Rainy season period and climate classification in sugarcane plantation regions in Indonesia

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Abstract. Sugarcane plantations in Indonesia are mainly grown on dry land with wide ranges of climatic conditions. This study aimed to present information about the average rainy season period and climate classification in each sugarcane development area in Indonesia. The rainy season period was determined based on early of the dry season and rainy season for 10 years from 2009-2018 in 67 Zone of Season (ZOM) of 342 ZOM issued by The Agency for Meteorology, Climatology and Geophysics of Indonesia. The rainy season period in sugarcane regions ranges from 20-25 ten day period in 59% of the zones in Sumatra, 15-20 ten day period in 73% of the zones in Java and Madura, 20-25 ten day period and 10-15 ten day period in 33% and 34% zones in Sulawesi, 12 ten day period in West Nusa Tenggara and 16-25 ten day period in Papua. Climate classification was also identified in each zone of sugarcane regions based on Oldeman classification map. Information about rainy season period and climate classification enables in the planning and production of crops for certain regions. Further studies on the prediction of water availability during sugarcane growth are needed.

Keywords: Saccharum officinarum, agroclimatic conditions, climate information

1. Introduction
Sugarcane is one of the important estate crops as the main source of sugar in Indonesia, the regions include Java, Sumatra, Sulawesi and West Nusa Tenggara. The five largest sugar producing provinces are East Java, Lampung, Central Java, South Sumatra and West Java [1] with wide ranges of agroclimatic conditions. Sugar consumption continues to increase to meet domestic consumption and industrial needs. The productivity of sugarcane and sugar is strongly influenced by climatic conditions from planting to harvest. Distribution of sugarcane throughout the world is very limited by its suitability to the climate conditions. The climate element affects each phase of sugarcane growth, because its growth is related to annual cropping cycle, so that it faces different environmental conditions throughout the growing season.

To improve sugarcane productivity, climate information related to rainfall is needed such as the beginning of the rainy season related to planting planning and the end of the rainy season or the start of the dry season related to sugarcane harvesting and transportation planning. The length of the rainy season is related to the duration of the rainy season received by plants and irrigation needed to meet plant water requirements and production estimates. The average rainfall to support high productivity is 1100-1500 mm/year with equitable distribution. Evapotranspiration during the growth of sugarcane ranges from 800 mm to 2000 mm [2]. Excessive rainwater during planting inhibits germination since it
damages the planting material, and if it occurs after planting is likely to cause flooding. Thus, the ideal planting time is conducted during the dry months, or at the beginning of the dry season.

Sugarcane plants require optimal rainfall during the vegetative phase to stimulate rapid growth, stalk elongation and internode formation. However, during the period of maturity requires dry conditions with low rainfall to improve the quality of sugarcane juice and reduce the water content in plant tissues. The efficiency of water use in sugarcane plants increased at irrigation rates from 56 to 83 kg/mm, which led to an increase in sugarcane yields ranging from 67.8 to 136.1 t/ha/year [3], and at fertilizer rates from 127.5 to 146.6 kg/mm [4]. Climate change due to 1°C temperature rise can reduce production by 10% and increase irrigation by 10% [5]. Water deficit can even reduce sugarcane yield by up to 60% [6, 7]. Therefore, the development of sugarcane is directed to the areas with high water availability for growth and production. The sugar industry relies heavily on weather information, especially on climate variability from planting to harvest, after-harvest transportation and milling processes.

Global climate change affects local climate patterns and variability. Of which, sugarcane productivity fluctuates according to the season. The areas of sugarcane development in Indonesia have different rainfall patterns between regions, thus the level of productivity also varies between regions following the rainfall pattern and other factors. The level of regional vulnerability to climate change in each development area is different, so that climate is still the dominant factor affecting the productivity of sugarcane in Indonesia. Climate and water are two components that must be considered especially in the tropics for agricultural development. This study aimed to present information about the average rainy season period and climate classification in each sugarcane development area in Indonesia. This information enables in crop management and irrigation planning in the sugarcane development areas. The implication of this study is to provide advantage in determining the expansion of sugarcane areas with longer rainy season period.

2. Materials and Methods
The data used were the beginning of the rainy season and the beginning of the dry season issued by The Meteorology, Climatology and Geophysical Agency (MCGA) of Indonesia from 2009 to 2018 (10 years) in 342 seasonal zones (ZOM) and collected in 2018. The early rainy season and the beginning of the dry season were released at the beginning of the season each year. A total of 67 ZOM out of 342 ZOM covers the areas of sugarcane development in Indonesia. The sugarcane development areas in each province were adjusted to the ZOM determined. A total of 17 ZOM (No. 4-46) are in Sumatra, 37 ZOM (No. 74-198) are in Java and Madura, 9 ZOM (No. 286-321) are in Sulawesi, 2 ZOM (No. 237-238) in West Nusa Tenggara and 2 ZOM (No. 341-342) in Papua.

The MCGA determined the criteria for early of the rainy season and dry season [8]. Early of the rainy season is determined by the amount of rainfall equal to or more than 50 mm/ten day period and is followed by two periods of the next ten days. The early of the dry season is determined by the amount of rainfall less than 50 mm/ten day period followed by two periods of the next ten days. The beginning of the rainy season and the dry season are expressed in the range of ten days (ten day period).

There are three ten day periods in each month, first ten day period (I) on 1-10 days, second ten day period (II) on days 11-20, and third ten day period (III) on the 21st onward of the month. The rainy season period was determined based on the length of the period from the early of the rainy season to the beginning of the dry season the following year. The beginning of the dry season, the rainy season and the annual rainy season period were compiled and then averaged in each ZOM of sugarcane development areas in each province. Climate classification in each zone was determined based on Oldeman climate maps [9-12]. Oldeman maps are commonly used to identify climate type in the regions of sugarcane plantation.
3. Results and Discussion

3.1. Rainy season period and climate classification in Sumatra

The areas of sugarcane in Sumatra spreads from North to South with a relatively long rainy season period of 18.6-26.1 ten day period with an average of 23.06 ten day period or 7.6 months (Table 1). The rainy season period occurred for around eight months which indicates sufficient rainwater supply to meet the water needs of sugarcane. The rainy season started from September to October and ended in April-May. Thus, there are only four dry months for the ripening phase of sugarcane or sugarcane milling period in the sugar mill. Planning for sugarcane planting time must be in line with the pattern of crop water needs, especially in areas with an average rainy season of 7.6 months. This is due to sugarcane ripening process is strongly influenced by the interactions of climatic elements, genotype and crop cultivation. If rainfall occurs during the harvest period, it will reduce the efficiency of the harvest. Therefore, the use of plant growth regulators are needed to stimulate sugarcane ripening when excessive rainfall occurs at harvesting time [13].

Table 1. The average of rainy season, dry season, rainy season period and climate classification in sugarcane regions in Sumatra

| No. ZOM | Regions | Early of rainy season | Early of dry season | Period of rainy season (ten day period) | Climate classification* |
|---------|---------|----------------------|---------------------|----------------------------------------|-------------------------|
| 4       | Bener Meriah, Central Aceh, Eastern part of Nagan Raya, North Gayo Lues | Oct III | Apr III | 18.6 | B1 |
| 6       | Langkat/ Deli Serdang/North Medan | | | 25.0 | C1 |
| 7       | East Langkat, Serdang Bedagai, Southern part of Medan, Binjai, Sergai, Tebing Tinggi, Pematang Siantar, Simalungun, Asahan | | | 25.5 | C1-D1 |
| 9       | Langkat, Deli Serdang, East Karo Banyuasin, Musi Banyuasin, North East Muara Enim, North East Prabumulih, North Ogan Ilir, East OKI | Sep III | May I | 21.8 | C1-D1 |
| 32      | East Musi Rawas, South West Musi Banyuasin, North Lahat, Central Muara Enim, South West Prabumulih, South West Ogan Ilir, north OKU | Sep II | May III | 26.1 | B1 |
| 33      | East Empat Lawang, Central and South Lahat, Pagar Alam, South Muara Enim, South East OKU Selatan, South West OKU | Sep III | May III | 25.1 | B1 |
| 34      | Central and South Empat Lawang, Central and South Lahat, Pagar Alam, South Muara Enim, South East OKU Selatan, South West OKU | Sep III | May III | 26.6 | B1 |
| 35      | West OKU, East Palembang, South East Banyuasin | Sep III | May II | 23.7 | B2 |
| 36      | North East OKU, South East Ogan Ilir, South West OKI | Sep III | May I | 23.6 | B2 |
| 37      | South East OKU, South West OKU, South East OKU | Sep III | May III | 24.8 | B1 |
| No. ZOM | Regions                                                                 | Early of rainy season | Early of dry season | Period of rainy season (ten day period) | Climate classification* |
|---------|------------------------------------------------------------------------|-----------------------|---------------------|----------------------------------------|--------------------------|
| 39      | Eastern part of West Lampung, Northern part of Tanggamus, South Way Kanan, Western part of North Lampung, Western part of Central Lampung, Central part of South OKU | Sep II                | May III             | 25.7                                   | B1                       |
| 40      | Southern part of North Lampung                                         | Oct II                | May I               | 20.7                                   | C1-C2                    |
| 41      | South East OKI, Northern part of West Tulangbawang, Tulangbawang, and Mesuji | Oct II                | Apr III             | 21.1                                   | C2                       |
| 43      | Southern part of West Tulangbawang, Northern part of Central Lampung, Eastern part of North Lampung | Oct II                | May I               | 21.1                                   | C2                       |
| 44      | Eastern part of Central Lampung, Eastern part of East Lampung          | Oct II                | May I               | 21.4                                   | C2                       |
| 45      | Southern part of Central Lampung, Metro, Western part of East Lampung   | Oct II                | Apr III             | 21.3                                   | C2                       |
| 46      | Western part of Central Lampung, Eastern part of North Tanggamus, Pringsewu, North Pesawaran | Oct II                | Apr III             | 19.9                                   | D2                       |
| Average |                                                                       |                       |                     | 23.1                                   |                          |

* Based on Oldemen classification map [10]

The observation showed that 8 out of 17 ZOM have the rainy season period below the average range, i.e. 18.6-21.8 ten day period (7 months), especially in Lampung (Table 1). In general, the rainy season period in sugarcane plantations in Sumatra is longer than in Java and other provinces. Hence, expanding sugarcane area in Lampung is a priority because it has a long rainy season period. This condition is ideal for sugarcane growth with a dominant C2 climate classification (5-6 wet months and 2-3 dry months). Meanwhile, the regions with a B1 climate type and rainy season exceed the average, such as in Aceh and North Sumatra, sugarcane can be harvested throughout the season as raw materials for producing brown sugar. Sugarcane plant requires at least three dry months for the ripening phase and harvesting, so ideally it has a climate type 2 subdivisions with 2-3 dry months. The sugarcane areas in Sumatra are dominated by B1-C2 climate types.

Cardozo et al. [14] obtained a correlation between the cumulative rainfall of 120 days before harvest with total yield of sugar in all types of maturity varieties. The response of varieties to cumulative rainfall varies, the early maturity varieties respond higher to the total yield of sugar than those of medium and late maturities. Rainfall during the stem elongation phase or 120 days before harvest is important because this phase requires the most water and affects the total yield of sugar obtained. Cabral et al. [15] also found that rainfall for the first 120 days determined the final yield of sugarcane in Brazil with a total evapotranspiration of about 69% of total rainfall. Carr and Knox [16] concluded that there is a linear relationship between evapotranspiration, sugarcane and sugar production with an average water efficiency of 100 kg/ha/mm water for sugarcane production and 13 kg/ha/mm water for sugar production.
3.2. Rainy season period and climate classification in Java and Madura

The average of rainy season in sugarcane areas in Java and Madura ranges from October to November and early of dry season in April (Table 2). The average of rainy season period was 17.93 ten day period or 5.9 months shorter than Sumatra. The Eastern part of Java has a shorter rainy season, particularly in Madura (15-16 ten day period) with ZOM number 195-198. The region with ZOM number 74-75 has a longer rainy season than the other regions in Java, which is 22.5-24.6 ten day period with the late dry season (May-June). The region with less than 15 ten day period of rainy season are very vulnerable to drought, thus additional irrigation and planting time management are needed. Sanghera et al. [17] emphasized the need to select the right planting time and varieties according to their maturities to support the sustainability of the sugar industry. On the other hand, Zhao et al. [18] reported that water stress occurred at 22-27 days during the stem elongation phase reduced the rate of stem elongation and formation of tillers, particularly in sandy soil compared to organic soil. Stress symptoms in sugar cane occur at 7-10 days earlier in sandy soil than organic soil. Therefore, development of sugarcane varieties which can increase productivity under water stress conditions are needed [19], this is due to losses can reach 50% even greater in high stress conditions. Meanwhile, Liu et al. [20] highlighted genotype selection program under sufficient water conditions to moderate levels of water shortage. Carr and Knox [16] reported that drought-resistant varieties respond by closing the stomata first. Of which, the development of leaves or stalk is a more sensitive indicator to drought than stomatal conduction or photosynthesis.

Table 2. The average of rainy season, dry season, rainy season period and climate classification in sugarcane regions in Java and Madura.

| No. ZOM | Regions | Early of rainy season | Early of dry season | Period of rainy season (ten day period) | Climate classification* |
|---------|---------|-----------------------|---------------------|-----------------------------------------|-------------------------|
|         |         | Month ten day period  |                     |                                         |                         |
| 74      | South Subang, West Sumedang, North Bandung, South Purwakarta | Oct II | Jun I | 24.6 | B1-B2 |
| 75      | Central Subang, North Purwakarta | Oct III | May III | 22.5 | D2 |
| 76      | North Subang, West Karawang | Oct III | Apr II | 18.4 | D3 |
| 77      | Northern part of West Indramayu, Eastern part of North Subang | Oct III | Mar III | 15.7 | D3 |
| 80      | Southern part of West Indramayu, Western part of Central Subang | Oct III | May II | 20.8 | C2 |
| 130     | North East Jepara, North Pati | Nov II | Apr III | 16.9 | D2 |
| 131     | North East Pati, North Rembang | Nov II | Apr II | 16.1 | E |
| 132     | Central Pati | Oct III | Apr III | 19.2 | D3 |
| 133     | South Pati, Central and South Rembang, North East Grobogan | Oct II | Apr III | 20.0 | C2-D3 |
| 148     | North and Central Blora, East Grobogan, North West Bojonegoro, South West Tuban | Oct III | Apr II | 18.0 | C2 |
| 149     | East Rembang, South Blora, North Tuban | Nov I | Apr II | 16.4 | E-D3 |
| 151     | Central and East Lamongan | Nov I | Apr II | 17.3 | D3-C2 |
| 152     | Southern part of South Bojonegoro | Oct III | Apr III | 18.0 | C2 |
| 161     | Central Jombang, West Mojokerto, North East Kediri | Nov I | Apr III | 18.1 | C2 |
| 162     | West Surabaya, South Gresik, North West and South Sidoarjo, North Mojokerto, Central Pasuruan | Nov I | Apr II | 17.3 | C2-C3-D3 |
The sugarcane development areas in Sulawesi are concentrated in South Sulawesi and Gorontalo and are currently developing into South East Sulawesi with the establishment of a new sugar mill. The average of rainy season period is 19.67 ten day period (Table 3). The rainy season started from November-December to March, and in some areas started from February to July, such as in Bone (ZOM no. 297-298). Jeneponto (ZOM no. 290) showed the shortest rainy season period (12.9 ten day period), with D4 climate type, whereas the longest 25.4 ten day period is in Southern Bone (C3 climate type). In

| No. | Area Description                                      | Rainy Season Period | Average Rainfall (mm) | Climate Type |
|-----|------------------------------------------------------|---------------------|-----------------------|--------------|
| 164 | South Sidoarjo, North Pasuruan, Pasuruan city       | Nov II              | Apr II                | 16.2         | C3-D3-E      |
| 165 | South Mojosari, South Pasuruan                      | Nov I               | Apr II                | 16.9         | D3-C3        |
| 167 | South East Kediri                                   | Oct II              | Apr III               | 20.2         | C3           |
| 168 | East Buitar, West Malang                            | Oct II              | Apr II                | 19.2         | C3           |
| 169 | South Malang                                        | Oct II              | Apr III               | 20.1         | C3           |
| 173 | West and South Probolinggo, North Lumajang          | Oct III             | Apr II                | 17.9         | D3           |
| 174 | North East Pasuruan, North Probolinggo              | Nov III             | Apr I                 | 14.0         | E            |
| 176 | South Lumajang, South West Jember                   | Oct II              | Apr II                | 18.7         | C3           |
| 177 | Central Lumajang                                    | Oct II              | Apr III               | 18.9         | C3           |
| 181 | North East Probolinggo, North Situbondo/Bondowoso   | Nov III             | Apr I                 | 14.1         | E            |
| 182 | North East and East Situbondo, North East Banyuwangi | Dec I              | Apr I                 | 13.0         | E            |
| 183 | South East Situbondo                                | Dec I               | Apr III               | 16.2         | E            |
| 184 | East Probolinggo, West Situbondo                    | Nov III             | Apr II                | 15.0         | E            |
| 185 | South Bondowoso, North East Jember                  | Nov III             | Apr III               | 17.7         | D3           |
| 187 | North Jember                                        | Oct II              | Apr III               | 19.8         | C2           |
| 188 | North West Jember                                   | Oct I               | May I                 | 21.7         | C2           |
| 189 | Central Jember                                      | Oct II              | Apr III               | 20.5         | C3-C2        |
| 190 | South Jember                                        | Nov II              | Apr III               | 17.4         | C3-D3-E      |
| 195 | South Bangkalan                                     | Nov II              | Apr I                 | 15.5         | D3           |
| 196 | Central and North Bangkalan                         | Nov II              | Apr III               | 16.9         | C3           |
| 197 | West and South Sampang                              | Nov III             | Apr II                | 16.1         | C3           |
| 198 | Central Sampang                                     | Nov III             | Apr II                | 16.1         | C3           |

* Based on Oldemen classification map [11]

Out of 37 ZOM in Java and Madura, there are 16 ZOM which have a rainy season below the average. Expansion of sugarcane area is not recommended to areas with a rainy season less than 4 months unless there are irrigation facilities. In areas with a short rainy season sugarcane will face drought during the stalk elongation phase which reduces the stalk length. Sugarcane plants need optimal rainfall for vegetative growth to support the rapid growth phase, elongation of stem and internode [21, 22]. The initial phase of growth is very sensitive to the availability of water, thus water stress causes a decline in plant populations in all varieties tested [23]. Sugarcane regions in Java and Madura are dominated by C3-D3 climate types and in some areas have E climate types.

Kumari et al. [24] calculated the total water needs of sugarcane are 18.492 m$^3$ higher than other plants, such as tobacco (2.278 m$^3$), rice (11.461 m$^3$) and corn (6.387 m$^3$). Climatic factors that influence the water needs of plants consist of temperature, wind speed, air humidity, sunshine duration and rainfall. Besides, the other factors which also influence crop water needs are types of varieties, crop age (crop duration), soil structure and percolation rate. The need to choose suitable varieties and water-saving technologies is important in regions with limited water availability.

3.3. Rainy season period and climate classification in Sulawesi

The sugarcane development areas in Sulawesi are concentrated in South Sulawesi and Gorontalo and are currently developing into South East Sulawesi with the establishment of a new sugar mill. The average of rainy season period is 19.67 ten day period (Table 3). The rainy season started from November-December to March, and in some areas started from February to July, such as in Bone (ZOM no. 297-298). Jeneponto (ZOM no. 290) showed the shortest rainy season period (12.9 ten day period), with D4 climate type, whereas the longest 25.4 ten day period is in Southern Bone (C3 climate type). In
Gorontalo, rainy season period is 24.3 ten day period with C1-C2 climate type. The rainy season period in the new development areas of sugarcane including South Konawe, Bombana and Rumbia is 23.6 ten day period with D2, D3 and C3 climate types.

Most of the areas in Gowa, Takalar and Jeneponto are dry land with more than 6 dry months, so that it is suitable for planting sugarcane with drought-resistant and late-maturity types. Conversely, in areas with 5-6 wet months and 2-3 to 4-6 dry months can be planted with early to mid-maturity varieties of sugarcane, because this area has a short period of ripening phase. In addition, radiation and temperature affect harvesting time, and optimum radiation and temperature in the stem elongation phase affect production compared to other phases [25].

Table 3. The average of rainy season, dry season, rainy season period and climate classification in sugarcane regions in Sulawesi.

| No. ZOM | Regions | Early of rainy season | Early of dry season | Period of rainy season (ten day period) | Climate classification |
|---------|---------|-----------------------|---------------------|----------------------------------------|------------------------|
| 286     | West Gowa/Takalar | Dec I | Mar III | 15.5 | D4 |
| 287     | West Barru/Pangkep/Maros, Central Makassar, Gowa/Takalar, West Jeneponto | Nov I | May I | 19.2 | D3 |
| 289     | Central Gowa, North Jeneponto, Eastern part of Takalar | Nov I | May III | 21.5 | D3 |
| 290     | Central and East Jeneponto | Nov III | Mar III | 12.9 | D4 |
| 295     | South Bone, East Sinjai | Nov I | Jul III | 25.4 | C3 |
| 297     | East Bone | Feb I | Jul III | 17.2 | D2 |
| 298     | East Bone | Feb I | Jul III | 17.4 | D2 |
| 313     | Rumbia, Bombana, South Konawe | Oct III | Jun II | 23.6 | C3-D3-D2 |
| 321     | North Gorontalo | Dec I | Jul I | 24.3 | C1-C2 |

*Based on Oldemen classification map [12]

3.4. Rainy season period and climate classification in West Nusa Tenggara and Papua
Rainy season period in West Nusa Tenggara is very short, which is only 12.2 ten day period (Table 4), below the average rainy season period in Java, thus determining sugarcane planting time and the use of drought resistant varieties is very important. The rainy season period started from the third week of November to mid-March. The availability of land is quite abundant but must be supported by irrigation facilities to support the successful development of sugarcane. Sugarcane is widely developed in Dompu District, West Nusa Tenggara, because there is a new sugar mill.

The climate classification in Bima and Dompu is D4-E4 types with a rainy season of 3-4 months even in some areas less than 3 months and a dry season of more than six months. Additional irrigation, particularly during tillers formation, is absolutely necessary to support the growth of sugarcane and to assist nitrogen absorption given at the beginning of growth. Prolonged stress due to a long dry season will reduce the growth and photosynthetic activity of sugarcane [26] which ultimately reduces biomass and sugarcane production [27, 28]. Sugarcane which has high efficiency in using nitrogen can help plants tolerate stress due to drought [29]. Leaf and stem growth as well as the number of green leaves can be used as an indicator that plants need to be irrigated to reduce the decrease in biomass accumulation [30].

The rainy season period in Merauke is 16.3 ten day period shorter than Jayapura (25.7 ten day period). In Jayapura, rainy season period started earlier from mid-October to the third week of June with a shorter dry period (Table 4). Climate classification in Jayapura is C1 type with a dry month of less than 2 months, this causes a period for a very short maturity phase. Meanwhile, Merauke has a D3 climate classification, similar to sugarcane regions in Java with 4-6 dry and 3-4 wet months.
Table 4. The average of rainy season, dry season, rainy season period and climate classification in sugarcane regions in West Nusa Tenggara and Papua

| No. ZOM | Regions                        | Early of rainy season | Early of dry season | Period of rainy season (ten day period) | Climate classification* |
|---------|--------------------------------|-----------------------|---------------------|----------------------------------------|-------------------------|
|         |                                | Month ten day period  |                     |                                        |                         |
|         | Nusa Tenggara Barat            |                       |                     |                                        |                         |
| 237     | North Bima and Dompu           | Nov III               | Mar II              | 12.2                                   | E4-D4                   |
| 238     | Dompu                          | Nov III               | Mar II              | 12.2                                   | D4                      |
|         | Papua                          |                       |                     |                                        |                         |
| 341     | Jayapura City, North Keerom,   | Oct II                | Jun III             | 25.7                                   | C1                      |
|         | Northeast Jayapura             |                       |                     |                                        |                         |
| 342     | Merauke                        | Nov III               | May I               | 16.3                                   | D3                      |

* Based on Oldemen classification map [9]

The distribution or percentage of the rainy period in Sumatra showed that 59% region have a rainy season period of 20-25 ten day period, 29% region with 25.1-30 ten day period, and 12% region with rainy season period 15-20 ten day period (Figure 1). In Java and Madura, 73% of ZOM have a 15.1-20 ten day period of rainy season and 19% of ZOM with 20.1-25 ten day period and only 8% of ZOM with 10-15 ten day period (Figure 2). The percentage of regions with rainy season period of 10-15 ten day period and 20.1-25 ten day period in Sulawesi is 33% and 34% of ZOM, respectively (Figure 3). In addition, 11% of ZOM in Sulawesi have a rainy season period of 25.1-30 ten-day period. Most of the regions with the opportunity to get longer rain (20-25 ten day period) are located in Sumatra, even in certain regions have longer rainy period of 25.1-30 ten day period. This condition is more suitable for sugarcane which can be harvested at any time for traditional (local) brown sugar production. Meanwhile, sugarcane areas in Java and Madura are dominated by dry land with a dominant rainy season of 15.1-20 ten day period.

Figure 1. Percentages of rainy season period in sugarcane regions in Sumatra

Figure 2. Percentages of rainy season period in sugarcane regions in Java and Madura

Figure 3. Percentages of rainy season period in sugarcane regions in Sulawesi

Sugarcane productivity is a function of water availability and water deficit in an area. Water deficit significantly reduces sugarcane production. There is a negative correlation between the potential rate of production and water deficit with a decrease in linear production [30]. Water availability is a major factor in the variability of production every year and the decline in productivity is closely related to the distribution of rainfall. Ruan et al. [31] projected an increase in sugarcane biomass dry matter, fresh matter and sugar yields of 7.8-14.2, 16.6-36.1, 2.7-6.1 kg/ha/mm, respectively in relation to rainfall. Santos and Sentelhas [32] found that a decrease or increase in annual rainfall of 10% in Brazil had a smaller effect on soil water availability than temperature changes, so that the effect of increasing
temperature as a result of climate change had more influence on sugarcane productivity variability, especially on dry land. Singels and Bezuidenhout [33] stated that the effect of rainfall on sugar production in South Africa is more influenced by its distribution than total rainfall, as long as rainfall is well distributed.

Dry land is the area most affected by the phenomenon of climate change which is characterized by increasing temperatures and stress due to drought. Adaptation strategies, such as planting time and the use of drought tolerant varieties are needed [35]. In areas where drought often limits sugarcane production, obtaining drought-resistant varieties is a priority. Tena et al. [36] conducted a survey on the preferences of sugarcane farmers in Ethiopia and found that farmers prioritized drought-resistant varieties rather than increasing yields due to climate change. The development of sugarcane in Indonesia is mostly carried out on dry land so that the government and policy makers must support sustainable agriculture and new technologies that are adaptive to climate change.

4. Conclusion

The rainy season period in sugarcane regions in Indonesia ranges from 20-25 ten day period in 59% of the seasonal zone in the Sumatra, 15-20 ten day period in 73% of the regions in Java and Madura, 20-25 and 10-15 ten day period in 33% and 34% of the regions in Sulawesi. Areas with a rainy period of 25-30 ten day period are more suitable for the development of sugarcane as raw material for the brown sugar industry and areas with a rainy season of 10-15 ten day period require additional irrigation to meet the water needs of sugarcane plants. Of which, areas with 15-20 ten day period is ideal for sugarcane growth. Climate classification was also identified in each zone of sugarcane regions based on Oldeman classification map. Information about the rainy season period and climate classification enables in crop management, irrigation planning especially in areas with short rainy seasons and the expansion of sugarcane plantations in Indonesia.

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References

[1] BPS-Statistics Indonesia 2018 Indonesian Sugarcane Statistics 2017 (http://www.bps.go.id) p 104
[2] FAO 2012 Crop yield response to water Sugarcane p174-80
[3] da Silva V de P R, da Silva B B and Albuquerque W G 2013 Agricultual Water Management 128:102-109
[4] Ghiberto P J, Libardi P L, Brito A S and Trivelin P C O 2011 Agricultural Water Management 102 1-7
[5] Afghan S and Ijaz M W 2015 Pakistan Sugar J. 30 17-24
[6] Ramesh P 2000 J.Agron. Crop Sci. 185 83-9
[7] Gentile A, Dias I I, Mattos R S, Ferreira T H and Menossi M 2015 Front. Plant Sci. 6 58
[8] Badan Meteorologi, Klimatologi dan Geofisika 2018 Prakiraan Musim Hujan 2018/2019 di Indonesia (Jakarta: BMKG) P 142
[9] Oldeman L R, Las I and Muladi 1980 The agroclimatic maps of Kalimantan, Maluku, Irian Jaya and Bali, West and East Nusa Tenggara Contr. Centr. Res. Inst. Agric. Bogor 60 32
[10] Oldeman L R, Las I and Darwis S N 1979 An agroclimatic map of Sumatra Contr. Centr. Res. Inst. Agric. Bogor 52 35
[11] Oldeman L R 1975 Contr. Centr. Res. Inst. Agric. Bogor, No.17:22 p
[12] Oldeman, LR 1977 An agroclimatic map of Sulawesi Contr. Centr. Res. Inst. Agric. Bogor 33 30
[13] Cardozo N P and Sentelhas P C 2013 Scientia Agricola 70 449-56
[14] Cardozo N P, Sentelhas P C, Panosso A R, Palhares A L and Ide B Y 2015 *Int. J. Biometeorol.* **59** 1913-25
[15] Cabral O M R, Rocha H R, Gach J H, Ligo M A V, Tatsch J D, Freitas H C and Brasilio E 2012 Bioenergy **4** 555-65
[16] Carr M K V and Knox J W 2011 *Expl.Agric.* **47** 1-25
[17] Sanghera G S, Sing R P, Singh O and Tyagi V 2018 *J. of Plant Sci. Res.* **34** 137-52
[18] Zhao D, Glaz B and Comstock J C 2010 *American J. Agric. and Biol. Sci.* **5** 403-14
[19] Sanghera G S and Kumar A 2018 *J. Plant Sci. Res.* **34** 23-35
[20] Liu J, Basnayake J, Jackson P A, Chen X, Zhao J, Zhao P, Yang L, Bai Y, Xia H, Zan F, Qin W, Yang K, Yao L, Zhao L, Zhu J, Lakshmanan P, Zhao X and Fan Y 2016 *Field Crops Res.* **196** 418-25
[21] Srivastava A K and Rai M K 2012 *Biodiversitas* **13** 214-27
[22] Kumarasinghe N C and Wijayawardhana L M J R 2011 Impact of climate change on the sugarcane cultivation in Sri Lanka *Proc.of International Conference on the Impact of Climate Change on Agriculture* (Kamburupitiya: University of Ruhuna) pp 124-9
[23] Barbosa F S, Coelho R D, Maschio R, Lima C J G and Silva E M 2014 *Eng. Agric. Jaboticabal* **34** 203-62
[24] Kumari M, Singh O P and Meena D C 2017 *Int. J. Agric. Env. Biotech.* **10** 253-62
[25] Ramburan S 2011 *South African J. of Plant and Soil* **28** 75-84
[26] Barbosa A M, Guidorizi K A, Catuchi T A, Marques T A, Ribeiro R V and Souza G M 2015 *Acta Physiologiae Plantarum* **22** 189-97
[27] Zhao D and Yang-Rui L 2015 Climate change and sugarcane production: potential impact and mitigation strategies *Int. J. Agron.* 10p. doi:10.1155/2015/547386
[28] Zhao D, Glaz B and Comstock J C 2010 *American Journal of Agricultural and Biological Sciences* **5** 403-14.
[29] Dinh T H, Watanabe K, Takaragawa H, Nakabaru M and Kawamitsu Y *Plant Production Sci.* **20** 412-22
[30] Caetano J M 2017 *Rev.Ceres. Vicosae* **64** 298-306
[31] Ruan H, Feng P, Wang B, Xing H, O’Leary G J, Huang Z, Guo H and Liu d L 2018 *European Journal of Agronomy* **96** 108-19
[32] Santos D L and Sentelhas P C 2012 *Brazil. Ambi-Aqua. Taubate* **7** 7-17
[33] Singels A and Bezuidenhout C N 1999 *South African J. of Plant and Soil* **16** 2:96-101
[34] Mosqueda E B, Gonzales A D B and Alfaro C A T 2014 *J. Crop Improvement* **28** 772-94
[35] Afzal M, Ghulam S, Ilyas M, Jan S S A and Jan S A 2018 *Pure and Appl. Biol.* **793** 965-72
[36] Tena E, Mekbib F, Shimelis H and Mwadzingeni L 2016 *Cogent Food and Agriculture* **2** 15