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Assessing Paddy Rice Yield Sensitivity to Temperature and Rainfall Variability in Peninsular Malaysia Using DSSAT Model

Danladi Yusuf Gumel[* a, c], Ahmad Makmom Abdullah [a], Alias Mohd. Sood [b], Rasheida E. Elhadi[a] , Mohammad Asrul Jamalani [a] Khaled Ali Ahmed Ben Youssef [a]

[a]*Eco- physiology Laboratory, Faculty of Environmental Studies, University Putra Malaysia.*
43400, UPM, Serdang, Selangor Darul Ehsan, Malaysia.
[b]*Department of Forest Production, Faculty of Forestry, University Putra Malaysia, 43400 UPM, Serdang, Selangor Darul Ehsan, Malaysia.*
[c]*Department of Geography, School of Arts & Social Sciences, Jigawa State College of Education, PMB 1002, Gumel, Nigeria.*

Abstract

The study assessed the seasonal potential effect of temperature and rainfall variability on MR219 using Ceres rice model v4.6.1.0 of the DSSAT modelling system. The model simulated sensibly rice yield with RMSPE OF 8.9%, with D- Index for grain yield of 0.99. However, the simulated yield positively correlates with observed yield (r = 0.715; p < .05), while the coefficient of determination (r^2 = 0.511). The model predicted changes in rice yield in all the three granary areas with varying degrees of gains and losses in the two seasons. The result from sensitivity analysis showed that during the main season $+1^0$C rise in the maximum temperature caused decrease in yield from -0.2 to -4.5% for MADA and KADA.A rise in maximum temperature up to $+5^0$C caused decrease in the yield ranging from -3.3 to -14.3 % for all the areas. Minimum temperature increase of $+1^0$C resulted in decrease in the yield ranging from -1.3 to -3.5%. During the off season, $+1^0$C increase in temperature caused decrease in yield from -0.5 to -2.3% for MADA and IADA. A rise in $+3^0$C maximum temperature caused decrease in the yield ranging from -2.5 to -7.5% for all the areas. While $+1^0$C rise in minimum temperature caused decrease in the yield from -3.1 to -6.6% for all the areas. Increase or decrease in the mean daily rainfall could be both beneficial as well as destructive depending on the season and location. The result showed that increase in mean daily rainfall of +1mm to +2mm decrease yield ranging from -4.0% to -51.5%. For MADA decrease in daily rainfall of 1mm to 2mm was shown to increase yield up to about 5.4%. In IADA, BLS during the main season decrease in the rainfall up to -7mm caused increased in yield from 6% to 7.2%. During the off season +1mm to +2mm increase in mean daily rainfall caused increased in yield ranging from 0.9% to 2.0%, but decrease in the mean daily rainfall caused yield to decreased ranging from -9.5% to -44.8%. For KADA, Kelantan during the main season increase or decrease in the rainfall decrease yield ranging from -4.4% to -22%. During off season, increase or decrease in the mean daily rainfall caused the yield to decrease ranging from -1.0% to -43.0%. Result from Analysis of variance revealed that under the likely changing condition, productivity in IADA will still likely be higher than in MADA, while KADA being the least will certainly continue to be more vulnerable to these changes than the other two granary areas.

Keywords: *Sensitivity, Paddy rice, Vulnerability, Temperature, Rainfall variability, DSSAT model*

1.0 INTRODUCTION:

Agricultural crop production remains largely vulnerable to the vagaries of Climate change variability. The relationship between agriculture and climate change are often intertwined globally with significant and direct impacts on agriculture and food systems (Brown and Funk, 2008). The impact of climate change on crop production globally has double-edged effects, the effects varies relatively depending on the climate change scenario and geographic location (IPCC 2007). But extreme events (drought, floods, and cyclones) will significantly reduce food production (Gregory et al., 2005; Parry et al., 1999; Reilly and Schimmelpfennig, 1999; Rosenzweig and Parry, 1994) for all areas across the globe. A number of empirical studies have demonstrated how agricultural productivity remain vulnerable to climatic perturbations (Nyang'au et al., 2014).

Although Malaysia, contribute minimally to the global rice output with share of 0.4%, yet Paddy rice cultivation predominates its rural economy. With nearly 286,000 Paddy farmers, about 41% (116,000) operates full time paddy cultivation. However, majority these rural Paddy farmers have an average land shareholdings of 1.06 hectare and wholly rely on income from the paddy cultivation (Alam et al., 2010; Toriman et al., 2013).

The recent scientific assessment showed that the coastal areas of the Southeast Asia as well as Malaysia, are extremely vulnerable to the effects of climate change (Alam et al., 2011). The challenges associated with this change is real and requires urgent attention in Southeast Asia. Global climate change scenarios prediction for Southeast Asian sub-region indicated that annual temperature will rise with about 0.4 to 1.3^o C by the year 2030 and may go up to 0.9 to 4.0^{o}C by 2070. Winter rainfall is predicted to decrease by about 10% in 2030 and further decreases by up to 20 to 30 % in 2070. While sea level rise may be as high as 3 to 16 cm by 2030 and 7 to 50 cm in the year 2070 (Tangang et al., 2011).

As for Malaysia, the climate change impact will be very significant (Alam et al., 2011), as it will negatively affect paddy rice productivity as well as the farmers' livelihood (Alam et al., 2013a; Alam et al., 2013b; Fazal and Abdul wahab, 2013). In spite of all deliberate efforts made by the government to achieve food self-sufficiency through paddy cultivation. The current climate change scenario indicated that, a rise in temperature above 25^{0}c may lead to the loss of grain mass of 4.4% per 1^{0}c rise in temperature and decline in yield as much as 9.6-10.0% per 1^{0}c increase in temperature respectively (Alam, et al., 2012; Barker and Allen, 1993). As paddy rice will continue to remain an important crop to the political economy of the country, achieving food self- sufficiency level through cultivation will require understanding of the vulnerability of rice production under the changing temperature and rainfall conditions.

However, temperature affects not only grain yields but also crop growth durations as such the time within which incident rays could be captured and converted into dry matter (Nyang'au et al., 2014). Temperature determines final leaf number, development of leaf canopy that determine the leaf area index and subsequent interception of the radiation incidence (Nyang'au et al., 2014; Yoshida, 1981).

Previous studies reported differential effects of temperature changes on paddy rice yield (Al-Amin et al., 2011; Lin et al., 2010; Singh et al., 1996; Vaghefi, 2013). The study by Al- Amin et al., (2011) reported the possible decrease in rice yield by up to 6.1% for every 1^0 c rise in temperature. Whereas, Lin et al., (2010) estimated a decline in rice yield by up to 17.8% with 3.1^0 c increases in temperature, that is for every 1^0 c rise in temperature this could lead to 6% decline in the rice yield. Also the study of Singh et al., (1996) reported that for 1^0 c rise in temperature under the current level of co_2 reduces yield to about 4.6 to 6.1% with the possibility of more decrease in yield with increasing temperature. Similarly in her study of the economic impact of climate change in Malaysia by Vaghefi (2013) reported that the yield of rice during main season decline from 4289 kg/ha in the year 2013 to only 3704 kg/ha by the year 2030. Rice yield during the off season will equally reduce to 3183kg/ha by 2030 from 4312kg/ha in 2013. Yield reduction were estimated at 0.8- 27.7% and 0.5- 42.8 % in the main and off seasons respectively.

Other studies showed how rice yield will decline between 4.6-6.1% per 1^0c rise in temperature and doubling co_2 concentration from 340ppm to 680ppm can resulted in 4^0c temperature increase on rice production in Malaysia (Alam et al., 2011; Alam, et al., 2013; Singh et al., 1996). Recent studies (Alam et al., 2013; Alam et al., 2010) showed that a 1% increase in temperature resulted in a 3.44% decline in current paddy yield and 0.03% decrease in paddy yield the following season, while 1% increases in rainfall causes 0.12% decline in current paddy yield and 0.21% decline in the subsequent season (Alam et al., 2013b; Alam et al., 2012).

Generally speaking, temperature is one of the major factors that constrains normal growth and yield in rice plant. It affects different vegetative and reproductive phases of rice plants including germination, root development, tillering, panicles initiation, anthesis and physiological maturity, and finally it affects grain yields (Yoshida, 1981). Temperature exceeding optimum levels relates negatively with rice production potential, as it retards photosynthetic processes, increases respiration, reduces vegetative and periods of grain filling (Nyang'au et al., 2014; Satake and Yoshida, 1978).

Similar studies showed that climate variability can influence crop yield under the influence of El- Niño causing oscillation in the onset and secession of rainy season (Lansigan et al., 2000). Moreover, Lansigan et al. (2000) indicated that crop physiological processes can be affected by the prevalence of sequences of wet and dry seasons, this can lead to premature acceleration or inhibition of crop growth and development. Also extended period of excessive rainfall could give rise to flooding at the early stage of crop development, leading to the termination of crop growth and significant decrease in grain yield. Typically when the flood incidence corresponds with critical growth period prior to harvest (Lansigan et al., 2000). However, the findings of (Eze and Bola, 2013) indicated that too much rainfall and too little of it retard normal growth and yield of rice, hence they concluded that rice performs best at reasonable or sufficient precipitation distributed throughout the rice growth cycle (90-160days).

Crop simulation models are capable of estimating the impacts of climate, weather variability, soil conditions, farm management, crop cultivar and the interface between crop growth and development, yields, efficient resource utilization and the environmental influences (Boote et al., 1996; Timsina and Humphrey, 2006). CSM are widely used to estimate the differences between probable and real crop yields, assess management alternatives, and detect the possible environmental effects. The aim of this study therefore, is to estimate the potential effect of temperature and rainfall variability on the future rice productivity MR219 Paddy rice from 2016 until 2035 with the view to understanding the relative vulnerability of each of the granary area.

2.0 MATERIALS AND METHODS

2.1 The study Areas

The study was conducted in three rice growing areas, Barat Laut Selangor and MADA, Kedah in the west coast and KADA, Kelantan in the east coast of Peninsular Malaysia. These areas were chosen to allow for comparative analysis as the three areas are located far apart.

Barat Laut Selangor (PBLS) region is located in the west coast zone. The climate of this area is characterized by seasonal evenly distributed rainfall. The area has dryness mostly prevailing in the months of February, June and July. The dryness is usually for a short span, lasting for less than one month. This area is also associated with occasional strong draughts of wind and early morning rainfall, particularly within the south west monsoon season starting from May to September. Moreover, the area has soils that are primarily marine and riverine alluvia with medium to heavy textured (Lin et al., 2010). Barat Laut Selangor is usually considered as the most highly productive rice growing areas in the Peninsular Malaysia, with higher performance more than MADA and KADA.

The Muda Agricultural Development Authority (MADA) is the biggest rice crop area, it covers a total area of 125 555 ha, found in the North- west of Peninsular Malaysia. Out of the total land area, 10,581 ha are in the north- western of Kedah and 20,304 ha are inside the southern part of Perlis state. Nearly 76% of the total area is under paddy cultivation with about 48,000 farming household (Singh et al., 1996). The area is located at about 5°45′–6°30′N latitude and 100°10′–100°30′E longitude in the vast flat alluvial Kedah-Perlis Plain which is 20 km wide and 65 km in length, between the foothills of the Central Range and the Straits of Malacca.

Kemubu Agricultural Development Authority (KADA), this granary area occupies greater part of the plain of Northern Kelantan; it is an area of high population density. The area comprises of five irrigation sites namely Tumpat, Pasir Mas, Pasir Puteh, Bachok and Kota Bharu. The total paddy cultivation area consisting of irrigation infrastructural facilities that aided two planting seasons in a year is about 31,464 hectares

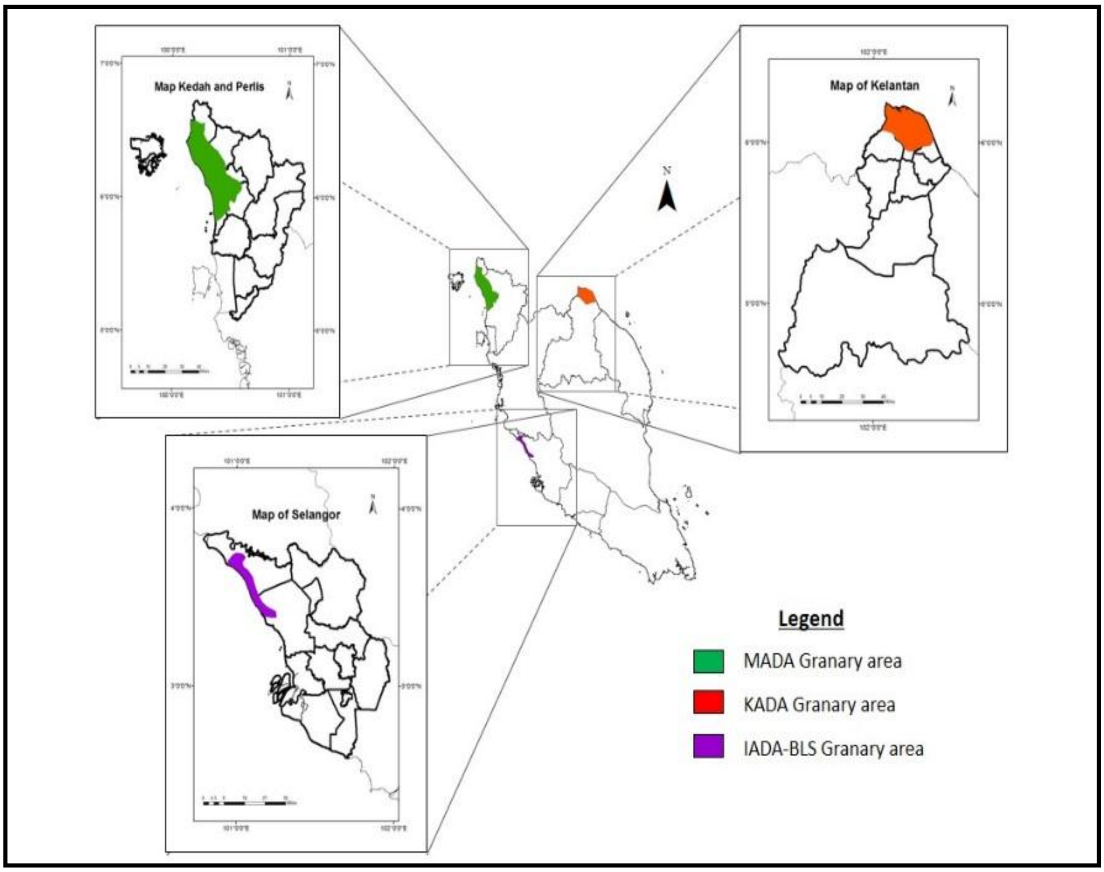

Figure 1: Map of Peninsular Malaysia showing the study Areas

2.2 Crop variety selection

The rice variety used is MR-219 as it is the most widely cultivated by many rice growers in Peninsular Malaysia. This variety was developed by the Malaysia Agricultural Development Institute (MARDI) in the year 2001. The cultivar has higher yield potentials, higher grains and is palatable. With best management performances and more fertilizer input, the cultivar has a potential of producing greater than 10tones/ ha, it has higher resistivity to common pests and leaf blight bacterial infestation. A grain of this cultivar weighs about 28 to 30mg; it has about 200 numbers of grains, and the maturity time ranging from 105 to 111 days (Vaghefi, 2013).

2.3 Crop model

The DSSAT CERES- rice modeling system is a physiologically-based highly developed rice crop growth simulation model. It has been extensively used to comprehend the relationship between rice and its environment. The model assesses yields of rice in irrigation and non-irrigation fields determines the period of each growth stage, estimate production of dry matter and partitioning, root system dynamics, the effects of soil water and nitrogen contents on photosynthetic processes, determine carbon balance and water balance. For comprehensive model description, see (Hoogenboom et al., 2012; Jones et al., 2003; Ritchie et al., 1987).

2.4 Data requirements

2.4.1 Site characteristics of the study areas

For each of the three granary areas under this study, data about the latitude and longitude, elevation, slope, aspects, drainage (type, spacing and depth) etc. were obtained from the Malaysia Department of Agriculture (DOA).

2.4.2 The crop management data

Management data required by the model include planting method, cultivar, planting date, planting density, row spacing, planting depth, plant per m^2, irrigation amount and frequency, fertilizer application dates, and amounts. These data were obtained from relevant department and agencies such as IADA, DOA, and MARDI etc (Table 1).

2.4.3 Soil and crop management data

Includes soil and hydrologic characteristics (i.e., pedological and hydrological data), and crop management. Input data related to soil characteristics include soil texture, number of layers in soil profile, soil layer depth, pH of soil in water for each depth, clay, silt and sand contents, organic matter, cat ion exchange capacity, etc. were collected from relevant department e.g. DOA, MARDI etc.

Table 1: Crop management data used in the Model

Serial No.	Simulation Parameter	IADA, BLS	MADA, Kedah	KADA,Kelantan
1.	Cultivar	MR219	MR219	MR219
2.	Planting date			
3.	Planting Method	Dry seed	Dry seed	Dry seed
4.	Emergency date	7 dys after planting	7days	7days
5.	Transplanting date			
6.	Planting distribution	Rows	Rows	Rows
7.	Row spacing	25cm x 25cm	25cm x 25 cm	25 cm x 25 cm
8.	Planting depth	2.5cm	2.5cm	2.5cm

9.	Transplanting age	14 days	14days	14days
10.	Plant per paddy field	200	200	200
11.	Plant per m^2			
12.	Fertilizer application			
	Nitrogen	140kg/ha		100kg/ha
	P_2O_5	150kg/ha		44kg/ha
	K_2O	200kg/ha		50kg/ha
	Organic	Urea 100kg/ha		100kg/ha

2.4.4. Weather data

These consisted of daily maximum temperature (T_{max}), daily minimum temperature (T_{min}), daily incoming solar radiation (Srad), daily precipitation and relative humidity (RH) for the two growing seasons. Data from Subang meteorological station representing Barat Laut Selangor, for Alor star representing MADA, Kedah, Kota Baru station representing KADA, Kelantan. The data were obtained from Malaysia Meteorological Department (MMD) for the year 1971- 2015 and forecasted climate data based on the IPCC 4AR A1B Emissions scenario, from 2016 until 2035 over Malaysia. Hence, six input files were created to run the model;

- (i) Weather file (weatherman) with annual daily solar radiation, maximum air temperature, minimum air temperature, precipitation and relative humidity
- (ii) Soil file (SBuild) file with the soil properties of the three granary areas under this study.
- (iii) Rice management file (XBuild) file
- (iv) Experimental data file (FILEA)
- (v) Genetic coefficient file (FILEC), with thermal time from emergency to the end of juvenile stage (P1), rate of photo-induction (P2R), optimum photoperiod (P2), thermal time for grain filling (P5), conversion efficiency from sunlight to assimilates (G1), tillering rate (TR), and grain size (G2). The cultivar coefficient for MR 219 were iteratively determined in the DSSAT v4.6 following (Rezzoug et al., 2008).

2.5 Data Analysis:

The DSSAT CERES rice model v4.6 was used to predict rice MR219 growth,development,and response to different prevailing climatic conditions in the three granary areas under this study. It follows by sensitivity analysis to determine the effect of changes in the weather conditions on the MR219 grain yields in the respective granary areas.

2.5.1 Model Calibration

This is aimed to reduce error between the model output and the real data and to determine parameters intended to be used in the model. Therefore, to calibrate the model, daily observatory weather data including both minimum and maximum temperature, solar radiation, rainfall and relative humidity spanning for the period 2001 to 2014 for Subang Jaya meteorological station were obtained from Malaysia Meteorological Department and used in the model to simulate yield for the Main season at IADA, Barat Laut Selangor.

However, the DSSAT CERES-rice module contains a number of adjustable genetic coefficients of different cultivars which needs to be calibrated as well. Here the calibration of MR 219 cultivar genetic coefficient were done iteratively primarily for the purpose of minimizing the RMSE and achieving higher accuracy in the yield prediction. Adjustments in the parameterization were purposefully done to calibrate specific conditions, were done individually while comparing the model output with the observed data in respect of each granary area.

2.5.2 Model evaluation and testing

The Model evaluation involves comparing the outputs of the model with actual data and a examining its appropriateness for a future purpose. In fact, it is a documentation of the accuracy of the output for particular predictions in specified environments, with appropriate consideration given to possible errors in input variables or evaluation data. For the model validity, RMSE, Root Mean Square Percentage Error (RMSPE) and Coefficient of Residual Mass (CRM) can be used to evaluate the error:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)^2} \tag{1}$$

$$\mathrm{RMSPE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{(P_i - O_i)}{O_i}\right]^2} \times 100 \tag{2}$$

$$\mathrm{CRM} = \frac{\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} O_i} \tag{3}$$

Where, P_i is the predicted value of the ith year, O_i is the ith year observed value. These statistics have been widely applied for model evaluation (Batchelor et al., 2004; Satake and Yoshida, 1978; Kobayashi and Salam, 2000).

3.0 RESULTS AND DISCUSSION

3.1 Model Validation

The validation results showed that the DSSAT model simulated yield differs from the observed yield with about 477.8 kg ha^{-1}. The model simulated sensibly the yield with RMSPE of 8.9% and the index of agreement (D- Index) for grain yield of (0.99) closer to 1 also reveals that the model performed well in predicting the yield (Nyang'au et al., 2014; Oteng-Darko et al., 2012). The RMSPE is a measure of dispersion of the simulated yield relative to the real observed yield. However, the result of the correlation coefficient indicated that there is a strong positive correlation between the simulated yields and observed yields (r = 0.715; $p < .05$), while the coefficient of determination ($r^2 = 0.511$) showed that observed yields help to explain 51.1% of the variance in the simulated yield by the model. (Figure 2). A positive CRM indicated that greater number of the yield from the model simulation are less than the observed yields. The average simulated yields is slightly lower than the average observed yield with about 5.2%. Even though, on a general note the model underestimate the yield with few instances of over estimation of the real yield, still the model demonstrated the trend in variability of the rice yield fairly well.

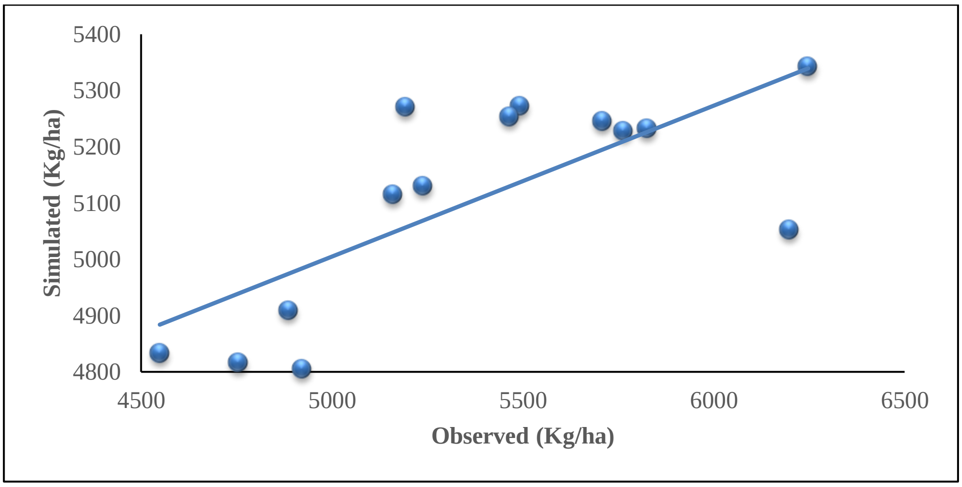

Fig. 2: A scatter Plot of Correlation between simulate and Observed Yield

3.2 The effect of Predicted temperature and rainfall changes on the Paddy rice Yield

Here the effects of temperature and rainfall in the three areas i.e. MADA, Kedah, IADA, Barat Laut Selangor during the two respective Main and off seasons as well as the average annual values were predicted. The objective here is to determine the effect of climate change variability on the Paddy rice yield from 2016 until 2035. Therefore, other environmental factors such as changes in the atmospheric CO_2, changes in plant nutrients, effects of pest and diseases etc. and management practices were not accounted for in this case. This assumption was premised on the fact that rice plant growth development and yield are critically determined by the climatic factors of temperature and rainfall as indicated in many literature (Van Oort et al., 2011). Therefore, the concern is to determine the effects of the changes in these two critical climatic factors as the two exhibits inherent variability in the climate of these areas.

Figure 3 & 4 presents the model results of the yield prediction in Muda Agricultural Development Area (MADA), Kedah for both main and off seasons from 2016 to 2035. A baseline production value was determined by taking the average production data of the last three years of seasonal production historical records 1981- 2014. The data was obtained from the department of Agriculture (DOA), Malaysia for each of the three study areas. As for MADA, 4057kg/Ha and 4685kg/Ha were used as a Baseline yield production value for the Main season (Sept- February) and off season (March to August) respectively. The predicted yield over the period shows varying percentages in gain and losses by obtaining the difference between predicted yields and the baseline values.

During the main season, the model result predicted increase in yield with varying percentages ranging from 7.4% in 2018 to as high as 27.8 % in the year 2029. While only two years with decrease in the yield were predicted by the model, i.e. in the year 2020 with -0.12% and in the year 2027 at -0.41%.

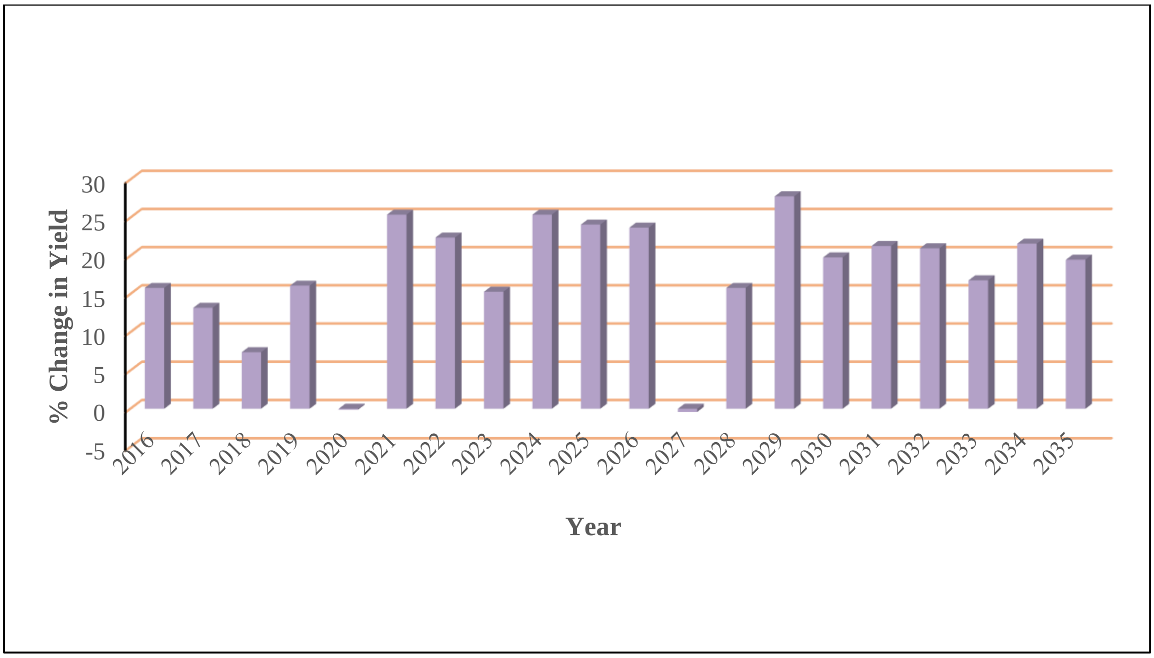

Figure 3: Percentage changes in the Paddy Yield for Main season at MADA

Moreover, the model prediction during the off season also showed increase in the yield for most of the years with varying percentages ranging from 4.2% in 2035 to as high as 27.0% in 2029. Over the period 2016 to 2035, only four years were predicted to have decrease in the yield with and the year 2024 was predicted to record highest decrease in the yield.

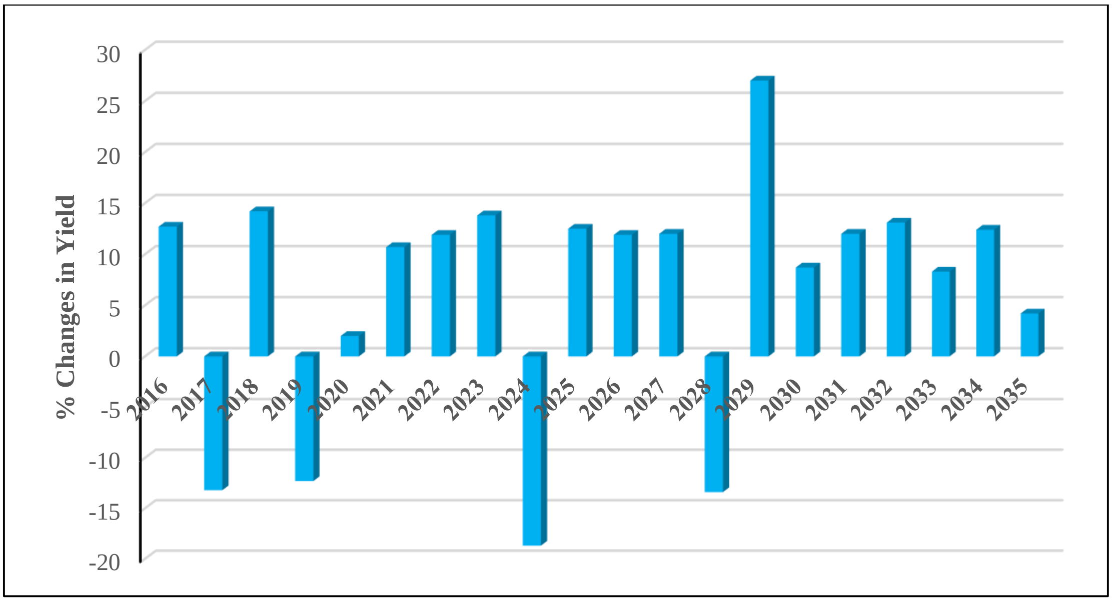

Figure 4: Percentage changes in the Paddy Yield for off season at MADA

Figure 5 & 6 presents the model results of the yield prediction for the IADA, BLS during the main and off seasons. The baseline yield of 6090kg/ha and 6358 kg/ha were used for main season and off seasons to determine yield variation over the period. The model predicted decrease in the yield for both main and off season throughout the entire period. During the main season, the model predicted highest decline in the yield by -20.4% in the year 2019. During the off season the model predicted the highest decrease in the yield of -22.2% by 2020.

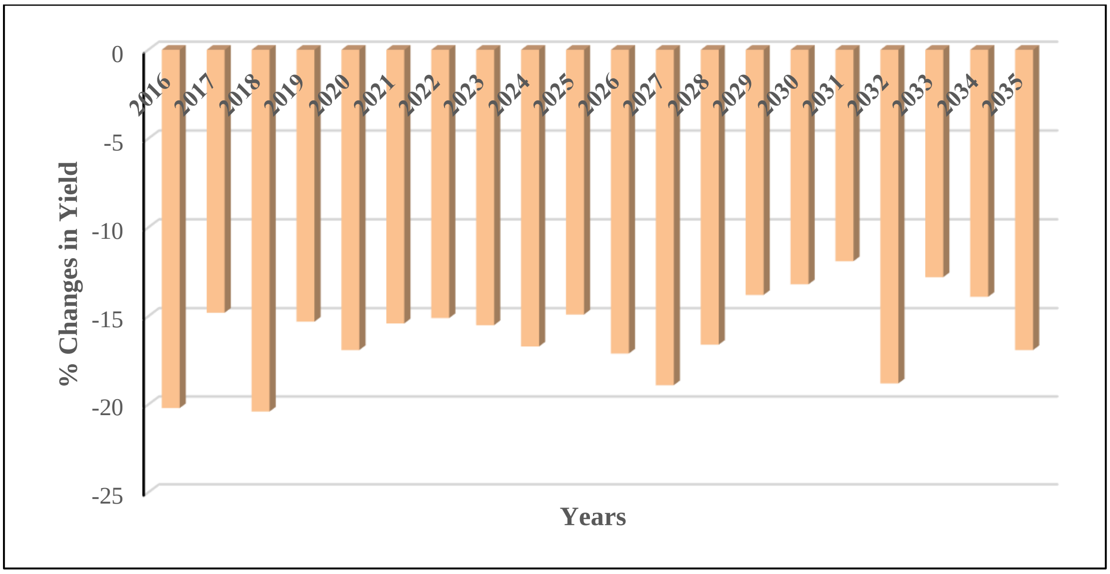

Figure 5: Percentage changes in the Paddy Yield for Main season at IADA, BLS

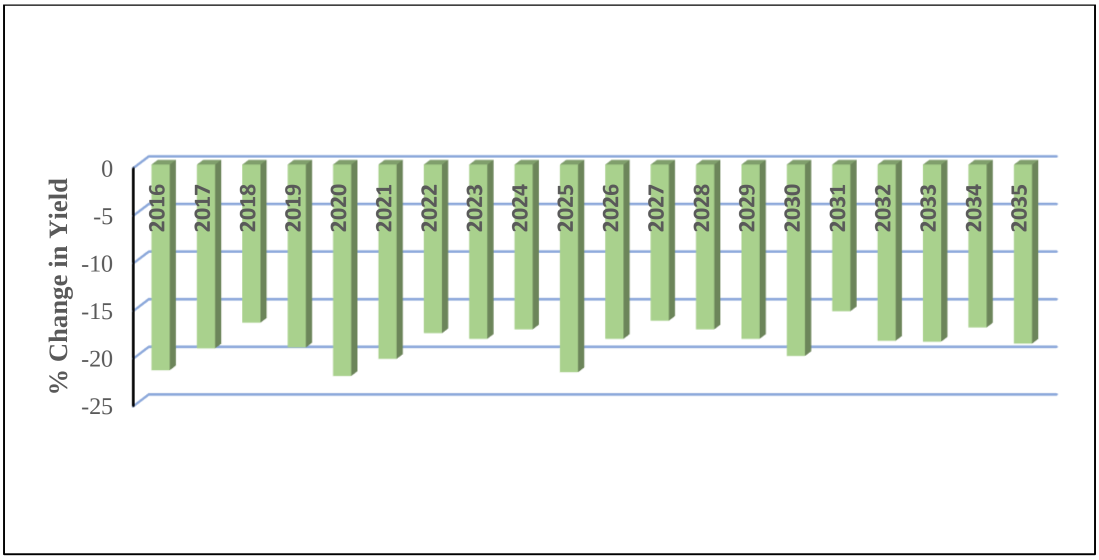

Figure 6: Percentage changes in the Paddy Yield for off season at IADA, BLS

Figure 7 & 6 contain result of the predicted yield for main and off seasons for Kemubu Agricultural Development Authority, KADA Kelantan. A baseline average production yield of 3959kg/ha and 3858kg/ha were used to determine the percentage change between the predicted and observed yield.

During the main season the model predicted increase in yield for twelve years and the rest of the eight years were forecasted to witness decrease in the yield with highest increased in yield of 20.4% in the year 2029. While highest decrease in yield was forecasted to be -16.3% in the year 2032.

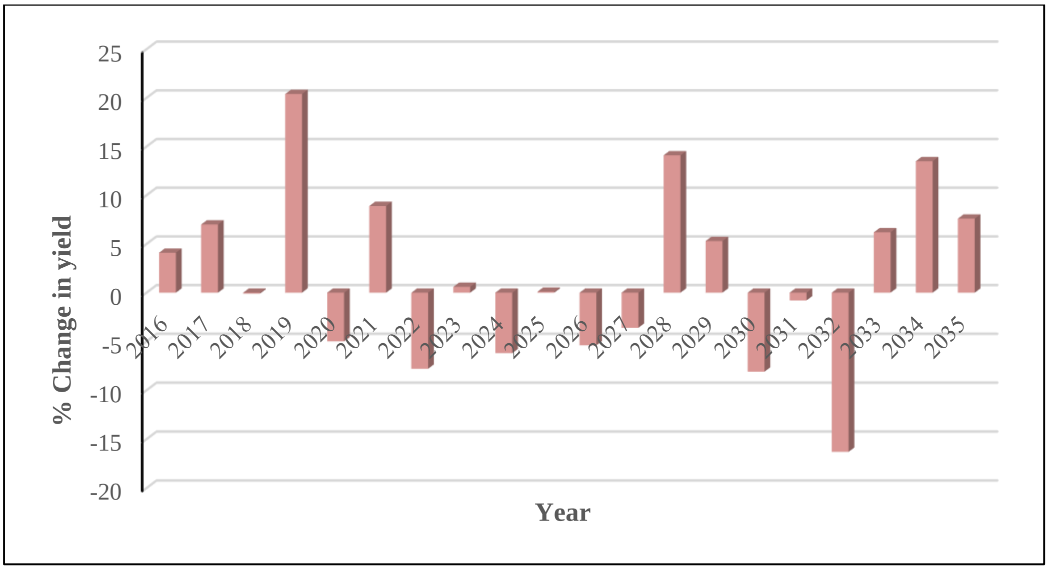

Figure 7: Percentage changes in the Paddy Yield for Main season at KADA, Kelantan

The off season model prediction showed that thirteen years may witness increase in the yield, with the highest increase of 28.6% in 2026, while the rest of the seven years were predicted to have decrease in the yield, with the highest decrease of -18.5% in the year 2030.

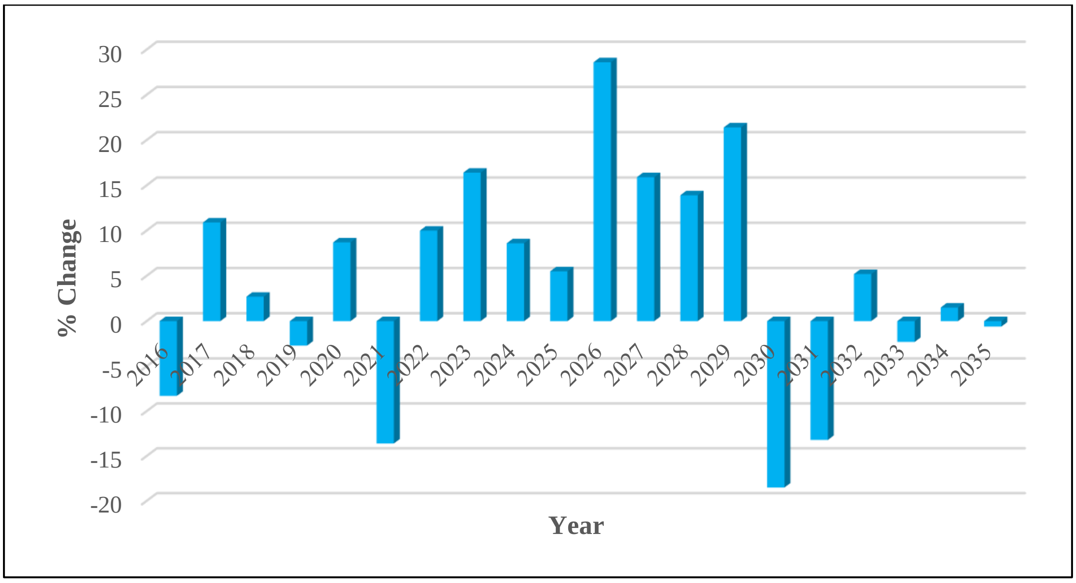

Figure 8: Percentage changes in the Paddy Yield for off season at KADA, Kelantan

3.3 Sensitivity of Paddy Rice Yield to the Changing Temperature

The amount of temperature considerably affects both the growth, duration and pattern of paddy rice plant. Changes in these factors of both diurnal minimum and maximum temperature, pattern of rainfall, or the interplay of both has a likely strong correlation with the grain yield (Nyang'au et al., 2014). The effects of changes in temperature on MR219 grain yield in MADA, Kedah, IADA, BLS and KADA, Kelantan granary areas were evaluated for both main and off season by changing the maximum and minimum temperature by +1, +2,+3, +4 and +5 and subsequently ran the simulations.

In MADA, Kedah under the 2016 main cropping season management practices, with a mean daily maximum temperature of 32.4^{0}C and the mean daily temperature of 23.5^{0}C, and the mean daily rainfall of 6.7mm. The model simulated a grain yield of 4699 kg/ha for the MR219. With an increase in the maximum temperature of +1^{0}C leads to the decrease in grain yield of -4.5 %, a rise in +2^{0}C caused a decline in the grain yield of -9.4%, a rise in +3^{0}C resulted in the grain yield decline of -12.0%, with +4^{0}C rise in the maximum temperature, the yield decrease by -13.0% and with temperature rise up to +5^{0}C the yield decline by -14.3%. Similarly a rise in the minimum temperature by only +1^{0}C resulted in the decrease in yield by -1.3% beyond this range the temperature became unbearable, hence the model could not be simulated (Table 2a).

In IADA, Barat Laut Selangor, during the 2016 main season cropping management practice with mean maximum daily temperature, mean minimum daily temperature, and mean daily rainfall of 32.6^{0}C, 24.1^{0}C and 7.6mm respectively. The model simulated a grain yield of 4857 kg/ha for the MR219. When the mean maximum daily temperature was increased by +1 the grain yield increases by 0.3 %, at +2^{0}C temperature increase the grain yield declined by -0.8%, further increasing temperature up to +5^{0}C cause the grain yield to decrease by -3.3%. When mean daily minimum temperature was increased by +1^{0}C the grain yield decreased by -1.4% beyond which the model could not be simulated due as the temperature is not favourable (Table 2b).

The mean daily maximum and minimum temperature and rainfall for the 2016 main season rice cropping period in KADA, Kelantan were 29.9^{0}C, 23.3^{0}C and 12.2mm respectively. As such under this condition the model simulated a grain yield of 4124 kg/ha. By adjusting the mean maximum temperature +1^{0}C the grain yield decreased by -0.2 %, further adjustment with +2^{0}C the grain yield decreased by -0.7%, with the increase in temperature up to +5^{0}C the grain yield decreased by -7.8%. Adjusting the mean daily temperature by +1^{0}C the model aborted could not be simulated as the minimum temperature and maximum gap gets reduced (Table 2c).

Table 2: Effects of Changing temperature on MR219 Yield during the Main season

Granary Area	Temp. Plus (^{0}C)	Grain Yield at Tmax (kg/ha)	% Change	Grain Yield at Tmin (kg/ha)	% Change
MADA Kedah a)	+1	4485	-4.5%	4636	-1.3%
	+2	4253	-9.4%	-	-
	+3	4135	-12.0%	-	-
	+4	4086	-13.0%	-	-
	+5	4023	-14.3%	-	-
IADA, BLS b)	+1	4872	0.3%	4785	-1.4%
	+2	4814	-0.88%	-	-
	+3	4806	-1.0%	-	-
	+4	4723	-2.7%	-	-
	+5	4696	-3.3%	-	-
KADA, Kelantan c)	+1	4116	-0.2%	3827	-3.5%
	+2	4093	-0.7%	-	-
	+3	4076	-1.2%	-	-
	+4	4038	-2.0%	-	-
	+5	3800	-7.8%	-	-

Note: Tmax means maximum temperature; Tmin means minimum temperature

During the 2016 off season in MADA, with mean maximum and mean minimum temperature and mean daily rainfall of 33.3^{0}C, 24.3^{0}C and 4.7mm respectively, the model simulated grain yield of 5282 kg/ha. With increase in mean maximum temperature of +1 resulted in decrease in the yield by -2.3%, addition of +2^{0}C the yield decline by -0.1%, with up to +5^{0}C increase in the mean daily maximum temperature caused the yield to decrease by -5.0%. Changes in the mean minimum daily temperature by +1^{0}C rise resulted in the decline in the grain yield by -3.1% while beyond this increase the yield not be simulated by the model as the temperature is too unfavourable (Table 3 a).

During the off season rice cropping period in IADA, BLS with mean daily maximum temperature, mean daily minimum temperature, and mean daily rainfall of 33.7^{0}C, 25.2^{0}C, and 6.4 mm respectively, the model simulated a grain yield of 4983kg/ha. With the increase in mean daily maximum temperature by +1^{0}C the grain yield decreased by -0.5%, with +2^{0}C increase in temperature the yield is reduced by -3.7%, with up to +5^{0}C increase in mean daily maximum temperature the grain yield decreased by up to -9.3%. As the mean daily minimum temperature was adjusted by up to +2^{0}C the grain yield decreased by -4.5% beyond this the temperature became unfavourable for the model to simulate the yield (Table 3b).

In KADA, Kelantan with the mean daily maximum and minimum temperature, and mean daily rainfall of 32.4^{0}C, 24.5^{0}C and 4.1mm respectively, during the 2016 rice cropping off season the model simulated grain yield of 3534 kg/ha. Adjusting the mean maximum temperature first by +1^{0}C the simulated grain yield increased by 3.5%, with adjusting the temperature by +2^{0}C the grain yield further increased by 4.1%, with increase in the temperature by 3^{0}C and up to +5^{0}C, the grain yield get reduced between -2.5% to -6.0%. The adjustment of the mean minimum temperature by up to +2^{0}C the grain yield decreased by -6.6%. Beyond this the model could not be simulated as the amount of the minimum temperature became unfavourable for the yield to be simulated (Table 3 c).

Table 3: Effects of Changing temperature on MR219 Yield during the off season

Granary Area	Temp. Plus (^{0}C)	Grain Yield at Tmax (kg/ha)	% Change	Grain Yield at Tmin (kg/ha)	% Change
MADA (a) Kedah	+1	5160	-2.3%	5113	-3.1%
	+2	5276	-0.1%	-	-
	+3	5140	-2.6%	-	-
	+4	5243	-0.7%	-	-
	+5	5017	-5.0%	-	-
IADA, (b) BLS	+1	4955	-0.5%	4911	-1.4%
	+2	4795	-3.7%	4754	-4.5%
	+3	4605	-7.5%	-	-
	+4	4692	-5.8%	-	-
	+5	4518	-9.3%	-	-
KADA, (c) Kelantan	+1	3660	3.5%	3300	-6.6%
	+2	3679	4.1%	3474	-
	+3	3444	-2.5 %	-	-
	+4	3323	-5.9%	-	-
	+5	3320	-6.0%	-	-

Note: Tmax means maximum temperature; Tmin means minimum temperature

The model simulation results presented in Table 2 and 3 shows that a rise in temperature leads to the corresponding decrease in the grain yield of MR219 in almost all the three granary areas. The increase in minimum temperature comparatively has a grave adverse effect on the MR219 yields than the maximum temperature. The severity of the impact of the minimum temperature rise on rice yield is posibly attributable to the increased respiration losses (Godwin et al., 1989; Nyang'au et al., 2014), as well as the reduction in the rate of grain growth in the initial and later stages of grain filling and diminished cell size and endoplasmic surface area (Morita, et al., 2005; Nyang'au et al., 2014). Moreover, wide ranging temperature can tremendously affect rice growth in terms of duration, pattern as well as the output (Yoshida, 1981).

3.4 Sensitivity of Paddy Yield to the changing Rainfall

Table 4 shows the effects of changing rainfall on MR219 yield during main and off seasons for the three rice growing areas. The mean daily rainfall during the 2016 main cropping season for MADA was 6.7mm, and therefore, to evaluate the sensitivity of rice yield to the changing amount of daily rainfall, the model simulated the yield by adding +1 mm of rainfall, the simulated grain yield was observed to have decrease by -6.7%, when rainfall was increased by +2 mm the yield decreased by -26.7%. But when the daily mean rainfall was decreased by -1mm the grain yield increased by 2.9%, a further reduction in the mean daily rainfall by -2mm the grain yield was further increased by 5.4%. This shows that excessive rainfall in MADA could be detriment to rice yield in this areas, however minor decrease in rainfall may not serve as a threat to rice growth except under the extreme spell as it was shown that when rainfall was reduced by up to -7mm the grain yield then reduced by -14.1% as shown in Table 4 (a).

Table 4: Effects of Changing Rainfall on MR219 Yield during the two seasons

Granary Area	Rainfall changes (mm)	Grain Yield at Main season RF (kg/ha)	% Change	Grain Yield at off season RF (kg/ha)	% Change
MADA	+ 1	4351	-6.7%	5225	-1.0%
Kedah	+ 2	3419	-26.7%	5246	-0.6%
(a)	-1	4805	2.9%	5138	-2.7%
	-2	4919	5.4%	4831	-8.5%
	-5	4543	-2.6%	-	-
	-7	4004	-14.1%	3010	-43.0%
IADA,	+ 1	3553	-26.8%	5028	0.9%
BLS	+ 2	2340	-51.8%	5083	2.0%
(b)	-1	5149	6.0%	4506	-9.5%
	-2	5211	7.2%	4116	-17.3%

	-7	5160	6.2%	2748	-44.8%
KADA, Kelantan **(c)**	+ 1	3942	-4.4%	3661	3.5%
	+ 2	3383	-17.9%	3646	3.1%
	-1	3984	-3.4%	3359	-4.9%
	-2	3960	-3.9%	3497	-1.0%
	-3	3775	-8.4%	3375	-4.4%
	-4	3215	-22.0%	3215	-9.0%

But during the off season in MADA, with a mean daily rainfall of 4.7 mm, increase or decrease in the mean daily rainfall generally cause decrease in the grain yields as shown in Table 4(a). Decrease in rainfall during the off season is shown to have more devasting effect on the grain yield than increase in amount of the mean daily rainfall in the off season. As +1mm increase in the mean daily rainfall resulted in only -1.0% decrease in the grain yield. Conversely, when rainfall was decreased by -1mm this resulted in -2.7% decrease in grain yield, however, increase in mean daily rainfall of +2mm caused only -1.6% decrease in grain yield. Whereas, derease in the mean daily rainfall by -2mm resulted in -8.5% loss in the grain yield. Severe decrease in rainfall up to -7mm resulted in decrease in yield by -43.0% .

In IADA, BLS, changes in the mean daily rainfall either increase or decrease has a profound effects on the grain yield in all the two seasons as shown in Table 4 (b). During the main cropping season, when mean daily rainfall was increased by +1mm this resulted in -26.8% decrease in the grain yield. A further increase in the mean rainfall by +2mm caused a decrease in the mean yield by -51.8%. However, when the mean daily rainfall was reduced by -1mm the grain yield increased by 6.0%, and -2mm decrease in the mean daily rainfall increased the yield by 7.2%. When the mean rainfall was reduced up to -7mm the grain yield increased by 6.2%. During the off season, an increased in the mean daily rainfall by +1mm caused grain yield to increase by 0.9%, an increase in +2mm of the mean daily rainfall caused the increase in yield by 2.0%. When the mean daily rainfall was reduced by -1mm the yield decreased by -9.5%, a reduction in the mean daily rainfall by -2mm the grain yield decreased by -17.3% , and a decrease in the rainfall by up to -7mm the grain decreased by -44.8%.

In KADA, an increase in the rainfall by +1mm during the main season caused the grain yield to decrease by -4.4%, a +2mm increase in mean daily rainfall in main season resulted in the decline of the yield by-17.9%. Equally when rainfall was decreased by 1mm yield declined by -3.4%, a decrease in the mean rainfall by -4mm caused a declined in the yield by-22.0%. During the off season, an increase in the mean daily rainfall by +1mm increased the grain yield by 3.5%, additional +2mm in the mean daily rainfall increased the yield by 3.1%. Whereas, a decrease in the mean daily rainfall by -1mm caused the yield to decrease by -4.9%, while -2mm decreased in the rain caused the grain yield to decrease by -1.0%. Decreasing the mean daily rainfall by -3mm caused the yield to decrease by -4.4% and up to -4mm decrease in the rain resulted decline in the yield by -9.0% (Table 4 c).

3.5 Variance Analysis of the Predicted Paddy Yields

Table 5 present the result of a One Way ANOVA test conducted to compare the difference between the predicted yield of the main season and predicted yield of the off season in the granary areas. The ANOVA result in Table 4.16 shows that there was a significant difference between granary areas on forecasted yield of the main season, F (2, 57) = 75.157, *p* = .000. Furthermore, the Tukey HSD Post Hoc test indicated that, there was a significant difference between MADA and IADA (Md = -345.300*, Std. Error = 90.779, *p* = .000), there was a significant difference between MADA and KADA (Md = 743.650*, Std. Error = 90.779, *p* = .000), and there was significant difference between IADA and KADA (Md = 1088.950*, Std. Error = 90.779, *p* = .000).

Table 5: ANOVA Test result of Predicted Main season and off season Yield

Variables	*n*	Mean ± SD	C.V	F	*p*
Main Season Yield				**75.157**	**.000**
MADA	20	4771.00 ± 317.67	0.066		
IADA	20	5116.30 ± 143.54	0.025		
KADA	20	4027.35 ± 354.54	0.088		
Off Season Yield				**41.462**	**.000**
MADA	20	4990.35 ± 123.59	0.093		
IADA	20	5168.95 ± 116.22	0.058		
KADA	20	4032.55 ± 470.51	0.111		

4.0 CONCLUSION

Temperature and rainfall changes effects on paddy rice yield in the three granary areas of Peninsular Malaysia were estimated. Increase in maximum and minimum temperature above optimal level of temperature for paddy rice production resulted in decrease in yield. However, the increase in minimum temperature comparatively has a grave adverse effect on the MR219 yields than the maximum temperature changes. Also changes in rainfall has different implication on the grain yield, but not as profound as the effect of changes in temperature. In MADA decrease in rainfall during the main season shows a marginal effect as against increase in rainfall which has a more devastating effect. In IADA rice growing areas rainfall changes have a more profound influence on the grain generally. In KADA, increase in rainfall in all the season is shown to have positive effects on the grain yield. But decrease in rainfall corresponding to off season has a serious negative effect on grain yield than during the main season. However, the result of the predictions clearly shows the unending vulnerability of paddy rice cultivation under the changing weather and climate. Moreover from our analysis of variation of the predicted yield elucidates vulnerability variation between the granary areas as well as between seasons. Therefore, relevant adaptations policy is needed relative to the anticipated changes in yield that the future may hold. Nevertheless, the veracity of the result from the yield prediction is limited by dearth of adequate and more accurate data. For instance the lack of available information on the genetic coefficient of the MR219 cultivar, and information on soil data was however, inadequate. Hence, further studies with more detailed and accurate data is still needed to confirm the findings of this study.

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