index in Metro Bataan from 2015 to 2019 Based on Mean of Heat Index-Based on Clark City Pampanga and Iba, Zambales.*

MEAN OF HEAT INDEX				
		HEAT INDEX		
YEAR	MONTH	CLARK PAMPANGA	IBA ZAMBALES	MEAN
2015	JANUARY	31.93	36.05	34.0
2015	FEBRUARY	32.97	36.57	34.8
2015	MARCH	36.21	39.70	38.0
2015	APRIL	42.56	46.66	44.6
2015	MAY	46.88	49.07	48.0
2015	JUNE	47.65	49.86	48.8
2015	JULY	40.15	40.87	40.5
2015	AUGUST	43.86	44.26	44.1
2015	SEPTEMBER	46.31	45.73	46.0
2015	OCTOBER	41.77	43.84	42.8
2015	NOVEMBER	40.05	46.07	43.1
2015	DECEMBER	38.00	41.86	39.9
2016	JANUARY	39.23	41.52	40.4
2016	FEBRUARY	38.59	40.15	39.4
2016	MARCH	45.93	43.12	44.5
2016	APRIL	54.15	51.13	52.6
2016	MAY	49.06	52.50	50.8
2016	JUNE	47.15	48.76	48.0
2016	JULY	44.94	45.03	45.0
2016	AUGUST	41.56	45.23	45.40
2016	SEPTEMBER	43.82	43.09	43.5
2016	OCTOBER	43.41	43.48	43.4
2016	NOVEMBER	40.12	46.04	43.1
2016	DECEMBER	39.14	44.66	41.9
2017	JANUARY	34.56	40.04	37.3
2017	FEBRUARY	35.24	41.22	38.2
2017	MARCH	41.01	43.89	42.4
2017	APRIL	45.63	47.02	46.3
2017	MAY	48.52	49.85	49.2
2017	JUNE	47.89	47.56	47.7
2017	JULY	42.62	44.57	43.6
2017	AUGUST	45.17	43.86	44.5
2017	SEPTEMBER	43.24	42.33	42.8
2017	OCTOBER	42.89	41.96	42.4
2017	NOVEMBER	39.81	41.82	40.8
2017	DECEMBER	38.26	38.87	38.6
2018	JANUARY	36.84	37.41	37.1
2018	FEBRUARY	38.80	36.85	37.8
2018	MARCH	40.28	39.31	39.8
2018	APRIL	44.22	41.53	42.9

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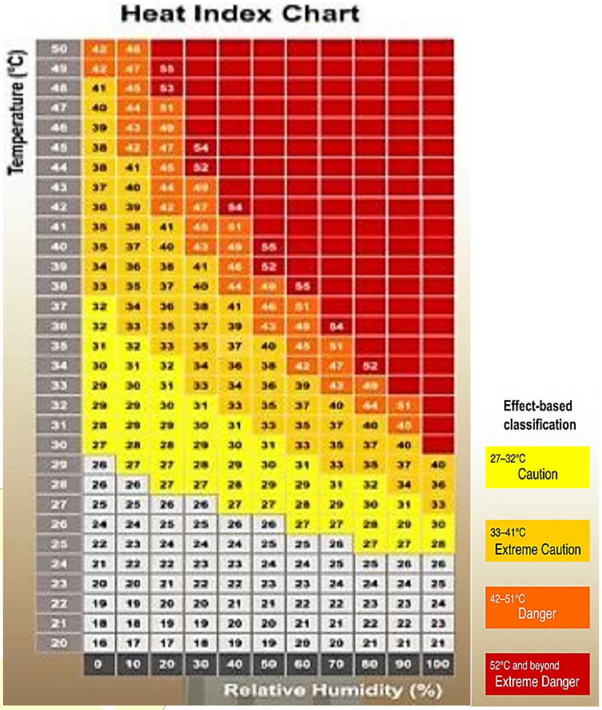

CAUTION EXTREME CAUTION
DANGER EXTREME DANGER

Note: Heat Index Values adapted from Steadman, 1979; classification threshold adapted from National Weather Services, National Oceanic and Atmospheric Administration. (NWS-NOAA) [*https://bagong.pagasa.dost.gov.ph/climate/climate-heat-index*](https://bagong.pagasa.dost.gov.ph/climate/climate-heat-index)

Extent of damage in rice farming in Metro Bataan attributed to the heat index

Table 7 shows that, from the beginning of the covered period (2015) up to the end year of the coverage of the study (2019), the quantity of harvest in Metro Bataan declined for five consecutive years from 2016 to 2019.

The decline was due to smaller grains and diminished quantity due to pests brought by extreme heat.

This data from the questionnaire is supported by the interviews conducted by the researchers.

Table 7. *Mean of the respondent's assessment of the agricultural stability in terms of quantity harvested for the past 5 years.*

Year	Mean	SD	Verbal Interpretation
2015	1.65	0.66	Decreased
2016	1.80	0.61	Decreased
2017	1.78	0.48	Decreased
2018	1.78	0.48	Decreased
2019	1.83	0.45	Decreased
Composite Mean	**1.77**	**0.54**	**Decreased**

**Legend: 2.34-3.00 Maintained; 1.67-2.33 Decreased; Source*

Relation between heat index and the damage it created

Table 8 provides data showing that the respondents believe that the heat index led to adverse conditions such as diminishing water supply, dropping quantity and quality of rice grains, and lower profits. As to the water supply, the effect highly deteriorated with the mean = 1.58 interpreted as high. This is very evident with the presence of drought in some of the irrigation systems in the farm areas of Metro Bataan. Many of the farmers were not planting anymore due to the tremendous

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decrease in the volume of tons (mean 1.55) of rice harvested due to extreme heat and the irrigation system is drying. Aside from water deterioration in the water level, during the extreme heat pest prevailed in the rice field lowering the volume of harvest. Because of extreme heat, even the quality of rice suffers to a high extent, as noted by the mean of 1.55 and because the volume of rice harvest decreased at a high level and poor quality of rice harvested results in low income on the part of the farmers.

Table 8. *Mean of Respondents' Assessment on the Effects of High Temperature on Rice Farming during Dry Cropping Season.*

Effects of High Temperature on Rice Farming during Dry Cropping Season	Mean	SD	Verbal Interpretation
Deteriorated water supply	1.58	0.55	High
Decrease in number of harvested rice	1.55	0.64	High
Poor quality of the harvested rice	1.55	0.68	High
Less income	1.53	0.68	High
Composite Mean	**1.55**	**0.64**	**High**

**Legend: 3.51-4.00 Very Low; 2.51-3.50 Low; 1.51-2.50 High; 1.00-1.50 Very High*

The adaptation Strategies in Rice farming from High Temperature during the dry-cropping season

Table 9 shows data that are relevant to the respondents' use of equipment and access to a type of irrigation. A relatively big proportion of the respondents, 67.5%, were farming within an irrigation system. During periods with normal temperature, 35% used a diesel pump to extract water from the river. This figure decreased to 22.5% during the hot season. On the other hand, some groups did not use any pump to get water from any source: 40% during normal temperatures and 52.5% during the hot season.

It should also be noted that only diesel pumps were being used by the respondents because they are more affordable. The decrease in the use of pumps during drought can be attributed to the decrease in the land area being cultivated during this time. The table also shows that the main source of agricultural water is the river. Sixty percent also said that they changed their crop calendar to adjust to the climate while 75% said that they didn't change to less water-consuming crops. Meanwhile, only 12.5% kept their land unsown because of the extreme heat. The majority still cultivated their land despite the challenges.

Table 9. *Descriptive analysis of the respondent's assessment of the adaptation strategies in rice farming from High Temperature during the dry-cropping season.*

Presence of Irrigation System	**Frequency**	**Percentage**
Yes	27	67.5
No	13	32.5
Total	40	100
Source of water/irrigation system during normal temperature	**Frequency**	**Percentage**
With an electric pump		
Dug Well	0	0
Bore Well	0	0
River	0	0
With diesel pump		
Dug Well	7	17.5

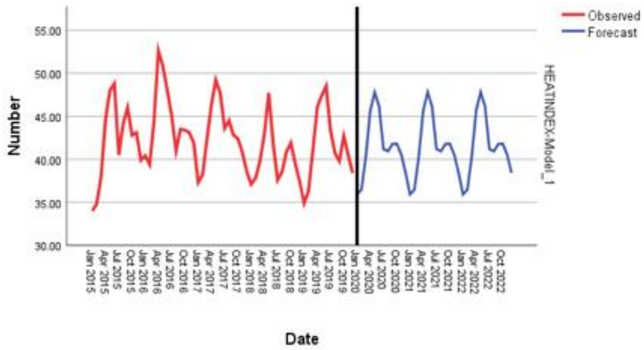
Bore Well	3	7.5
River	14	35.0
No Pump	16	40.0
Total	40	100
Source of water/irrigation system during high temperature		
With an electric pump		
Dug Well	0	0
Bore Well	0	0
River	0	0
With diesel pump		
Dug Well	7	17.5
Bore Well	3	7.5
River	9	22.5
No Pump	21	52.5
Total	40	100
Irrigation used		
None	13	32.5
Flood/river irrigation	25	62.5
Sprinkler/dip	0	0
Mixed	2	5.0
Total	40	100
Do you change the crop calendar year?	**Frequency**	**Percentage**
Yes	24	60.0
No	16	40.0
Total	40	100
Do you change less water-consuming crops?		
Yes	10	25.0
No	30	75.0
Total	40	100
Do you keep land unsown?		
Yes	5	12.5
No	35	87.5
Total	40	100

Math Model for Observed and Predicted Heat Index

Based on the available official data which as mentioned earlier in the limitations, did not aligned with the original aim of the research, researchers were able to compute the observed and predicted heat index.

Table 10 shows that the lowest heat index occurred from January of 2015 to 2019, while the highest heat index occurred in July of those past years. Thus, it can be forecasted that the heat index will follow those patterns in the coming years, and proactive steps can be undertaken to mitigate the impact.

Graph 1. *Observed and Predicted Heat Index In Metro Bataan*



Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	40.753	1.171		34.800	.000
	M1	-2.962	1.425	-.200	-2.079	.043
	M2	-2.360	1.423	-.160	-1.659	.104
	M3	1.542	1.421	.104	1.085	.283
	M4	6.924	1.419	.469	4.880	.000
	M5	9.086	1.417	.615	6.411	.000
	M6	7.468	1.416	.505	5.274	.000
	M7	2.550	1.415	.173	1.802	.078
	M8	2.352	1.414	.159	1.663	.103
	M9	3.234	1.413	.219	2.288	.027
	M10	3.316	1.413	.224	2.347	.023
	M11	2.118	1.412	.143	1.500	.140
	t	-.042	.017	-.178	-2.473	.017

a. Dependent Variable: heat_index

MATH MODEL FOR PREDICTED HEAT INDEX

$$\textbf{HEAT INDEX} = 40.753 - 2.962M1 + 6.924M4 + 9.086M5 + 7.468M6 + 3.324M9 + 3.316M10 - 0.42t$$

Predicted Data from January 2020 – December 2022

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Date	Predicted Values	Lower Range	Upper Range
Jan-20	**35.92**	32.64	39.2
Feb-20	**36.48**	32.82	40.14
Mar-20	**40.34**	36.33	44.35
Apr-20	**45.68**	41.35	50.01
May-20	**47.8**	43.17	52.43
Jun-20	**46.14**	41.23	51.05
Jul-20	**41.18**	36	46.36
Aug-20	**40.94**	35.51	46.37
Sep-20	**41.78**	36.11	47.45
Oct-20	**41.82**	35.91	47.72
Nov-20	**40.58**	34.45	46.71
Dec-20	**38.42**	32.08	44.76
Jan-21	**35.92**	29.37	42.47
Feb-21	**36.48**	29.73	43.23
Mar-21	**40.34**	33.39	47.29
Apr-21	**45.68**	38.54	52.82
May-21	**47.8**	40.48	55.12
Jun-21	**46.14**	38.63	53.64
Jul-21	**41.18**	33.5	48.86
Aug-21	**40.94**	33.09	48.79
Sep-21	**41.78**	33.76	49.8
Oct-21	**41.82**	33.63	50.01
Nov-21	**40.58**	32.23	48.93
Dec-21	**38.42**	29.91	46.93
Jan-22	**35.92**	27.25	44.59
Feb-22	**36.48**	27.66	45.3
Mar-22	**40.34**	31.37	49.31
Apr-22	**45.68**	36.56	54.8
May-22	**47.8**	38.54	57.06
Jun-22	**46.14**	36.73	55.55
Jul-22	**41.18**	31.63	50.73
Aug-22	**40.94**	31.25	50.63
Sep-22	**41.78**	31.95	51.61
Oct-22	**41.82**	31.86	51.78
Nov-22	**40.58**	30.48	50.68
Dec-22	**38.42**	28.19	48.65

Extreme weather patterns are likely to prevail in the coming years and decades. Like other places, Metro Bataan will definitely not be spared from these phenomena. To mitigate the impact, and even to thrive, several points need to be taken into consideration.

1. 1.There is a need in the Philippines to formulate Math-based systems for predicting natural phenomenon. These systems or models should be able to give advanced warning, give precautionary measures and estimate damages. They should also be able to recommend how much funding and assistance will be needed in an area. There should be a system for heat index, and separate systems for typhoons, flooding, earthquakes, and other calamities. When these Math-based systems are in place, responses can be delivered faster and more efficiently. Such systems will prevent disparate and random guesses which lead to waste of time and resources. These prediction systems should be standardized to provide an almost uniform recommendation for swift responses and solutions.
2. Farms that are located near natural water sources are more likely to be fertile regardless of the climatic temperature. Farms that are remote from water sources are likely to be deprived of water, especially in the absence of fair water distribution system. Thus, there is a need for government agencies to pay closer attention to these farms so that assistance can be expedited.

3. Infrastructure and machinery are indispensable. Farms that are equipped with hydroengineering facilities such as impounding canals, and those with available equipment such as diesel pumps are likely to survive and thrive. This factor is tied to the financial capability of the farmers. The more financial resources they have, the more solutions they can implement. Therefore, access to financial aide is crucial. Farmers in the province need to have access to no-interest or low-interest loans to tide them over during lean season.
4. Farm owners and workers need updated technical knowhow. Farmers who are knowledgeable about the latest technological progress in agriculture are more capable of dealing with challenges. Thus, there is a strong need for government agencies to reach out, re-educate and re-tool farmers. Older farmers may be averse to or intimidated by new technology, and the government needs think of a way to approach them in a more convincing way.
5. Membership in agriculture-related organizations. Farmers who are active in such organizations are able to obtain benefits such as free seedlings and fertilizers, as well as technical and business assistance.
6. Operations of businesses like resorts and similar establishments should be regulated and monitored by the government, so as not to jeopardize the water supply of nearby farms. The approval of government engineers and agriculturists should be advised, if not required, for the final approval of business permits. Moreover, there should be annual monitoring and consultation with farm owners regarding the effect of these businesses on their farms.
7. The government should also look into the effects of the privatization of water distribution services. As alleged by one respondent, the rates are much higher now and farmers can hardly afford to pay for the water for irrigation purposes. There can be special discounted rates for agricultural uses of water.
8. Mediation from the government is necessary to de-escalate tension between farmers who are arguing about the fair scheduling of water flow. A knowledgeable and impartial government staff should organize dialogues and recommend solutions that are acceptable to the majority, if not to all parties involved.
9. The BPSU, as an academic institution, has an important role to play in improving the condition of agriculture in Bataan. Its research department should conduct more studies on the state of agriculture in the province and in the country as a whole and lend their academic knowledge and expertise in solving problems in this field. BPSU should further collaborate with government agencies in providing farmers with modern and up to date farming technology and as well as business-related ideas in order to ensure profitability. A copy of this research had been turned over to DA and the DOST. It is hoped that the research will help the said agencies in making timely, sound, appropriate, and effective decisions to improve the state of agriculture in Metro Bataan.

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