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ABSTRACT

This study aims to analyze the effects of climate change on the rice yield of Pampanga in an effort to help the farmers of Pampanga to estimate the proper cropping calendar for rice in the province. The climate and yield data used was for a period of 20 years between 1998 to 2017.

Descriptive and inferential methods of research were utilized. The rice production in Pampanga showed an increasing trend within a twenty year period. The correlation of rice yield vs. rainfall and temperature were also examined. It was found out that there is no significant relationship between rice yield and temperature *(r-value = - 0.083 and p-value = 0.463)*. While the relationship of rainfall and rice yield is inverse and significant *(r-value = - 0.382 and p-value = 0.000)*. Taking into account the monthly averages of rainfall and temperature as well as the climatic needs of the different stages of development of rice, a new cropping calendar was proposed. The current cropping calendar which starts at the month of May is proposed to be moved one month forward to the month of June while the second cropping which starts at the month of November is proposed to be moved to December so that the ripening phase which is susceptible to excess rainfall will be moved to a month where less amount of rain is expected. The results of this research will be communicated to the farmers of Pampanga once approved and examined by the concern government agencies.

1. Introduction

Climate change is a broad range of global phenomena which is primarily and mostly created by burning fossil fuels, which add heat-trapping gases to the Earth's atmosphere (NASA, 2016). It is one of the biggest challenges facing humanity in the 21st century.

The Intergovernmental Panel on Climate Change (IPCC) predicted that throughout the century, climate change will have an effect on the economic growth, food security and crop production (Navarro, 2017).

The impact of climate change on crop yields are estimated to be different in various areas. In some areas, crop yields will increase, and for other areas it will decrease depending on the latitude of the area and irrigation application. Climate change impacts on soil water balance will lead to changes of soil evaporation and plant transpiration, therefore, the crop growth period may shorten in the future impacting on water productivity (Yinhong, 2009).

Rice is one of the two most important cereal crops after wheat for human consumption. It is cultivated on an estimated 3% of the world's agricultural land, and serves as a primary source of calories for over half the world's population (Bailey et al., 1976).

Rice plants take around 3–6 months to grow from seeds to mature plants, depending on the variety and environmental conditions. They undergo three general growth phases: vegetative, reproductive, and ripening. Rice varieties can be categorized into two groups: the short-duration varieties which mature in 105–120 days and the long-duration varieties which mature in 150 days (Ricepedia, 2018).

There are two classifications of rice environment: rainfed and irrigated. Irrigated rice can be planted any time of the year. It requires the use of water pump machine to draw water from nearby river or other source to wet the rice field on a regular basis. On the other hand, rainfed rice depends on natural rainfall to grow and it's usually planted during rainy season (Vincent, 2017).

Central Luzon, or Region 3, is a major industrial and agricultural center just north of Metro-Manila. It is strategically located between the commercial center of Manila and the industrial and trading centers of Northern Luzon. Central Luzon is also known as the 'central plains' of Luzon. It is the traditional rice granary of the Philippines. It consists of six provinces: Bulacan, Nueva Ecija, Pampanga, Tarlac, Bataan and Zambales. The climate is dry from November to April and wet from July to October. Typhoons are also frequent in the region.

Pampanga is located in the middle portion of Central Luzon. It is bounded on the north by Tarlac and Nueva Ecija, on the east by Bulacan, on the west by Zambales, and on the southwest by Bataan. It has a total land area of 116,494.70 hectares divided for planting of rice (61,987 hectares), corn (16,987), sugar cane (6,500), lowland vegetables (3,500) and the remaining for orchards such as mango, calamansi, chico, coconut and dragon fruit. There are 20 municipalities, two cities, and 538 *barangays*. The province has two pronounced seasons: dry from November to April and wet from May to October. The heaviest rains come in July and sometimes last until October. These rains bring severe flooding to several municipalities. Average temperatures range from an average minimum of 24 degrees Celsius, usually in January, to a maximum of 30 degrees, occurring in May (Delgado et al., 2006).

According to Philippine Rice Research Institute, Pampanga has two planting periods that occur in the beginning of May up to the end of August and in the beginning of November up to the end of April. The harvesting periods are during the beginning of August up to end of November and in the beginning of February up to the end of July. Its planting rate are 60-80 Kg/Ha for the transplanting and 150-200 Kg/Ha for the direct seeding.

The researcher would like to know the effects of climate change on rice yield of Pampanga. The researcher chose Pampanga in conducting this study for it is known as one of the largest producers of rice in the region. Studying this may help the community of Pampanga to be aware on what are the effects of climate change in their rice yield. Knowing these results may help them in the further development of their crop production.

2. Methodology

Descriptive and inferential methods of research were applied in this study. Excel and SPSS were used as the research instruments. Bar graphs were used to show the graphical representation of the data. Trend line was used to determine the pattern of the data. Pearson’s Correlation and was used to determine the relationship of the variables.

The datasets in this study were gathered from Philippine Statistics Authority (PSA), San Fernando, Pampanga, Department of Agriculture Office of the Secretary, Quezon City, Department of Agriculture Region 3, San Fernando, Pampanga, and Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Clark, Pampanga.

3. Results and Discussion

This chapter deals with the analysis and interpretation of data. The gathered data were presented in accordance with the specific problems of this study.

3.1. Temperature of Pampanga

Figure 1 shows the values of the annual temperature of Pampanga. These were gathered to identify the behavior of temperature in the province for the past 20 years. The average temperature per year as seen in Figure 1, is inconsistent. It ranges from 26.62°C to 28.31°C. The years 2016 and 2017 obtained the highest recorded temperature for the past 20 years. In addition, based on the data, the trend is positive. It is increasing for the past years.

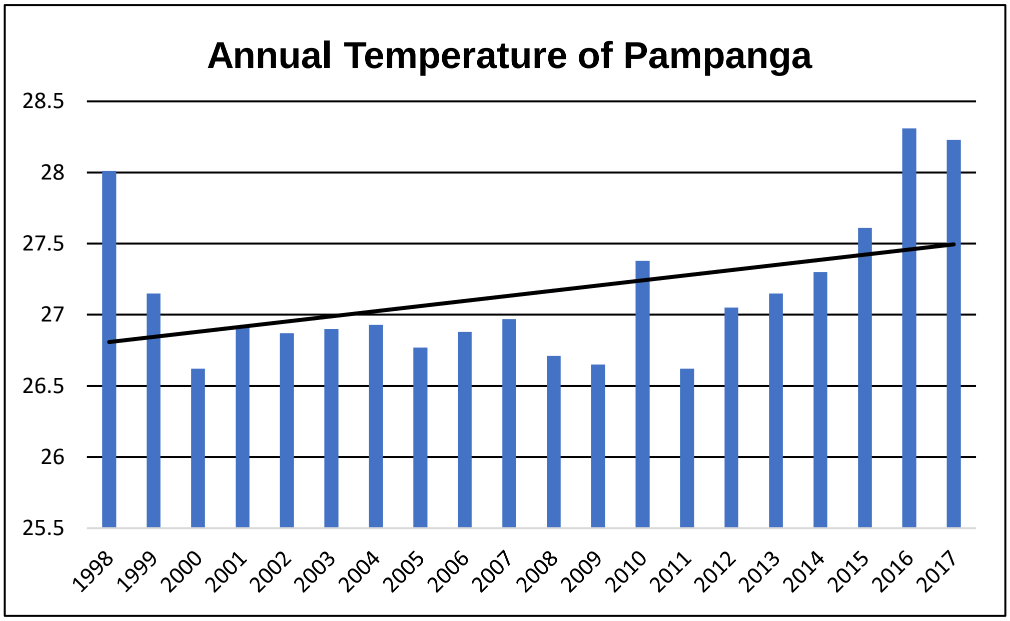

Figure 1. Average annual temperature of Pampanga from 1998-2017

Figure 2 shows the average monthly temperature of Pampanga from 1998-2017. It can be seen that April to June has the highest temperature among the other months. These months happens to be the summer period hence these results are actually expected. On the other hand, the coldest months are December and January.

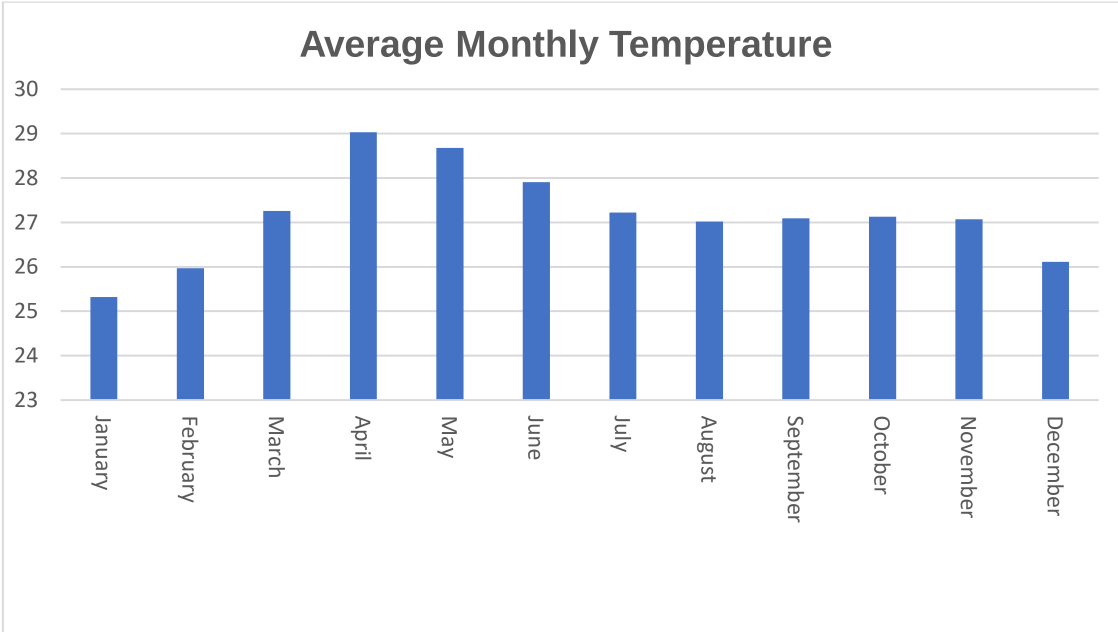

Figure 2. Average monthly temperature of Pampanga from 1998-2017

3.2 Amount of Rainfall Received by Pampanga

The data for rainfall were averaged according to year. The changes in rainfall of Pampanga as seen in Figure 3 is inconsistent. There are extreme rainfall counts that occurred in 1999 and 2002.

According to the National Disaster Coordinating Council (1999), an immense flood ruined a big part of Luzon specifically Pampanga in 1999. 798 houses were destroyed and 10,964 were damaged. 2,096,341 persons were affected (418,106 families) and 64,296 had been evacuated (13,437 families). Estimated total losses caused by the rains: PHP 686.9 million, among which PHP 466.3 million concerned the agricultural sector.

In the middle of the year 2002, Typhoon Gloria and Hambalos caused a large amount of flood in Pampanga hence a huge volume of rainfall was recorded in this year.

Figure 4 shows the average monthly rainfall of Pampanga from the past 20 years. The province is receiving huge amount of rainfall during the month of July and August. It is also during these months were flooding are frequent in the province.

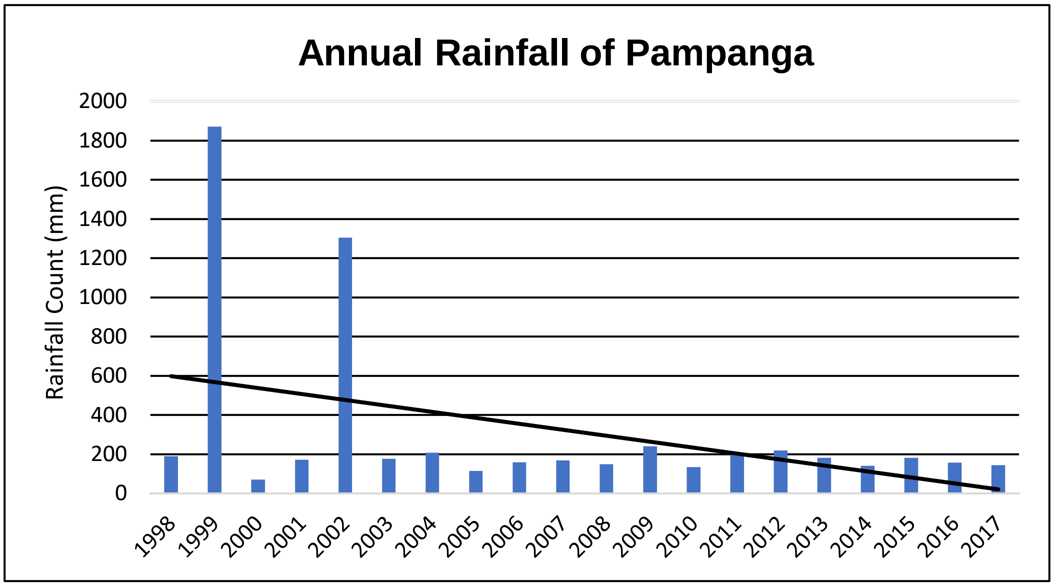

Figure 3. Average annual rainfall of Pampanga (1998-2017).

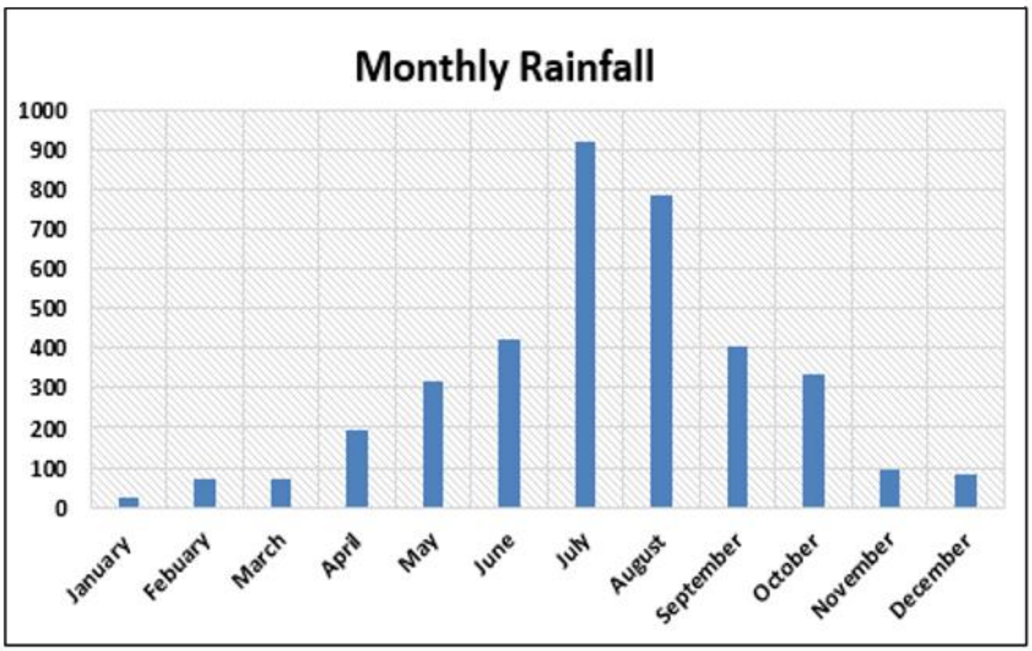

Figure 4. Average annual rainfall of Pampanga (1998-2017).

3.3 Rice Yield of Pampanga

Figure 5 shows that the rice yield of Pampanga has a positive trend. This means that the rice production of Pampanga is increasing for the past years. However, in 2009 and 2011, there is a sudden drop in the rice yield of the province.

Historical data shows that in 2009, typhoon “Ondoy” and “Pepeng” hit the Philippines. In a study made by Go (2009), he stated that the damage to the agriculture sector caused by tropical storm “Ondoy” and typhoon “Pepeng” reached about P10 billion. Ondoy’s damage is estimated at P 6.8 billion while Pepeng destroyed P3.2-billion worth of crops and agricultural facilities.
For the rice sector in Regions I, II, III, V and the Cordillera Autonomous Region (CAR), the affected area was 126,603 hectares where 164,259 metric tons (MT) of palay worth P2.8 billion were lost and P9 million worth of investment of farmers were wasted.

Meanwhile in 2011, The Bureau of Fisheries and Aquatic Resources (BFAR) in Central Luzon said that 7,000 hectares of rice lands in the coastal villages of Pampanga, Bulacan, and Bataan have been damaged from salt water forcing farmers to convert 1,000 hectares into fish ponds. Thus causing a decrease in the rice production of the mentioned provinces.

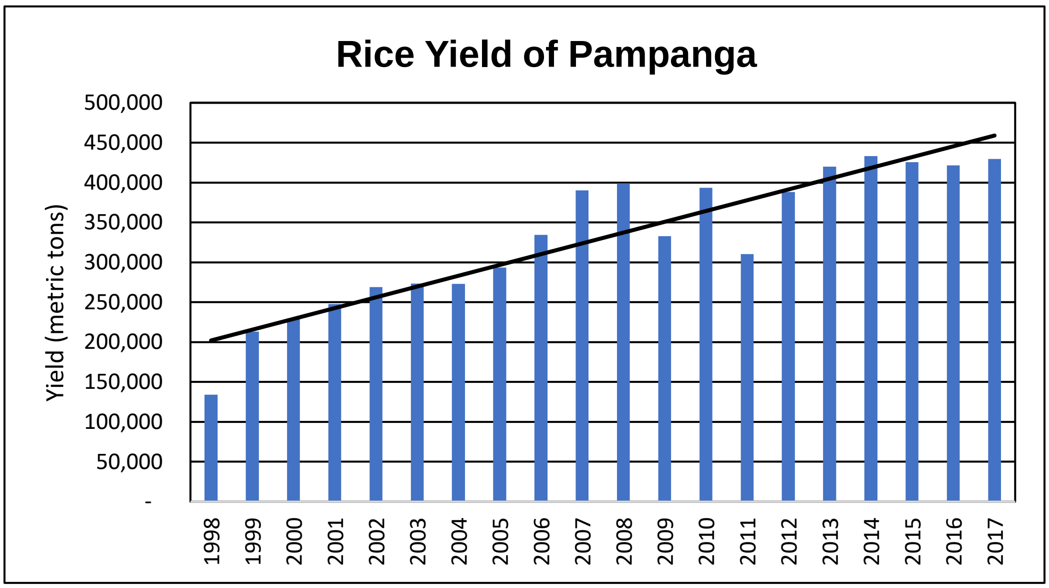

Figure 5. Average annual rice yield of Pampanga (1998-2017).

Breaking down the average annual rice yield into average quarterly rice yield, we obtained the data as shown in Figure 6. Quarter 1 obtained the highest rice production with a 121,762.65 tons. This quarter is the dry season. During the dry season, when there is abundant sunlight, the rice plants produce more yield compared during the rainy season. This is because the rice plants receive greater solar radiation during the dry season (Pinoy Rice Knowledge Bank, 2018).

Quarter 3 obtained the least because this quarter is said to be the wet season. According to Pinoy Rice Knowledge Bank (2018), during the wet season, the rice do not get enough light energy therefore they produce less grains.

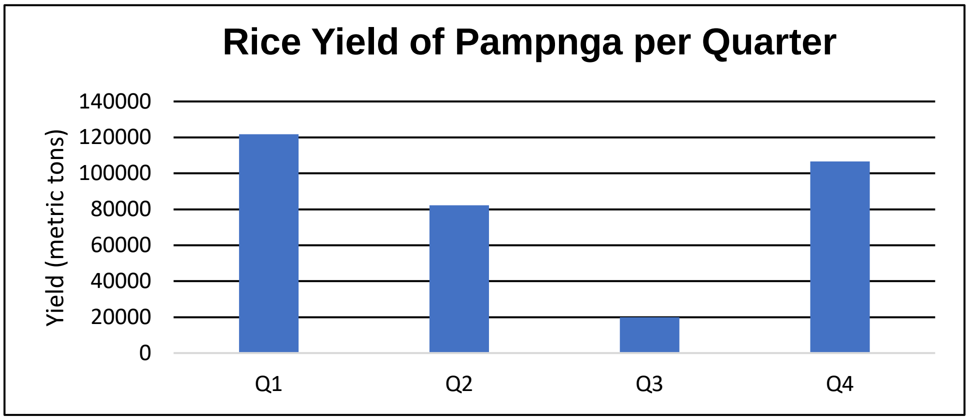

Figure 6. Total rice yield of Pampanga per quarter (1998-2017)

3.4 Relationship of Temperature and Rainfall on Rice Yield

3.4.a Relationship of Temperature and Rice Yield

Pearson's correlation was used to determine if there exist a significant relationship between the temperature and the rice yield of Pampanga from 1998-2017.

As seen on Table 1, computed r-value (-.083) and p-value (.463) imply slight inverse and not significant relationship between temperature and rice yield.

This supports the study of Virnean, Tran and Tran (2017), wherein they evaluated the relationship between climate variables and rice yields during 1993–2012 in Cambodia. They concluded that high temperature did not correlate to rice yield. Therefore, temperature is found to be negatively significant to rice output.

Table 1. Pearson's correlation results for relationship between temperature and rice yield

		Temperature	Rice Yield
Temperature	Pearson Correlation	1	-.083
	p-value		.463
Rice Yield	Pearson Correlation	-.083	1
	Sig. (2-tailed)	.463	

Legend:

0.00 to ±0.20	*slight correlation*
±0.21 to ±0.40	*low correlation*
±0.41 to ±0.60	*moderate correlation*
±0.61 to ±0.80	*high correlation*
±0.81 to ±1.00	*very high correlation*

3.4.b Relationship of Rainfall and Rice Yield

Pearson's correlation was used to determine if there exist a significant relationship between the rainfall and the rice yield of Pampanga from 1998-2017.

Table 2, shows that computed r-value (-.382) and p-value (.000) imply low inverse and significant relationship between rainfall and rice yield. This result revealed that when rainfall decreases, the yield in rice will increase and vice versa.

This supports the study of Khadka (2016), which says that there is a moderate impact of climate change on rice yields. Under climate change scenarios, the rainfall received by Vangvieng (a valley in Laos) is excessive, which is the main cause for reducing yield. The impact caused by the rainfall is approximately 1.5% loss in rice yields. Social and economic factors are not considered.

According to the farmers in Pampanga, they produce less yield during the rainy season because of typhoons, tropical cyclones, tropical storms, and Southwest Monsoon. Strong wind and rain makes the rice plants lie closely to the land and producing low yields.

Table 2. Pearson's correlation results for relationship between rainfall and rice yield

		Rainfall	Rice Yield
Rainfall	Pearson Correlation	1	-.382
	p-value		.000
Rice Yield	Pearson Correlation	-.382	1
	Sig. (2-tailed)	.000	

Legend:

0.00 to ±0.20	*slight correlation*
±0.21 to ±0.40	*low correlation*
±0.41 to ±0.60	*moderate correlation*
±0.61 to ±0.80	*high correlation*
±0.81 to ±1.00	*very high correlation*

3.5 Cropping Calendar of Pampanga

3.5.a Water Requirement of Rice

A 120-day variety, as shown in Figure 8, spends about 60 days in the vegetative phase, 30 days in the reproductive phase, and 30 days in the ripening phase when planted in a tropical environment (Ricepedia, 2018). Rice plants during their early stage of growth and development (vegetative stage), which takes 60 days, need only a little amount of water, so the two consecutive months that have less rainfall must be chosen.

During their reproductive stage, which takes 30 days, the rice plants need larger amount of water up to the flowering stage so this phase should be undertaken in a month wherein the rainfall count is high.

The ripening stage, which takes 30 days, is from milk, dough, yellowish and full ripening of grains, only a little amount of water is needed by the rice plants. No standing water is needed after the grains have become yellowish in color. Normally, no more water is needed when the ripened grains of the rice plants are about to be harvested. The draining of the farm land is usually done ten days before harvesting. The month that has less rainfall is suitable for this phase.

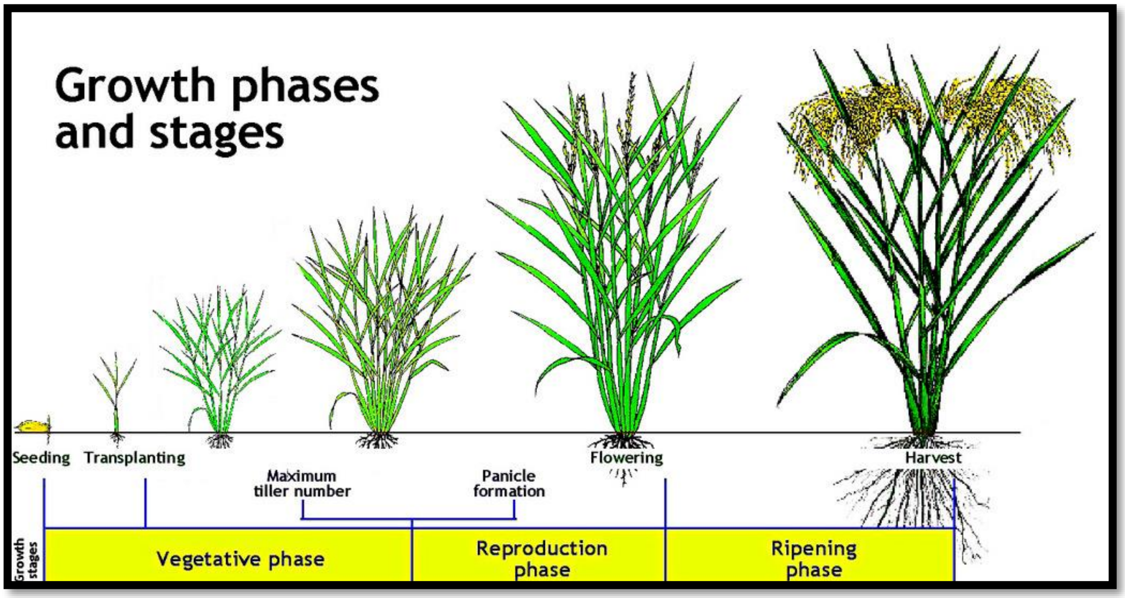

Figure 8. Growth Phases and stages or rice plant.

3.5.b. Proposed Cropping Calendar

Before proposing a new cropping calendar, the current cropping calendar must be observed first. Table 3, Table 4, Table 5, and Table 6 were the bases in choosing the better months for each stage. The temperature and rainfall based on the current cropping calendar must meet the temperature and rainfall needed per stage.

Table 3. First planting season of the current cropping calendar

Stages (First Cropping)	Temperature needed	Temperature based on the Current Cropping Calendar	Rainfall needed	Rainfall based on the Current Cropping Calendar
Vegetation (May-June)	22-31°C	28.30	Little amount of water	369.55mm

Reproduction (July)	22-31°C	27.22	Large amount of water	922.03mm
Ripening (August)	22-31°C	27.02	No standing water	783.83mm

Table 4. First harvesting season of the current cropping calendar

Stages (First Cropping)	Temperature needed	Temperature based on the Current Cropping Calendar	Rainfall needed	Rainfall based on the Current Cropping Calendar
Harvesting (August-November)	22-31°C	27.08	No water needed	403.84mm

Table 5. Second planting season of the current cropping calendar

Stages (Second Cropping)	Temperature needed	Temperature based on the Current Cropping Calendar	Rainfall needed	Rainfall based on the Current Cropping Calendar
Vegetation (November-February)	22-31°C	28.30	Little amount of water	87.14mm;52.45mm ;91.04mm
Reproduction (January-March)	22-31°C	27.22	Large amount of water	22.97mm;68.07mm ;70.09mm

Ripening (February-April)	22-31°C	27.02	No standing water	68.07mm;70.09mm ;193.07mm

Table 6. Second harvesting season of the current cropping calendar

Stages (Second Cropping)	Temperature needed	Temperature based on the Current Cropping Calendar	Rainfall needed	Rainfall based on the Current Cropping Calendar
Harvesting (February-July)	22-31°C	27.08	No water needed	332.06mm

Proposed Cropping Calendar

Table 7, Table 8, Table 9, and Table 10 show the suggested months for the planting and harvesting season for the first and second cropping.

For the first cropping, the planting starts from June to September while the harvesting starts from September to December. For the second cropping, the planting season begins from December to April while the harvesting season begins from February to June.

Since the vegetative phase needs a little amount of water, it is best to start on the month of June for the first cropping, and December for the second cropping. As seen on the Table 12, the rainfall count in June and December are enough for the vegetative stage.

The reproductive phase needs a lot of water so the months that are suitable for it are the months July and August for the first cropping, and January, February and March for the second cropping.

The ripening stage needs a few to zero water. Therefore, the months that are appropriate in this phase are September for the first cropping, and March and April for the second cropping.

During the harvesting of grains, the farm land should be drained (Pinoy Rice Knowledge Bank, 2018). With this, the harvesting season must be on the months with less rainfall.

The rainfall count during the harvesting seasons of the proposed cropping calendar is less than the rainfall count of the current cropping calendar.

The period for the second planting season of the proposed cropping calendar is short compared to the period of the second planting season of the current cropping calendar. This is to avoid the months that obtained the highest rainfall count for the past 20 years. These are the months of July and August. In order to make sure that the harvesting period was finished prior to these months to avoid extreme losses.

Table 7. First planting season of the proposed cropping calendar

Stages (First Cropping)	Temperature needed	Temperature based on the Current Cropping Calendar	Rainfall needed	Rainfall based on the Current Cropping Calendar
Vegetation (June-July)	22-31°C	27.57	Little amount of water	670.52mm
Reproduction (August)	22-31°C	27.02	Large amount of water	783.83mm
Ripening (September)	22-31°C	27.09	No standing water	402.27mm

Table 8. First harvesting season of the proposed cropping calendar

Stages (First Cropping)	Temperature needed	Temperature based on the Current Cropping Calendar	Rainfall needed	Rainfall based on the Current Cropping Calendar
Harvesting (September-December)	22-31°C	26.85	No water needed	228.37mm

Table 9. Second planting season of the proposed cropping calendar

Stages (Second Cropping)	Temperature needed	Temperature based on the Current Cropping Calendar	Rainfall needed	Rainfall based on the Current Cropping Calendar
Vegetation (December-February)	22-31°C	28.30	Little amount of water	52.45mm;91.04mm
Reproduction (February-March)	22-31°C	27.22	Large amount of water	68.07mm;70.09mm
Ripening (March-April)	22-31°C	27.02	No standing water	70.09mm;193.07mm

Table 10. Second harvesting season of the proposed cropping calendar

Stages (Second Cropping)	Temperature needed	Temperature based on the Current Cropping Calendar	Rainfall needed	Rainfall based on the Current Cropping Calendar
Harvesting (March-June)	22-31°C	27.08	No water needed	250.57mm

Table 11. Average Monthly Temperature of Pampanga (1998-2017)

Month	Temperature
January	25.32
February	25.97
March	27.26
April	29.03
May	28.68
June	27.91
July	27.22
August	27.02
September	27.09
October	27.13
November	27.07
December	26.11

Table 12. Average Monthly Rainfall of Pampanga (1998-2017)

Month	Rainfall(mm)
January	22.97
February	68.07
March	70.09
April	193.07
May	319.31
June	419.79
July	922.03
August	783.83
September	402.27
October	336.93
November	92.35
December	81.92

After studying all the variables and taking all the factors into consideration, another cropping calendar based on the results of this study was produced. Figure 9 presents the proposed cropping calendar for the farmers in Pampanga. There is a slight adjustment in each planting and harvesting periods to avoid the heavy rainfalls during the ripening stage of rice plant and during the harvesting seasons.

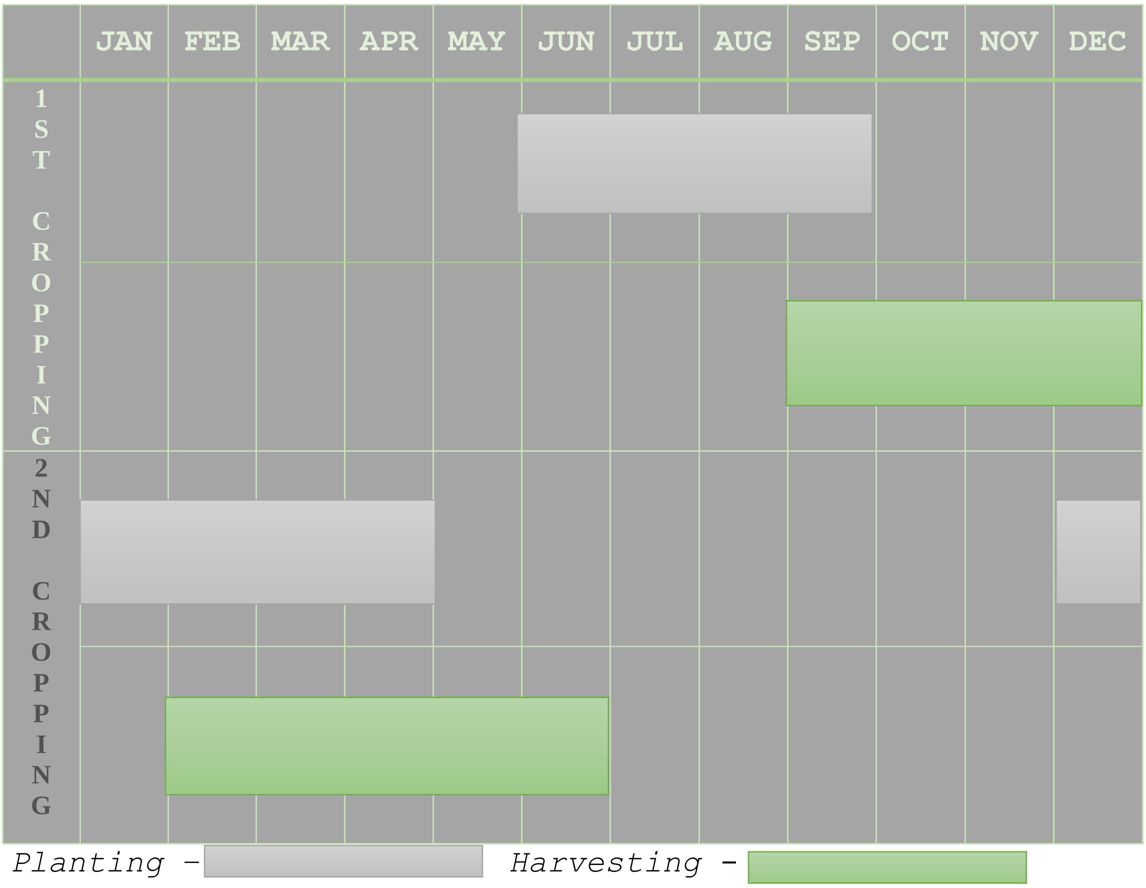

Figure 9. Proposed Cropping Calendar for the farmers in Pampanga

Figure 10 differentiates the current cropping calendar to the proposed cropping calendar. Farmers in Pampanga may use this as a reference in revising their existing cropping calendar or if they wish to make a new one.

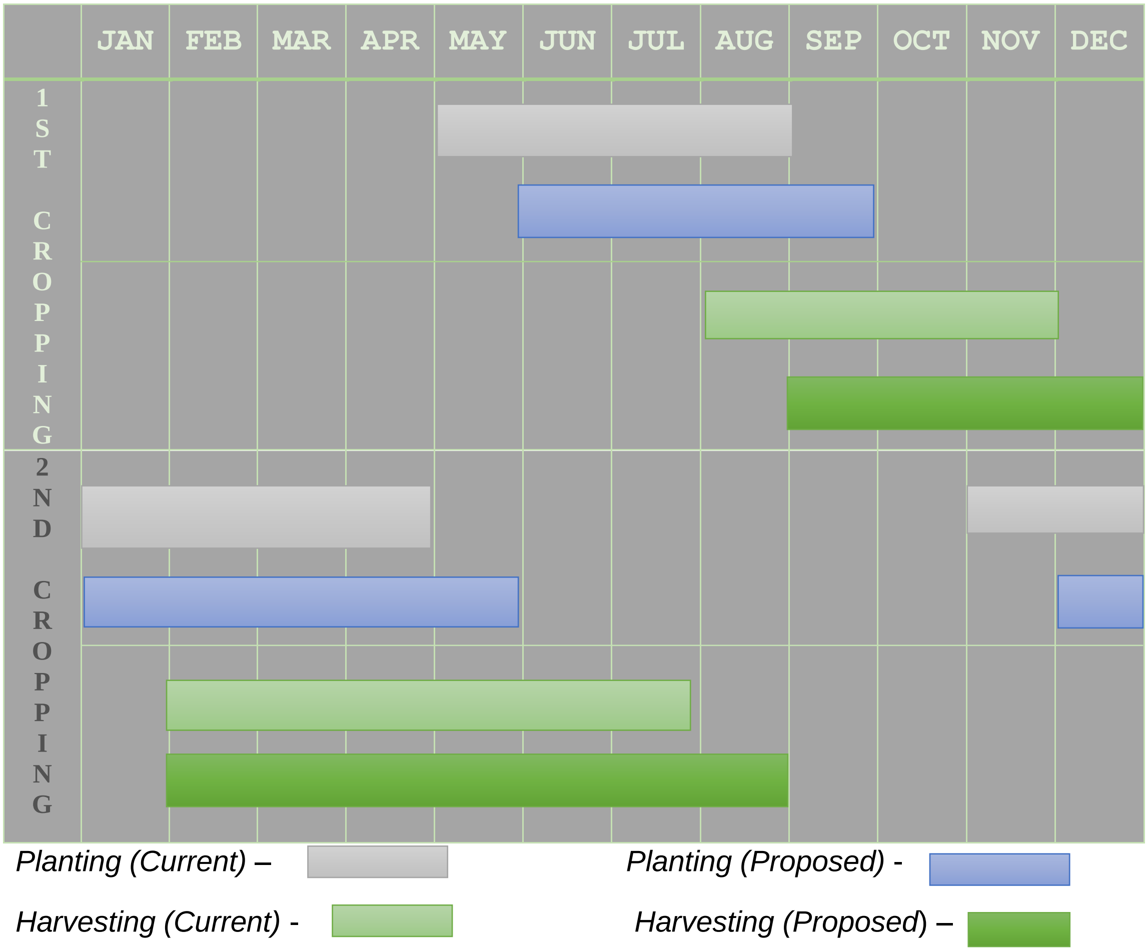

Figure 10. Comparison between the current cropping calendar and the proposed cropping calendar of Pampanga

Conclusions

1. It was observed that the temperature in Pampanga is increasing for the past years. Quarter 2 obtained the highest recorded temperature from 1998-2017. On the other hand, the years 1999 and 2002 had extreme rainfall counts. Quarter 3 obtained the highest rainfall count for the past 20 years.

2. The trend of the rice yield of Pampanga is positively increasing. The number of tons of rice that were produced were expanding.

3. There is a slight and not significant relationship between the temperature and rice yield. While the relationship of rainfall and rice yield is low inverse and significant.

4. In proposing a new cropping calendar, the period for the planting and harvesting seasons of the current cropping calendar should be adjusted to avoid the heavy rainfalls during the ripening stage of rice plant and during the harvesting seasons.

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