Exposure pattern of tobacco cultivation places due to climate change in Probolinggo district, East Java

Sobirin, F Dzikraini and T L Indra
Department of Geography, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia

Corresponding author’s email: tito.latif@sci.ui.ac.id

Abstract. Probolinggo District is one of the centers of tobacco producer in Indonesia, paiton tobacco as local varieties included in dry season type of tobacco (Voor Oogst). Rainfall as well as dry season dynamics in 2015 and 2016 which had already been global, is affected tobacco cultivation and additional values to farmers in Probolinggo district. This research has purpose to identify the exposure patterns of tobacco cultivation places in Probolinggo district related to climate change. Based on daily rainfall data during 1990–2016 from 50 rain gauge stations, parameters of exposure due to climate change are processed by using de Boer method and mapped by using Thiessen polygon method. Determination of level of exposure places are done by scoring method and map overlay technique, then associated with landuse. The analysis results showed that exposure pattern with low level tend to be in the coastal areas and lowlands, stretching from West to East. The higher elevation is, the higher level of exposure places.

Keywords: Climate change, exposure places, daily rainfall, map overlay and paiton tobacco

1. Introduction

The world has experienced warmer conditions during the last three decades almost in all regions [1] and most of them indicate major impacts on agriculture [2]. Rainfall cannot be predicted and tend to vary as the consequences of climate change in the last few years that the onset of seasons come through the shifts in a number of places [3]. In 2016, BMKG [4] states that there is a deviation of rainfall in the form of wet drought that will occur in May and June. La-Nina has predicted to emerge with 50 % chance in October–December, so the amount of rainfall at the end of dry season could be increased [5]. In other hand, uncertain rain leads to be a problem in tobacco management planning [6].

Probolinggo district is one of centres producing tobacco in Indonesia, locally known as tobacco paiton. Tobacco paiton belongs to tobacco Voor-Oogst type that started to be cultivated at the onset of dry season [7]. As a seasonal crop, tobacco paiton requires enough rainfall at the beginning of the planting period and dry conditions during harvest [6]. Tobacco paiton is unsuitable to be planted when there is still having rain, it is tantamount to wasting costs and more efforts because tobacco is likely to be surely dead or damaged [5]. One step to helping tobacco farmers in cultivating, planning, and managing the crops in facing climate change is to map the distribution of tobacco cultivation places that is exposed due to climate change. The mapping of exposure places is done by overlaying the parameters of climate change with the area of cultivation of tobacco in the research area. This paper therefore aims to discover the distribution places of tobacco’s cultivation that has been exposed by climate change based on various exposure levels.
2. Method
Rainfall is one of climate factors that deviate due to climate change [8]. In research of exposure of tobacco cultivation places due to climate change, there is five parameters that is determined from daily rainfall data in normal condition by the average years of 1990–2015 and deviate condition by the year of 2016. The five parameters in form of climate deviation contain of (1) onset of dry season, (2) duration of dry season, (3) rainfall intensity at tobacco planting period, (4) rainfall intensity at tobacco harvest period, and (5) amount of rainy days at tobacco harvest period. Data processing is divided into two, that is tabular and spatial. Tabular data that has been obtained then created to be database as a whole and compiled using Microsoft Excel software.

There are several stages in the processing of rainfall data, starting with rainfall data processing based on rain gauge station for 27 years. Daily rainfall data is classified into tenth-day (decad) or 36 decads in one year from 50 rain gauge stations in Probolinggo district. Data computation is divided into two, that is average value data (normal condition) and reference value data (deviate condition). The five parameters are being determined of (1) the onset of dry season based on criteria by de Boer [9], (2) dry season duration based on last decad reduction over first decad of dry season, (3) average rainfall intensity in tobacco planting period, (4) average rainfall intensity in tobacco harvest period, and (5) amount of rainy days in tobacco harvest period. After all parameters are determined, the results are being averaged at every rain gauge stations to generate matrix value of all deviations. Upper or lower limit for all parameters are determined by compute standard deviation value annually, then being added or reduced with average normal condition values. If matrix value of all deviations is outside the upper or lower limit, that is a deviation. Deviation values should be calculated to differencing the matrix value and the limit value either it is below or above normal condition. Deviation values are classed by figuring the number of classes and class intervals over all parameters that turns into seven classes with different intervals on the scale 1–7 based on theirs value. At the end, the five scores each parameter in rain gauge stations with theirs coordinate points are combined to be spatially processed into attribute data.

Spatial data processing is done for knowing the spatial pattern using ArcGIS 10.1 software. Spatial data based on every rain gauge station in Probolinggo district are being interpolated with Thiessen Polygon method. Spatial data measurements made at each station are assumed representative of the surrounding area [10], that purposed to knowing the rainfall places with weighting in each polygon area. Exposure levels due to climate are mapped by calculating scores of five parameters in each polygon area with equal weighting according to formula based on Adger [11], which ‘P’ means parameter as:

\[
    \text{Levels of exposure} = P_1 + P_2 + P_3 + P_4 + P_5
\]

The results are divided into three classes consist of low, medium, and high exposure. The overlay mapping of tobacco cultivation places due to climate change based on exposure levels and administration map of Probolinggo District in order to know the pattern of tobacco cultivation places that is exposed due to climate change.

3. Results and discussion
At the last seven years, tobacco cultivation in Probolinggo district are distributed in 18 sub-districts. There are four tobacco varieties such as burley, kasturi, menyono, and paiton. However, the lastest superior tobacco varieties which still exist are paiton and menyono. Paiton tobacco is the prime variety spreads in eleven sub-districts on the east, consist of Paiton, Kotaanyar, Besuk, Gading, Kraksaan, Krenjengan, Pakuniran, Maron, Pajarakan, Banyuanyar, and Gending. At the same time on the west of district, menyono tobacco spreads in four sub-districts include Bantaran, Kурipan, Lumbang, and Wonomerto. In tobacco cultivation, paddy fields need to be managed by drying and fertilizing the soil before planting the first tobacco seed. Along with the management of the cultivation places, tobacco seedling in a number of supplier areas such as Kotaanyar sub-district.
Tobacco are vulnerable to excess water that affects plants quality, then the last planting of tobacco is in July and the harvest is done no later than October. One reason behind this, groundwater has already started to rise in September and tobacco growth lasts for 3–4 months until the first harvest period. The facts based on local tobacco collectors; the earliest tobacco harvest period coincided with independence day on August seventeenth Climate change in the form of wet drought in 2016 greatly affects tobacco cultivation places in Probolinggo district. Climate change will be reviewed in determining the exposure of tobacco cultivation places based on deviation of dry season and deviation of rainfall during dry season.

3.1. Deviation of dry season and rainfall during dry season
Seasonal and rainfall deviations are measurable parameters of climate change. Seasonal deviations are determined from onset of dry season that shifted backward or forward and changing period length of the dry season. Rainfall deviations are the condition where the values are above or below limits at the right times and places. In Probolinggo district, onset of dry season has been shifted backward or being late that causes duration of dry season by the year of 2016 lasted shorter, while the rainfall is well above normal condition.

Based on deviation data of dry season (table 1), there is a season deviation in 2016 compared with normal conditions in 1990–2015. The onset of dry season is shifted four decades backward and the end of dry season is shifted a decad forward, as well as the duration of the season is reduced by five decades or tends to be faster than usual. The dry season in Probolinggo district is identical with low average rainfall.

Under normal conditions, the average rainfall tendency of dry season is less than 200 mm per year, whereas in 2016 the average rainfall season tendency is around 300-450 mm per year (figure 1) This indicates dry season that occurs in Probolinggo district is more wet than usual, which is caused by increasing rainfall. This condition has negative impact on sector of a seasonal crops, along with tobacco that can be confirmed as distracted.

| Table 1. Dry season deviation by 2016 and average of 1990–2015 in Probolinggo district. |
|------------------------------------------|---------------------------------|-----------------|-----------------|
| Dry season | Onset | Withdrawal | Duration |
| Average of 1990–2015 | II April (Decad of 11) | III October (Decad of 30) | 20 decades |
| Year of 2016 | III Mei (Decad of 15) | II Oktober (Decad of 29) | 15 decades |
| Numbers of deviation | 4 decades backward | 1 decad forward | 5 decades reduced |

Figure 1. Deviation graphic of average rainfall during dry season per rain gauge stations in Probolinggo district, East Java.
3.2. Level of exposure due to climate change
The level of exposure places is derived from the calculation of five parameters of climate change (table 2), in the form of climate deviations. Climate change in this study is a climate deviation that occurred in 2016 against the climate in normal conditions in Probolinggo District. Onset of dry season’s deviation occurs unevenly in Probolinggo District, dominated by 30% undeviated places. Duration of dry season in most areas tend to have low deviation places, located almost along the coastal areas.

Deviation of rainfall during tobacco planting period occurs almost in the Probolinggo district at all deviation classes, while the un-deviated classes by 7% are away from the coastal areas. Deviation of rainfall during tobacco harvest period occurs in all over places of Probolinggo district, with tendency of low deviation classes. The amount of rainy days during harvest period’s deviation scattered unevenly in every places of the district, the un-deviated places are dominated on the east of district by 18% from total district area. Generally, the amount of rainy days of tobacco harvest period in Probolinggo district tends to have a major deviation, located away from the coastal areas.

3.3. Exposure pattern of tobacco cultivation places due to climate change
Based on the most spacious areas, exposure places with medium level is the most dominating in Probolinggo district, reaching 60% of the total district area. The tobacco cultivation places on the west (figure 2) has a low exposure level in the central region to the northeast in the form of an increasingly lower terrain and tends to be having high exposure level towards the southwest higher terrain. In the eastern places, the level of exposure tends to be low in the centre to the north (lowlands and coastal areas) and higher towards the southeast (highlands).

The most places of tobacco cultivation are exposed to climate change with medium level of exposure by 57%, while high level of exposure only reaches 3% of the total research area. In 2016, the climate condition of Probolinggo district has tended to be more wet with higher frequency and intensity of rainfall. During the dry season, rain still occurs throughout the year. There were many farmers that continue to plant tobacco, but the loss cannot be denied because there was number of incidents of crop failure in some cultivation places in Probolinggo district.

Based on data from related institution, the most extensive tobacco cultivation places are located in Krejengan sub-district and the smallest is in Tongas and Leces sub-district. Tobacco production in 2016 is the lowest compared to 2015 and the average years. The impacts of climate change on these seasonal plants are clearly represented by the years of climate phenomenon. There was a long drought in 2015 that affects tobacco production to be higher than normal. On the other hand, in 2016, there is wet drought that affects tobacco production to be lower than normal conditions.

| Deviation classes | Onset Duration Dry season | Rainfall in planting period | Rainfall in harvest period | Number of rainy days in harvest period |
|-------------------|--------------------------|----------------------------|---------------------------|---------------------------------------|
| 0                 | 30 21                    | 7                          | 0                         | 18                                    |
| 1                 | 16 15                    | 9                          | 38                        | 25                                    |
| 2                 | 9 22                     | 16                         | 15                        | 28                                    |
| 3                 | 13 20                    | 21                         | 22                        | 17                                    |
| 4                 | 27 22                    | 29                         | 13                        | 0                                     |
| 5                 | 5 0                      | 14                         | 2                         | 4                                     |
| 6                 | 0 0                      | 3                          | 4                         | 0                                     |
| 7                 | 0 0                      | 1                          | 6                         | 8                                     |
4. Conclusion
The pattern of exposure of tobacco cultivation places due to climate change in Probolinggo District tends to be low in the coastal and lowland areas stretching from west to east. The higher the elevation is, the exposure increases. The places of tobacco cultivation is exposed to climate change with moderate levels in some areas in Probolinggo District. The exposure of tobacco cultivation places is due to climate change in the form of wet drought in 2016. Climate change that occurred are drift backward the onset of dry season, reduced duration of dry season, the average rainfall of cropping and harvesting period of tobacco deviate above the usual limit, and the number of rainy days of harvesting period of tobacco occurs beyond normal conditions. In 2016, the impacts of climate change in the tobacco cultivation area in Probolinggo district are the number of incidents of crop failure and reduced tobacco production.

References
[1] Chen J, Brissette F P, Lucas-Picher P and Caya D 2017 J. Hydrol. 549 534-6
[2] Stocker T F, Qin D, Plattner G-K, Tignor M, Allen S K, Doschung J, Nauels A, Xia Y, Bex V and Midgley P M 2013 Climate Change 2013 (Cambridge: Cambridge University Press)
[3] Woods B, Nielsen H O, Pedersen A B and Kristofersson D 2017 Land Use Policy 65 109-20
[4] Badan Meteorologi Klimatologi dan Geofisika (BMKG) 2019 Perubahan Iklim available at https://www.bmkg.go.id/iklim/?p=ekstrem-perubahan-iklim
[5] Aldrian E, Karmini M and Budiman B 2011 Adaptaasi dan Mitigasi Perubahan Iklim di Indonesia (Jakarta: Badan Meteorologi Klimatologi dan Geofisika, Indonesia)
[6] Ratnawati I 2016 Waspadai Tembakau Rusak Akibat Terjadi Kemarau Basah available at https://docplayer.info/32946613-Waspadai-tembakau-rusak-akibat-terjadi-kemarau-basah.html
[7] Sholeh M 2000 Curah Hujan dan Waktu Tanam Tembakau Temanggung (Malang: Balai Penelitian Tamanan Pemanis Dan Serat)
[8] Rachman A H 2007 Status Pertambakuan Nasional available at http://balittas.litbang.pertanian.go.id/images/pdf/sby1.pdf
[9] Manurung M T, Irsal I and Haryati H 2015 J. Online Agroekoteaknologi 3 564-73
[10] De Boer H J 1947 On Forecasting the Beginning and the End of the Dry Monsoon in Java and Madura (The Netherlands: Van Ingen)
[11] Damant C, Austin G L, Bellon A and Broughton R S 1983 J. Hydrol. 62 81-94
[12] Adger W N 2006 Global Environ. Chang. 16 268-81