Impact of climate change to fall armyworm attack on maize in Karo District, North Sumatera

Sri Endah Nurzannah*, Setia Sari Girsangb, Moral Abadi Girsangc, Roy Effendi

a, b, c North Sumatera Assessment Institute for Agricultural Technology; d Indonesian Cereals Research Institute

*Email: sriendahn8@gmail.com

Abstract. Climate change affects agriculture in some ways including changes in average temperatures, rainfall, and climate extremes with an important impact on pests and diseases. Several types of pests that arise as a result of the climate change and attacked corn plant is Spodoptera frugiperda. This study aims to analyze the relationship between various climate factors with the area affected by Spodoptera frugiperda in the Karo District, North Sumatera. The area used in this study is Karo District, North Sumatera because this is the area with the widest area affected by FAW on maize cropping. The highest area affected on maize in Karo District occurred in April of 1.533 ha. The analysis used in this research is multiple linear regression. Climate factor data are used as independent variables and area affected data as dependent variables. Based on data analysis with multiple linear regression owned by all factors influence on the area affected with a coefficient of determination (R^2) of 0.882. Climate factors that have a significant influence on the area affected are rainfall.

1. Introduction
One of the biggest threats in the world of agriculture is the occurrence of global climate change which is likely to result in crop failure [1]. Agriculture and climate change have a very close connection because the agricultural sector is very dependent and very vulnerable to climate change so that the knowledge of farmers in the magnitude of climate change is needed [2]. The impact and consequences of climate change for agriculture tend to be more severe for countries with higher initial temperatures, areas with marginal or already degraded lands and lower levels of development with little adaptation capacity. These changes may also affect insect pest occurrence. Increased temperature can potentially affect insect survival, development, geographic range, and population size. Temperature and rainfall, in particular, have a very strong influence on the development, reproduction, and survival of insect pests and as a result, it is highly likely that these organisms will be affected by any changes in climate [3]. Besides, several types of pests arise as a result of climate change and attack corn plants, namely Spodoptera frugiperda.

Spodoptera frugiperda (J. E. Smith), commonly called the fall armyworm (FAW), is a major endemic and agricultural pest in America native to subtropical and tropical regions [4]. The name is derived from the movement of the larvae insect in military column formation en masse, devouring crops and leaving no vegetation [5]. It is a well-known sporadic and long-distance migratory pest with the adult moths being able to fly over 100 km in a single night. Because of the FAW has a wide
distribution, it is subjected to much climatic diversity, namely, temperature, moisture, and soil type [6].

The pest is an exotic (invasive) pest [7] which is indigenous in the Americas, is highly polyphagous, causing economic damage in various crops such as maize, sorghum, beans and cotton [8]. Over 30 countries have identified the pest within their borders including the island countries. The yield losses in maize ranging from 8.3 M to 20.6 M tons per year from 12 maize producing countries. The impact of FAW between 22 and 67% of yield in Ghana and Zambia, resulting in millions of US$ in losses. Similarly, [9] estimated the impact of FAW on 32% of yield in Ethiopia and 47% of yield in Kenya. These estimates, however, are based on socio-economic surveys focusing on farmers perceptions, but not on rigorous field scouting methods. This invasive pest was first reported in West Africa in late 2016 [10]; by early 2017, the pest invaded Sub-Saharan Africa. Recent reports confirmed the occurrence of fall armyworm in Indonesia includes island of Sumatera [11]. In early 2019, it was reported that FAW damaged the corn plantations in Karo District which is a corn production center in the North Sumatera Province. Yield losses in Karo district due to FAW reached 1,729.9 ha.

This research aims to analyze the relationship between various climate factors with the area affected in the Karo District, North Sumatera. Anticipatory strategy and technology adaptation to climate change and pest attack is one aspect that must be a strategic plan for addressing climate change. Therefore this research is expected to provide approved for production reduction approval also failed to harvest.

2. Materials and Methods

2.1. Data Preparation

The area used in this study is Karo District, North Sumatera because this is the area with the widest area affected by FAW on maize cropping. Area affected data used is monthly attack data from the planting period of January 2019 to August 2019 so that the conservation data is adjusted to the extent of the area affected. Area affected data on such attacks are maize crops that are expressed in hectares. Area affected were obtained from the Food Crops and Horticulture Protection Unit and climate data obtained from the Meteorology, Climatology and Geophysics Agency of Sampali, Medan.

2.2. Data Analysis

The analysis used to understand the influence of the climate factor on the area affected is multiple linear regression. Climate factor data are used as independent variables and area affected data as dependent variables. Multiple linear regression analysis was performed to obtain the relationship of four climate factors, namely the average temperature, humidity, rainfall, and wind speed against widespread attacks so that it could be related to the relationship between climate factors and the area affected in general. The multiple linear regression equation is as follows:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$$

Where:

- $Y$ = Area affected by FAW
- $X$ = Climate factors (average temperature, humidity, rainfall, and wind speed)
- $a, b$ = Constant

(The level of closeness of the relationship between $y$ and $x$ is expressed in the coefficient of determination $R^2$, the value ranges from 0-100%).

3. Results and Discussion

The factors influenced the maize area affected in North Sumatera can be seen through multiple linear regression analysis methods the dependent variable ($Y$) is the area affected and the independent variables ($X$) is average temperature ($X_1$), rainfall ($X_2$), humidity ($X_3$), and wind speed ($X_4$). Based on the analysis of the data can be written, multiple linear regression as follows:
\[
Y = 26088 - 322.40X1 + 217.04X2 - 237.23X3 - 0.59X4 \text{ with } R^2 \text{ value of } 88.2%.
\]

The equation shows that there is a relationship between average temperature, rainfall, humidity, and wind speed with the area of attack. Average temperature, humidity, and wind speed have an insignificant relationship while rainfall has a significant relationship with the area of the FAW attack. The coefficient of determination (\(R^2\)) of 0.882 shows that 88.2%. Factors affecting the area of the area affected can be explained by average temperature, rainfall, humidity, and wind speed while the remaining 11.8% is influenced by other factors outside the model.

The biotic environment such as climate has an important influence on insect pests [12]. Insect pest responses to environmental change are crucial for understanding how agroecosystems will respond to climate change. Population abundances of pests, beneficial insects, competitors, and symbionts may go through substantive changes with a changing climate include FAW. These changes can cause interactions (positive, negative and neutral) to become more or less intense [13]. For example, if a pest species is released from competitive interactions with a congeneric, its abundance may increase with a changing climate and it may become more invasive and impact on a wider number of species within its realized niche [14]. The correlation between average temperature and area affected can be interpreted in Figure 1.

**Figure 1.** Correlation of monthly average temperature with the area affected

Based on Fig. 1 the highest average temperature in Karo District occurred in June of 19.46 °C, causing a low area affected of 83.50 ha. The largest area affected occurred in April that is with a total attack of 1.533 ha at a monthly average temperature of 19.13 °C. The temperature has an influence the area affected but is not significant. The temperature has an influence on the duration of \(S. \text{ frugiperda's}\) lifecycle. \(S. \text{ frugiperda}\) completes its lifecycle in about 30 days during the summer, 60 days in spring and autumn, and 80 to 90 days during the winter [15]. The number of generations occurring in an area varies with the appearance of the dispersing adults. Up to eight generations per year can, however, occur in maize fields in tropical areas. \(Spodoptera \text{ frugiperda}\) is a tropical pest that does not have the ability to diapause when temperatures decrease. Rising temperatures increase rates of insect development and the number of pest generations. In cooler climates, development slows down to one or a few generations per year. The optimum temperature for larval development is 28°C (development can take place within a range of between 11°C and 30°C), although the egg stage and pupal stage require slightly lower temperatures. The correlation between monthly rainfall and area affected can be interpreted in Figure 2.
Based on Fig. 2, it is widely understood that area affected in the 2019 period starting from January to August increased with increasing rainfall. The lowest average rainfall occurs in July. An increase in the area affected occurred in April followed by an increase the rainfall in Karo District, amounting to 14.33 mm. Rainfall has a significant influence on the area affected. Rainfall, in particular, has a very strong influence on the development, reproduction and survival of insect pests and as a result it is highly possible that these organisms will be affected by any changes in climate. Distribution and frequency of rainfall may also affect the incidence of pests directly as well as through changes in humidity levels. It is being predicted that under the climate change, frequency of rainfall would decline while its intensity would increase. This would lead to heavy showers and floods on one hand and drought on the other. Under such situations, incidence of small pests such as aphids, jassids, whiteflies, mites, etc. on crops may be reduced as these get washed away by the heavy rains [16]. The average rainfall is predicted to decrease in several regions and the occurrence of summer droughts is likely to increase. Relationship between outbreaks of armyworm, Mythimna separate (Walker) and to a lesser extent Spodoptera Mauritia (Boisd.) and rainfall from 1938 to 1965 and observed that all but three outbreaks occurred when rainfall exceeded the average 89 cm [17]. The increase in the area attacks in the rainy season is influenced by the higher planting area of maize during the rainy season. Rainfall is one of the most important factors controlling maize yield [18]. The availability of a broad host causes the FAW attack to be high during the rainy season. The correlation between monthly humidity and area affected can be interpreted in Figure 3.
Based on Figure 3 it is known that the highest area affected occurs when the humidity reaches 91.02%. The highest humidity of 91.94% occurred in February and caused an attack area of 14 ha while the lowest humidity of 86.80% occurred in July and caused an area of attack of 22%.

The attack rate influenced by diet, temperature and humidity. Rising temperatures increase rates of insect development and the number of pest generations. In cooler climates, development slows down to one or a few generations per year. The optimum temperature for larval development is 28°C (development can take place within a range of between 11°C and 30°C), although the egg stage and pupal stage require slightly lower temperatures. Frost kills the insect. Rainfall may wash off some of the immature stages of the insect and wind speed may aid the dispersal of moths [19].

![Figure 4. Correlation of monthly wind speed with the area affected](image)

Based on Figure 4 it is known that wind speed has no significant effect on the area of FAW attacks in Karo District. During the high area affected in April, the wind speed in Karo District was 98.24 m/s. The wind speed in April was the lowest wind speed in Karo District on the January-August 2019 period. The highest wind speed occurred in June of 135.99 m/s and caused an area affected of 83.50 ha. FAW is capable of migrating long distances on prevailing winds, but it can also breed continuously in areas that are climatically suitable [20]. Research to date suggests that both strains of FAW that are found in the Americas entered Africa, perhaps as stowaways on commercial aircraft, either in cargo containers or airplane holds, before subsequent widespread dispersal by the wind. The probability is high (>90%) that the introduction to Africa was from the characterized Florida strain of FAW, which is restricted to the eastern seaboard of the USA, and the Caribbean islands. Noctuids are generally considered strong fliers and are assumed to migrate at night and downwind. Fall armyworm adults are nocturnal and their early evening movement near fields is generally with the wind. There are records of 16–30 hour tethered flight by FAW males. Newly hatched larvae first feed near where the egg mass was laid, then move upwards on the maize plants, and then disperse by wind using silk threads [21].

4. Conclusion
1. Damage due to FAW is much greater than caterpillar pests that already exist in Indonesia causing the planting of maize threatened to crop failure so it is necessary to conduct research on early control in areas where there are reported FAW using biological control agents or chemical insecticides if there is an increase in attacks.
2. The highest area affected by FAW in April 2019 of 1.533 ha in Karo District.
3. Climate factors that have a significant influence on the area affected are rainfall
References

[1] Yohannes, H. 2016. Relationship between climate change and agriculture. *Journal Earth Science Climate Change.* 7 (2): 1-8.

[2] Keane, J., S. Page, A. Kergna, J. Kennan. 2009. Climate Change and Developing Country Agriculture: An Overview of Expected Impacts, Adaptation and Mitigation Challenges, and Funding Requirements. Switzerland (CH): International Centre for Trade and Sustainable Development.

[3] Kambrekar, D.N., S.S. Guledgudda, A. Katti, Mohankumar. 2015. Impact of climate change on insect pests and their natural enemies. *Karnataka Journal Agriculture Science.* 28 (5): 814-816.

[4] Cabral, N.Y.Z.R., L. Kumar, F. Shabani. 2017. Climate change and agriculture research paper future climate scenarios project a decrease in the risk of fall armyworm outbreaks. *Journal of Agricultural Science.* 1-20. Doi:10.1017/S0021859617000314.

[5] Casmuz, A., M. L. Juarez, M.G. Socías, M. G., Murua, S. Prieto, S., Medina, E., Willink, G. Gastaminza, (2010). Revision de los hospederos del gusano cogollero del maíz, Spodoptera frugiperda (Lepidoptera: Noctuidae). *Revista de la Sociedad Entomologica Argentina.* 69, 209–231.

[6] Kebede, M, T. Shimalis. 2019. Out-break, distribution and management of fall armyworm, Spodoptera frugiperda J.E. Smith in Africa: The status and prospects. *American Journal of Agricultural Research.* 4 (43): 1-16.

[7] Prasanna, B.M, H.E. Joseph, R. Eddy, M.P. Virginia. 2018. Fall armyworm in Africa: A Guide for Integrated Pest Management, First Edition. Mexico (MX): International Maize and Wheat Improvement Center (CIMMYT).

[8] Day R, Abrahams P, Bateman M, Beale T, Clotey V, Cock M, Witt A. 2017. Fall armyworm: Impacts and implications for Africa. *Outlooks on Pest Management.* 28 (5):196-201.

[9] Kumela, T., J. Simiyu, B. Sisay, P. Likhayo, E. Mendesil, L. Gohole, T. Tefera. 2018. Farmers knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (Spodoptera frugiperda) in Ethiopia and Kenya. International *Journal Pest Management.* 1–9.

[10] Goergen, G., K.P. Lava, S.B. Sankung, A. Togola, M. Tamo. 2016. First Report of Outbreaks of the Fall Armyworm Spodoptera frugiperda (J E Smith) (Lepidoptera, Noctuidae), a New Alien Invasive Pest in West and Central Africa. *Plos One.* 11(10): e0165632. doi:10.1371/journal.pone.0165632.

[11] Trisyono, Y. A., Suputa, V. E.F. Aryuwandari, M. Hartaman, Jumari. 2019. Occurrence of heavy infestation by the Fall Armyworm *Spodoptera frugiperda*, a new alien invasive pest, in corn in Lampung Indonesia. *Jurnal Perlindungan Tanaman Indonesia.* 23 (1): 156-160.

[12] Nigel, R. Andrew, S.J. Hill. 2017. Environmental Pest Management: Challenges for Agronomists, Ecologists, Economists and Policymakers, First Edition. England (UK): John Wiley & Sons Ltd.

[13] Lankau, R.A. and Strauss, S.Y. 2011. Newly rare or newly common: evolutionary feedbacks through changes in population density and relative species abundance, and their management implications. *Evolutionary Applications.* 4: 338–353.

[14] Bolnick, D.I., T. Ingram, W.E. Stutz, L.K. Snowberg, O.L. Lau, J.S. Paull. 2010. Ecological release from interspecific competition leads to decoupled changes in population and individual niche width. *Proceedings of the Royal Society of London Biological Sciences.* 277: 1789–1797.

[15] Plessis, H, J. Berg, N. Ota, D. J. Kriticos. 2018. Spodoptera frugiperda (fall armyworm) background information. Pest Geography. 1-7 pp.

[16] Pathak, H., P.K. Aggarwal, S.D. Singh. 2012. Climate Change Impact, Adaptation and Mitigation in agriculture: Methodology for Assessment and Application Division of Environmental Sciences. India (IN): Indian Agricultural Research Institute.
[17] Pareek, A., B.M. Meena, S. Sharma, M.L. Tetarwal, R.K. Kalyan, B.L. Meena. 2017. Impact of Climate Change on Insect Pests and Their Management Strategies.

[18] Huang, C., S. W. Duiker, L. Deng, C. Fang, W. Zeng. 2015. Influence of precipitation on maize yield in the Eastern United States. Sustainability. 7: 5996-6010.

[19] Igyuve, T.M., G.O.S. Ojo, M.S. Ugbaa, A.E. Ochigbo. 2018. Fall army worm (Spodoptera Frugiperda); It’s biology, impact and control on maize production in Nigeria. Nigerian Journal of Crop Science. 5 (1) : 70-79.

[20] CABI. 2017 digest of an Evidence Note commissioned by the UK Department for International Development (Fall Armyworm: Impacts and Implications for Africa). The full report is available at www.invasivespecies.org/fawevidencenote.

[21] Heinrich, E.A., J. Sidhu, R. Muniapaan, A. Fayad, A. Adiga, A. Marathe, J. Mcnitt, S. Venkatramanan. 2018. Pest Risk Assessment of the Fall Armyworm, Spodoptera frugiperda in Egypt. Virginia Tech. 54 pp.