ASSESSMENT OF ADVERSE AGRO-CLIMATE CONDITIONS FOR RICE PRODUCTION IN THE 2019 SUMMER-AUTUMN ACROSS VIET NAM

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Abstract*: The data on daily sunshine hours, daily average temperature and daily precipitation collected from 143 meteorological stations across Viet Nam for 2018 and 2019 years is used for this studying. The effects of adverse weather conditions of light, temperature, wetness and drought during three main stages of rice growth and development in the 2019 summer-autumn is assessed and compared with the 2018 summer-autumn because rice varieties and cultivation conditions for two consecutive seasons are less different. Specifically, the assessment results show that adverse weather conditions affect the 2019 summer-autumn rice less than the one in 2018, which is one of the reasons contributing to the increase of 2019 rice productivity about 2 % compared with 2018.*

Keywords*: Adverse Agro-climate, rice production, 2019 summer-autumn.*

1. Introduction

Rice is the main food crop in Viet Nam's agricultural development target to ensure national food security and export. Currently, Vietnam is one of the world's biggest rice producers with about 7.3-7.4 million hectares of area harvested and with paddy output of about 43.4 million tons in 2019. Viet Nam is also the one of the world's biggest rice exporters with an annual shipment worth more than 6.34 million tons in 2019 (MARD, 2020). These data present that rice production in Viet Nam is a significant proportion of the economy, labor force, and world rice market.

In Viet Nam, weather and climate play important factors affecting the agricultural sector. As climate change harms rice yields, and as continuous growing population threaten food security, rice producers and the Vietnamese government will be forced to further address rice production's contribution to global climate change. Nevertheless, understanding of the environmental variables that affects regional rice yield is limited and econometric estimation of production functions to identify rice production average and variability have received little attention in Viet Nam.

According to the General Statistics Office in Viet Nam (GSO, 2020), there were about 1,595.7 thousand hectares of 2019 summer-autumn rice crop in Viet Nam including 1,163 thousand hectares in the North and 432.7 thousand hectares in the South. The country's rice yield in 2019 was estimated at 5,010 kilogram/ha, an increase of 100 kilogram/ha compared to the crop of 2018, the output reached 8.08 million tons, down 188.2 thousand tons compared to 2018. In particular, the productivity in the Northern provinces reached 5,070 kilogram/ha, an increase of 130 kilogram/ha compared to the crop in 2018 (about 2.7%), the output reached 5.43 million tons, a decrease of 24.6 thousand tons copared to 2018 (about 2.7%). Particularly in the Red River Delta region reached 5,550 kilogram/ha, an increase of 150 kilogram/ha; production reached 2.76 million tons, a decrease of 28.6 thousand tons compared to 2018. In the southern provinces,

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the estimated rice yield of 4,890 kilogram/ha, an increase of 40 kilogram/ha (about 0.82%); production reached 2.64 million tons, a decrease of 163.6 thousand tons.

Argo-climate conditions in 2019, less pests and more favorable than in 2018. Thus, growing and developing of rice was more advantage than in 2018. The 2019 rice yield was higher than in 2018, but the yield was lower. The number of natural disasters occurred less than in 2018, but caused serious damage to agricultural production. However, the main reason for the decrease rate in rice production is that localities continue to change land use purposes, change crop structure and crops. Some localities had a decrease in cultivated area compared to the previous year such as: Ca Mau decreased by 38.3 thousand hectares; Nghe An reduced 6 thousand hectares; Thanh Hoa decreased by 5.2 thousand hectares; Ha Noi decreased by 5.4 thousand hectares, etc (IMHEN., 2019).

In general, assessments of the Ago-climate conditions within the specific duration are the identification of detail climate condition following the growth procedure of rice. The growing duration can be the general growing duration or sub-duration, defined by weeks or months.

Weather conditions defined for agriculture are primarily sunshine and temperature as well as rain-fed. These are indispensable and replaceable factors for growth rice procedure as well development and composition of crop productivity. The impacts of weather and climate on agricultural activities are defined by both negative and positive ways. This study aims to answer the following open questions of adverse Agro-climate conditions in the 2019 summer-autumn rice crop in Viet Nam based on the meteorological observations.

2. Materials and methodology

2.1. Data

The 2018 and 2019 summer-autumn meteorological data collections implemented by following as:

- Sunshine duration (hours): Daily data
- 2m temperature (^oC): Daily data
- Rainfall amount (mm): Daily data

These data were collected from IMHEN for 143 stations across Viet Nam.

2.2. Methodology

The approach to define the optimal and adverse Agro-climate conditions referred by Ha et al (2008). The optimal Agro-climate conditions assessed for three growing durations of rice: (1) Beginning crop (planting or soaking rice seeds, ricegreen-roots, branching); (2) Mid-crop (branching-flowering); (3) Late-crop (ripening process of rice grains and dead-ripe stage).

a) Normal Agro-climate conditions

In this study, the optimal Agro-climate conditions is defined by Ha et al (2008). The optimal Agro-climate condition is calculated for each growing durations of rice-crop and for each Agro-climate variable.

The normal Agro-climate conditions in temperature are optimal sunshine and temperature (Table 1) that referred by optimal total sunshine and temperature in assessment for developmental stages of rice (optimal value multiply by number days during developmental stages of rice).

For optimum moisture conditions (or the water requirement of rice) will be defined by:

$$W_{iopt} = kc \times PET_i \quad (1)$$

Where:

kc: The coefficient of crop

PET_i: Daily potential evapotranspiration. PET_i is defined by the FAO Penman-Monteith method (Allen et al., 1998; Ha et el., 2008).

Optimum moisture conditions for developmental stages of rice is total optimal value of W_{iopt} in each day of stages.

Table 1. Optimal conditions of light (L_{opt}) and temperature (I_{opt}) (Ha et al., 2008)

TT	Condictions	Transplant-Branching (Beginning)	Branching-Flowering (Mid)	Flowering-Ripe (Late)
1	Sunshine (hours/day)	4.0	5.5-7.0	5.0
2	Temperature (^0C/day)	20.0-28.0	25.0-30.0	20.0-28.0

b) Satisfaction and adverse condition in sunshine

Satisfaction condition in sunshine for rice is defined by below equation, determined by $I(L_i)$.This index represents the optimum level of sastisfaction in the sunshine demand of rice (Ha et al, 2008).

$$I(L) = W(L_{tti})/W(L_{opti}) \quad (2)$$

Where:

I(L): Ssatisfaction sunshine index of rice

W (L_{tti}): Total real sunshine for all days during growth stages of rice

W (L_{opti}): Total opimal sunshine (L_{opt} * n)

i (day): 1 → n (n is daily number during growth stages of rice)

In the the equation (2), $W(L_{tti})=W(L_{opti})$ is that the sunshine duration is optimal condition (the most favorable sunshine condition for development of rice).

The adverse of sunshine defined by $W(L_{tti})-W(L_{opti})>0$ or <0, the level of adverse of sunshine for rice defined by below:

$$I'(L)=\begin{cases} 1-I(L) & \text{nếu } W(L_{tti}) - W(L_{opti}) < 0, \quad \text{lack of sunshine} \\ I(L)-1 & \text{nếu } W(L_{tti}) - W(L_{opti}) > 0, \quad \text{dry-hot condiction} \end{cases} \quad (3)$$

Equation (3) show:

I (T) < 1 when $W(L_{tti}) < W(L_{opti})$ and

I (T) > 1 when $W(L_{tti}) > W(L_{opti})$

The lower I'(L) is the adverse of sunshine duration condition due to shorter duration than normal. The bigger I'(L) is the adverse of sunshine duration condition due to longer duration than normal.

c) Satisfaction and adverse condition in temperature

Satisfaction level in temperature:

The actual satisfaction in temperature within difference duration scales (week, month, etc.) for rice is defined by satisfaction temperature index of each rice within each specific crop. Which is defined by the below equation 4 (Ha et al, 2008):

$$I(T) = W(T_{hđi})/W(T_{opti}) \quad (4)$$

Where:

I(T): Ssatisfaction temperature index of rice

$W(T_{hđi})$: Total actual temperature for all days during growth stages of rice

$W(T_{opti})$: Total optimal temperature (I_{opt} * n)

i: 1 → n (n is daily number during growth stages of rice)

Equation (4) show: I(T)< 1 when $W(T_{hđi}) <W(T_{opti})$ and I(T) >1 when $W(T_{hđi}) > W(T_{opti})$.

The adverse condition in temperature (temperature shortage).

When the $W(T_{hđi})$ > or < $W(T_{opti})$, the adverse condition in temperature is defined. In which, the adverse condition level in temperature calculated by below equation 5:

$$I(T) = \begin{cases} 1-I(T) & \text{if } W(T_{hđi})- W(T_{opti})<0, \text{ lack of temperature} \\ I(T)-1 & \text{if } W(T_{hđi})- W(T_{opti})>0, \text{ temperature shortage} \end{cases} \quad (5)$$

d) Satisfaction in wet condition and adverse condition due to wet condition

Satisfaction in wet condition:

The actual satisfaction of wet condition for rice is defined by equation 6:

$$I(H) = W(R_{hhi})/W_{iopt} \quad (6)$$

Where:

I(H): Ssatisfaction wet index of rice

Equation (6) show: The optimal condition defined by I(H)=1; the dry condition defined by I(H)<1 and the wetter (more water availability) condition defined by I(H) > 1.

W_{iopt} (Eq.1): Total water requirement of rice for all days during growth stages of rice

$W(R_{hhi})$: Total effective rainfall for all days in growth stages of rice

i (day): 1 → n (n is daily number during growth stages of rice)

Daily effective rainfall is defined in the below equation (R_{hhi}):

$$\begin{cases} R_{hhi} = (P_{itot}/25.4)^{0.75} \text{ x } 25.4 & \text{if } R_{itot} \geq 25{,}4\text{mm} \\ R_{hhi} = R_{itot} & \text{if } R_{itot} < 25{,}4 \text{ mm} \end{cases} \quad (7)$$

Where: R_{itot} is daily rainfall

The adverse condition due to wet condition:

The adverse condition due to wet

condition assessed in both case of below water availability (drier) and above water availability (wetter). The level of above water availability is defined by level of above rainfall with the 3% decrease rate of optimal rice product/100mm of rainfall (above 100mm level of rainfall causing rice-product decreased by 3%). This is defined fllow by Eq.8.

$$I'(H)=\begin{cases} 0 & \text{if } R_{tot}- W_{iopt}<0, \quad \text{dry} \\ 3\% & \text{if } R_{tot}- W_{iopt}>100\text{mm}. \quad \text{wetter} \end{cases} \quad (8)$$

The adverse water availability condition due to dry condition is defined adverse dry condition base on the drought index (R/PET) in the Table 2.

Table 2. Classification of the drought index (Ha et al., 2008)

Level	Meaning	R/PET
I	Wetter	>1.2
II	Normal	0.8-1.2
III	Slight dry/drought	0.4-0.79
IV	Extreme dry/drought	<0.4

3. Result and discussion

3.1. The adverse Agro-climate condition in sunshine

The adverse Agro-climate condition in sunshine (I'(L)) of 2019 summer-autumn rice crop compared with its in 2018 showed in Fig.1. Assessment of the 3 development periods of rice shows that:

- **Beginning-crop duration:** The higher level of adverse sunshine condition in 2019 than 2018 is found in most of North-West, Red River Delta, Central Coast, northern-western Central Highlands and the South. In which, the significant higher adverse sunshine condition (more excessive sun exposure) is found in Ha Tinh-Quang Binh, Quang Ngai-Nha Trang and Mekong River Delta. The significant lower adverse sunshine condition in 2019 than 2018 is found in North-West and eastern Central Highlands (Fig.1a).

- **Mid-crop duration:** The significant higher adverse sunshine condition in 2019 than 2018 is mostly found in North-Central Coast, Binh Dinh-Phu Yen and eastern part of the South. Especially, the significant lower adverse sunshine condition in 2019 than 2018 spreads from North-West to western part of North-East, Red River Delta and Mekong River Delta (Fig.1b).

- **Late-crop duration**: The significant lower adverse sunshine condition in 2019 than 2018 is found in over the North. The significant higher adverse sunshine condition is found in North-Central Coast (Fig.1c).

3.2. The adverse Agro-climate condition in temperature

The adverse Agro-climate condition in temperature assessed by temperature and number of hot days. The calculation method is defined by equation (3).

Adverse temperature condition:

- Beginning-crop duration: The significant lower adverse temperature condition in 2019 than 2018 is found in North-West and northern part of Central Highlands. The higher adverse temperature condition in

2019 than 2018 is found in most Central Coast. In the South, the lower adverse temperature condition in 2019 is similar to in 2018 (Fig.2a).

- Mid-crop duration: Moving the mid-crop, the lower adverse temperature condition in 2019 than 2018 is found in larger area in the North and new area in the Mid-Central Coast. The significant higher adverse temperature condition is found in a part of North-East, and northern part of the South (Fig.2b).

- Late-crop duration: By the late-crop, the significant lower adverse temperature condition in 2019 than 2018 spreads over most North-East, Red River Delta, South-Central Coast and Mekong River Delta. The higher adverse

temperature condition is found in North-West, and Central Highlands (Fig.2c).

Adverse in number of hot days:

From the beginning-crop to late-crop duration, number of hot days is defined by 0-10 days lower in 2019 than 2018 over most of the North, South-Central Coast, Central Highlands and the South. Especially, lower number of hot days in 2019 compared with 2018 is significantly found over most country by the late-crop duration (Fig.3c). The higher number of hot days in 2019 compared with 2018 is mostly found in the North and Mid-Central Coast during three growing durations. These results show that the adverse in number of hot days in 2019 is basically lower than 2018.

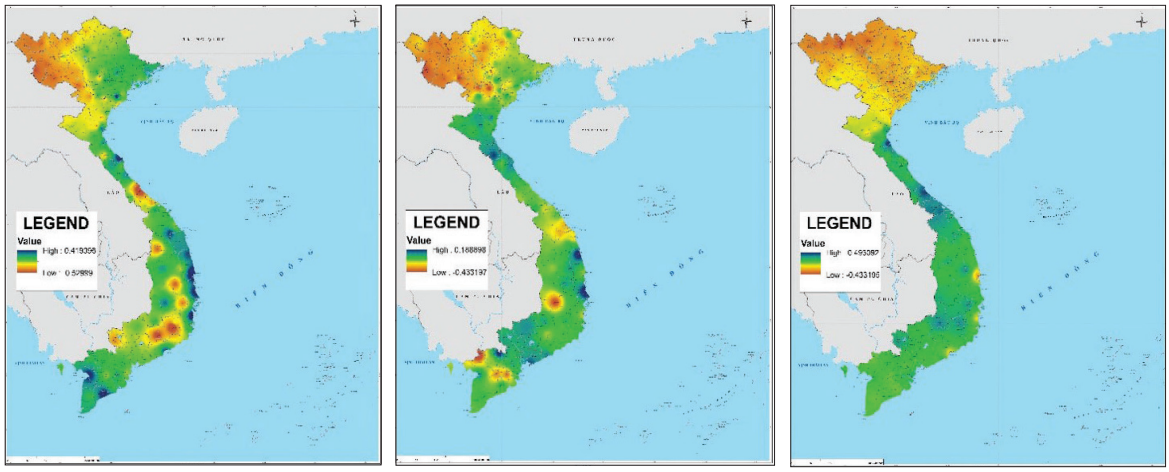

Fig.1. Changes in adverse sunshine condition I'(L) of 2019 summer-autumn rice compared with that in 2018 for three growing durations: (a) Beginning; (b) Mid; (c) Late

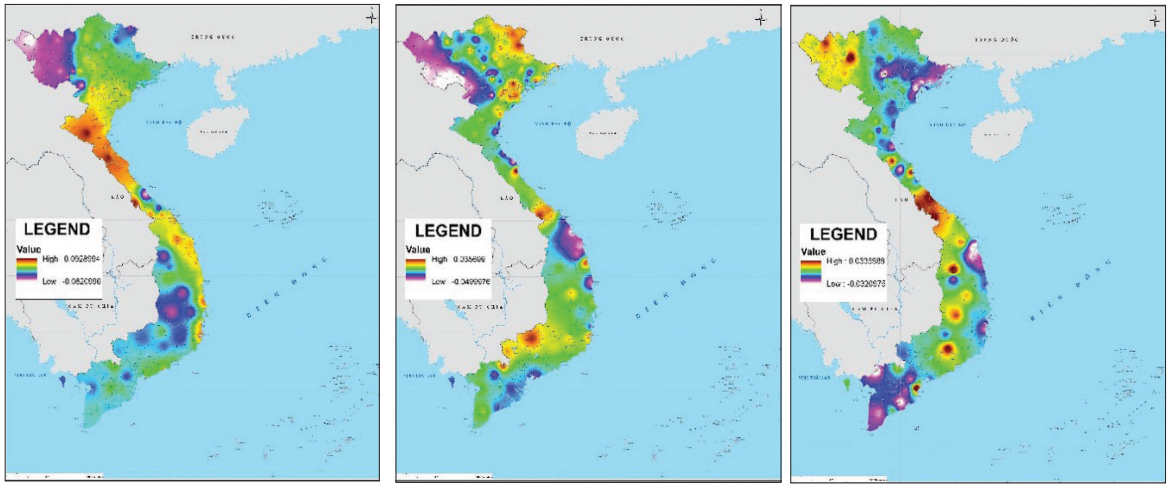

Fig.2. Changes in adverse temperature condition I'(T) of 2019 summer-autumn rice compared with that in 2018 for three growing durations: (a) Beginning; (b) Mid; (c) Late

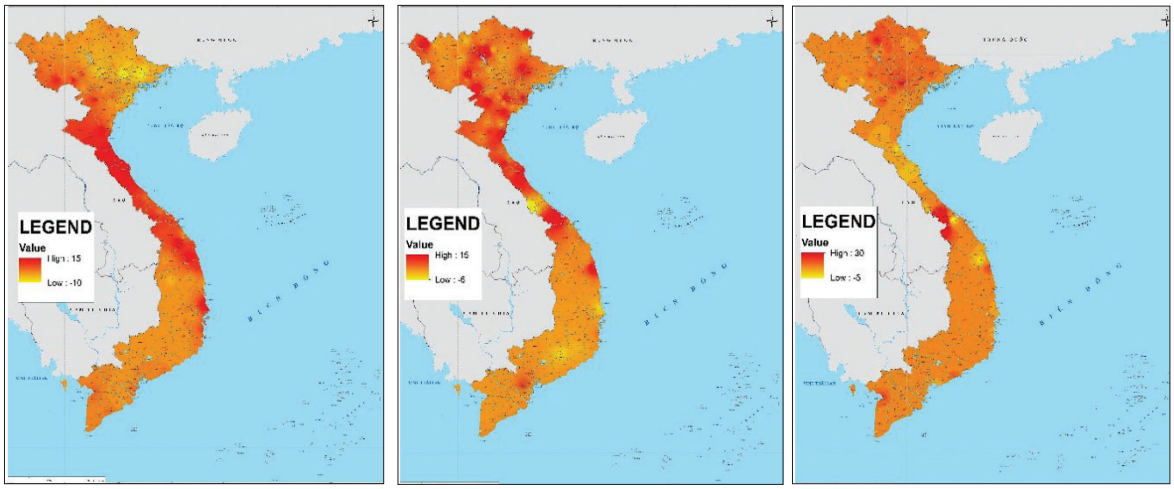

Fig.3. Changes in adverse hot days condition of 2019 summer-autumn rice compared with that in 2018 for three growing durations: (a) Beginning; (b) Mid; (c) Late

3.3. The adverse Agro-climate condition in wet condition

The adverse dry/drought condition:

- **Beginning-crop duration**: The greater adverse dry/drought condition in 2019 than 2018 is found in most Central Coast and northern part of Central Highlands with the level from shortage to serious shortage. A slight greater adverse dry/drought condition is found in Red River Delta-Thanh Hoa. However, the wetter condition in 2019 is found in most of the North, southern part of Central Highland and South-Central Coast and the South (Fig.4a).

- **Mid-crop duration**: In compared with 2018, the adverse dry/drought condition in 2019 is only found in some very small areas in Mid to South-Central Coast and Central Highlands. Over most country, the wet (no shortage) and wetter (excess shortage) are found (Fig.4b).

- **Late-crop duration**: The adverse dry/drought condition in 2019 compared with 2018 is found in a part of the North. The wet and wetter conditions are found in most country (Fig.4c).

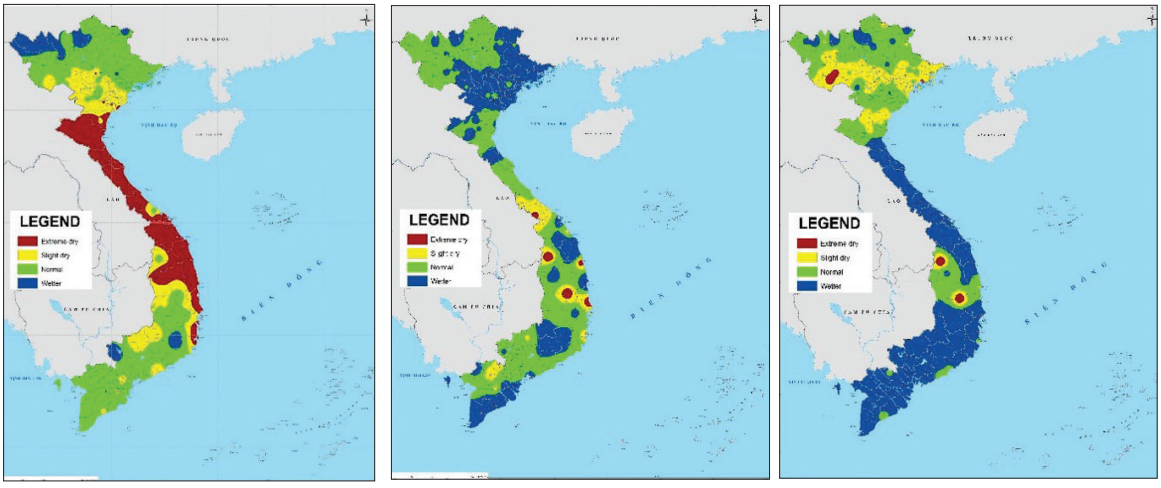

Figure 4. Changes in adverse dry condition (R/PET) and I'(H) of 2019 summer-autumn rice compared with that in 2018 for three growing durations: (a) Beginning; (b) Mid; (c) Late

Ability reducing rice product due to impacts of wetter condition in 2019:

- **Beginning-crop duration**: Compared with 2018, impacts of wet condition in 2019 on

reducing rice product is ranged from lower to normal 2018. The higher impacts on reducing rice product can be found in some small area in Bac Quang (Ha Giang), Binh Thuan and Mekong River Delta (Fig.5a).

- Mid-crop duration: The higher ability reducing rice product due to impacts of wet condition in 2019 compared with 2018 is found in Central Coast, Central Highland and the South. However, the lower ability reducing rice product due to impacts of wet condition is found in the North (Fig.5b).

- Late-crop duration: Compared with 2018, the lower-normal ability reducing rice product due to impacts of wet condition in 2019 is found in the North, South Central, Central Highlands and the South. The higher ability reducing rice product due to impacts of wet condition is only found in the North-Central Coast (Fig.5c).

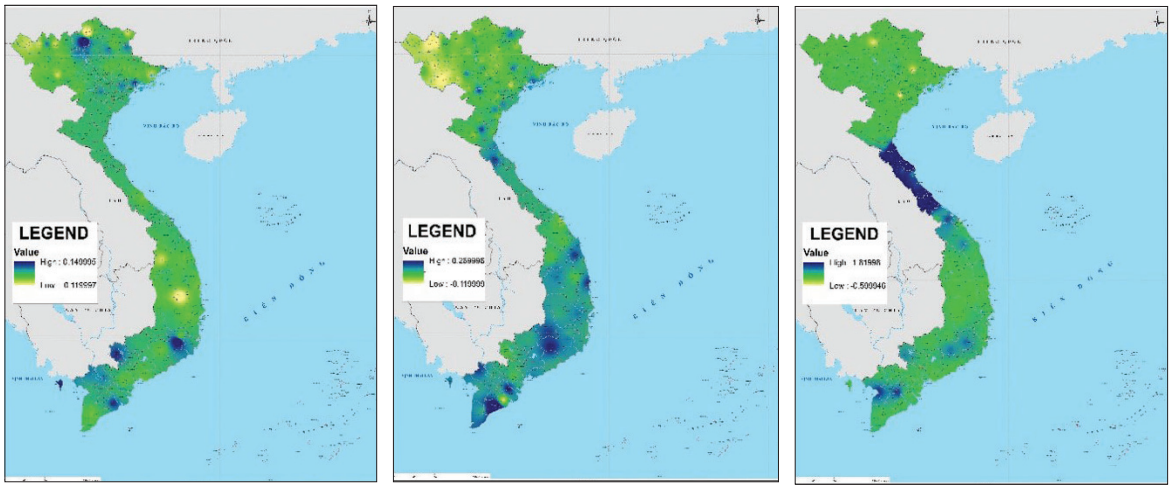

Figure 5. Possibility of decreasing rice yield due to excess moisture in 2019 compared with that in 2018: (a) Beginning; (b) Mid; (c) Late

3.4. Impacts of hydro-meteorological hazards on 2019 summer-autumn rice crop

The information of the hydro-meteorological hazards on 2019 summer-autumn rice crop is collected from IMHEN (2019).

Beginning-crop duration:

- June 2019: Good Agro-climate conditions for agricultural activities were found in over country.

- July 2019:

Heat waves event during early July caused extreme impacts on agricultural actives in Central Coast region. There were about 19.180 hectares of agricultural land being extreme drought and shortage due to heat waves. Extreme lower water level occurred at water reservoirs. The reservoir capacity is very low compared to the standard design; in particular, Trung Thuan reservoir (Quang Trach) is only 7% of the designed capacity. In Ha Tinh provinces, 16 serious forest fires occurred, damage over 160 hectares of forest cannot be recovered. In Quang Ngai, heat waves occurred in long days that cause 200 hectares of acacia plantations in Pho Thanh, Pho Cuong and Pho Khanh (Duc Pho district) to be died due to extreme drought.

Very heavy rainfall occurred in long days in Mekong River Delta combined with the floodwaters from upstream flooded very large area, causing flooding hundreds of hectares of summer-autumn rice fields in the ripe duration that damages 20-30% of total.

Very heavy rainfall also caused extreme loses in northern provinces, including 69 hectares of rice and vegetables damaged in Son La province; 1000 hectares of rice and vegetables damaged in Cao Bang; 1120 hectares of rice and vegetables damaged in Yen Bai.

During July 4 2019, the No. 2 typhoon travelled to Hai Phong-Nam Dinh area causing very extreme loses in agricultural sector,

damages: 650 hectares of rice and 457 hectares of vegetables in Nghe An were flooded; 2,240 cattle and poultries, 1,000 hectares of rice and vegetables flooded, 182 hectares of aquaculture flooded and 110m of canals damaged in Thanh Hoa province.

Mid-crop duration:

- August 2019:

Extreme events due to heavy rainfall: Very extreme rainfall and flood events in the North, Central Coast and the South; thunder storm events in most country.

Foehn events occurred and impacted in provinces in Central Coast.

Impacts of typhoon: The No. 3 typhoon caused extreme loses in the northern provinces. In Thanh Hoa, is the most loses in the North, including 1,200 rice and vegetables damaged and 1,700 domestic animals died. The No.4 typhoon hitting Nghe An-Quang Binh area; and flash floods occurred in the mountainous area in the North.

- September 2019:

Major extreme events in September 2019 were typhoon, heavy rainfall, flash flood, flood, tornado and landslides. The damage occurred was 24.8 thousand hectares of rice and more than 4 thousand hectares of vegetables were damaged. The localities that suffered much from natural disasters including Ha Giang and Yen Bai; Thanh Hoa, Nghe An, Ha Tinh, Quang Binh and Quang Tri.

Late-crop duration:

The most extreme event during the late-crop duration is the No. 5 typhoon (Matmo typhoon) and its extreme rainfall in the Central Coast region. Damage occurred: 10-12 hectares of rice and 30 hectares of vegetables flooded in Phu Yen province; 4,500 hectares of rice and 20 hectares of aquaculture flooded and damaged in Binh Dinh province; 297 hectares of vegetables, 20 hectares of acacia and 15 hectares of fruit trees flooded and damaged in Quang Ngai province.

Compared with 2018, the lower-normal ability reducing rice product due to impacts of wet condition in 2019 is found in the North, South Central, Central Highlands and the South. The higher ability reducing rice product due to impacts of wet condition is only found in the North-Central Coast (Fig.5c).

During November 2019, the No. 6 typhoon caused great loses of agricultural production in Binh Dinh-Khanh Hoa area. In Dak Lak: 255 hectares of newly sown rice, 16 hectares of maize and 20 hectares of sweet potato flooded. 50 hectares of sugarcane locally flooded in Phu Yen province. In Binh Dinh, there were 15,2 hectares of fruit trees broken and fallen. In Khanh Hoa: 330 hectares of rice and 20 hectares of vegetables were flooded. In addition, pests and diseases appeared in some localities, causing difficulties for agricultural, forestry and fishery production.

Conclusion

From comparing the adverse Agro-climate conditions in the 2019 summer-autumn rice crop in Viet Nam with that in 2018, conclusions can be suggested as:

1) The beginning-crop duration: Agro-climate conditions (sunshine, temperature, water availability) in 2019 summer-autumn rice crop were more favorable for rice cultivation and green anise rooted rice over most country. However, the greater adverse dry/drought and hot conditions occurred in 2019 than 2018 in the Central Coast causing the disadvantages for the green-spring-rooted rice.

2) The mid and the late crop duration: Comparing with 2018 the Agro-climate conditions (sunshine, temperature, water availability) in 2019 were normally quite favorable for rice growth, especially in the Northern provinces. However, heavy rains occurred in the Central Coast and the South, causing significant disadvantages to rice fields, flowering and seed production.

The situation of pests and diseases rarely occurred, agricultural production losses due to meteorological disasters in the last 6 months of 2019 were mainly heavy rains and floods, causing widespread litter across the country. In the Northern provinces in the early months of the mid-crop and late-crop in the South.

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