The distribution and impact of fall army worm (Spodoptera frugiperda) on maize production in North Sumatera

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Abstract. Maize is the second most important cereal crop in the world after wheat, contributing substantially to the total cereal grain production in the world economy as a trade, food, feed, and industrial grain crop. The presence of S. frugiperda or Fall Armyworm (FAW) and climate change has affected the corn productivity in North Sumatra. The objective is to determine the distribution and impact of FAW on maize production in North Sumatra. The method used was a survey, observation, and interview farmers and extensions, also secondary data of the FAW attacked from the North Sumatra Food Crops and Horticulture Protection unit (January to August 2019). Sampling was done by simple random sampling with 30 respondents. Analysis data in the form of agronomic advantages and FAW distribution were mapped by overlaying the district administration map with the corn area that was attacked using ArcView GIS. The results showed that the heaviest attack in Karo District was 1,729.9 ha started at 25 days after planting until flowering. The effect of FAW is an increase in production costs by 4.2%, reduction production by 26.6% wherein labour is the highest cost production. Rainfall and wind speed factors have a positive and negative influence on the development of FAW in North Sumatra, early anticipation at the beginning of the plant growth period can reduce the impact on corn production and cost.

1. Introduction
Maize is one of the most important food and cash crops for both commercial and many rural farm families [1]. The growth in demand for human consumption of maize in the developing world is predicted to be 1.3% per annum until 2020. Globally, 765 million metric tons (mt) of maize were harvested in 2010 from just under 153 million hectares (m ha).

North Sumatra is the fourth corn producer in Indonesia after East Java, Central Java and Sulawesi with a production of 7.7% of national production (1.5 million tons Vs. 19.6 million tons). Maize productivity in North Sumatra has increased throughout the period 2008-2017 and optimal in 2015 reached 6.23 t ha\(^{-1}\) [2]. Although the productivity of maize in North Sumatra was 16.9% higher in 2015 compared to national production (6.23 Vs. 5.18 t ha\(^{-1}\)), it still had a high gap of 6.77-7.77 with production potential [3].

Data from food crops for the goals of national production 2018 33.9, million tons the corn industry feed 32% of the total production of the food needs of 14% of total production. The cause of the limited production of corn mainly to poor soil fertility, frequent occurrence of droughts, high incidence of insect pests, diseases and weeds, farmers' limited access to fertilizer, and lack of access to improved maize seed [4].
Fall armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae), is an exotic (invasive) pest [5] and economically important pest that attacks maize and other graminaceous crops throughout its native tropical and sub-tropical America region [6]. Invasive species are a major cause of crop loss and can adversely affect food security [7]. Exotic (invasive) insect species reproducing naturally in a designated area where they were brought by unusual means, such as air, ocean current, and accidental or intentional introduction. Recently, FAW has invaded and shown rapid spread in many of the countries [8] especially in North Sumatra and threatens the food security of the millions of people.

FAW is a polyphagous Lepidopteran pest which has a host range of 353 plant species from 76 plant families, namely Poaceae, Asteraceae and Fabaceae from Brazil [9]. Over 30 countries have identified the pest within their borders including the island countries. The yield decreased in maize from 8.3 M to 20.6 M tons per year from 12 maize producing countries [10].

There was limited information about this pest in all aspects. It is crucial to have detailed information on the way or means of introduction, the progress of distribution of this pest and associated crops losses, management practices taken so far, and encountered challenges and opportunities. Thus, the objective of this paper is to determine the distribution and impact of FAW on maize production in North Sumatera as well as to develop a better understanding of the fall armyworm, *Spodoptera frugiperda*.

2. Materials and Methods

2.1. Experimental site
The study area was located in 33 districts in North Sumatra and focused in Karo and Langkat Districts. The corn areas in North Sumatera is 281,311, 4 ha while the largest is Karo Districts of 89,633 ha.

2.2. Weather parameters
Cumulative precipitation (mm), solar radiation (MJ m$^{-2}$), humidity, and mean temperature ($^\circ$C) were collected from vegetable research center Tongkoh and agriculture extension center Hinai Station.

2.3. Statistical Method
The data of FAW attacks on the corn crop from planting period January to August 2019 are secondary data from the North Sumatera Food and Horticulture Department. The method used was a survey, observation, and interview farmers and extensions. Sampling was done by simple random sampling with 30 respondents. Analysis data in the form of agronomic advantages and FAW distribution were mapped by overlaying the district administration map with the corn area that was attacked using ArcView GIS. 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
FAW have entered Indonesia and invade some maize production centre in several provinces such as Aceh, West of Sumatra, North of Sumatra, Riau, South of Sumatera, Lampung, Banten, West of Java, Central of Java, West of Kalimantan, East of Kalimantan, and Gorontalo. Widespread attack of maize crop attacked by FAW in North Sumatera can be seen in Table 1.
Table 1. Widespread attacked by FAW on maize crop in North Sumatera

| No | Rate Attack | Widespread Attack (ha) |
|----|-------------|------------------------|
| 1. | Slight      | 2.375.                 |
| 2. | Moderate    | 52.2                   |
| 3. | Severe      | 3                      |
| 4. | Crop Losses | -                      |
|    | Total       | 2.430.2                |

Source: Food Crops and Horticulture Protection Unit, 2018

Based on Table 1 the total area of maize attacked by FAW is 2.430.2 ha which is divided into 4 categories, namely slight, medium, severe, and crop losses. The extent of the attacked due to FAW with a slight attacked was 2.375 ha, moderate attack was 52.2 ha, the severe attack was 3 ha, and none caused crop losses. Fall armyworm has rapidly spread throughout most of the maize-producing areas of North Sumatera as suggested by the slight to severe levels of infestation of FAW in almost all maize fields surveyed. This is according to the statement CABI [11], FAW has now appeared in Africa and are rapidly spreading throughout the tropical and subtropical regions of the continent. Its impact on maize yields in Africa has been and is likely to continue to be, significant. [12] added that FAW is capable of migrating long distances on prevailing winds, but it can also breed continuously in that area are climatically suitable.

Based on Fig.1 it was discovered that the damage caused by FAW are scattered over several districts situated in North Sumatera. The level of severe attack happened in 2 districts were Karo and Toba Samosir Regency, the level of moderate attacks happened in Deli Serdang Regency, the level of slight happened North of Tapanuli, Simalungun, Dairi, Langkat, Humbang Hasundutan, West of Pak-Pak, Samosir, Serdang Bedagai, Batu Bara, Medan, Binjai, and 20 districts that is free from FAW are Nias, Mandailing Natal, South Tapanuli, Centre Tapanuli, Labuhan Batu, Asahan, South Lawas, South of Nias, Lawas, South of Labuhan Batu, North of Labuhan Batu, North of Nias, West Nias, Sibolga, Tanjung Balai, Pematang Siantar, Tebing Tinggi, Padang Sidempuan, Gunung Sitoli, and Lake Toba Regency.

Figure 1. Distribution of FAW in North Sumatera and Karo District
Most of the sub-districts in Karo District were attacked by FAW except Namanteran, Merdeka and Kabanjahe. Chemical control was done with the application of pesticides with Deltametrin 25 g/l by 3-4 times per season. The attack occurred from vegetative to generative growth where 20-60 days after planting (DAP). However, the application of pesticides is done when the plant has been attacked with moderate to severe intensity. Many plants die because of late control. On the other hand, some farmers use pesticides incorrectly which causes armyworms to become resistant to pesticides.

Table 2. Show that corn production decreased by 26.6% while inversely to the production costs such as labour and pesticides was increased by 50.0% and 71.4%, respectively due to the FAW attack in 2019. This has an impact on farmers’ income was decreased R/C ratio from 1.9 to 1.3. The results of the farming business analysis from the average 30 respondents interviewed are the total cost for 1 hectare of land of Rp. 19,499,641, with an average yield of 9.2 tons per ha with a gross income of Rp.36,800,000 where labour costs are the highest component (31.7%).

| Component         | Cost (Rp.) | Cost FAW affected (Rp.) |
|-------------------|------------|-------------------------|
| Seeds             | 1,720,000  | 1,720,000               |
| Anorganic Fertilizer | 3,945,000  | 3,945,000               |
| Organic Fertilizer | 600,000    | 600,000                 |
| Pesticide         | 919,641    | 1,669,641               |
| Labour:           | **6,178,000** | **6,268,000**         |
| 1. Land management| 1,000,000  | 1,000,000               |
| 2. Fertilizer application | 500,000    | 500,000                 |
| 3. Planting       | 880,000    | 880,000                 |
| 4. Weeding        | 144,000    | 144,000                 |
| 5. Pest control   | 144,000    | 504,000                 |
| 6. Harvest        | 2,430,000  | 2,430,000               |
| 7. Post harvest   | 1,080,000  | 810,000                 |
| Tax               | 150,000    | 150,000                 |
| Land lease        | 5,000,000  | 5,000,000               |
| Loan interest     | 987,000    | 987,000                 |
| Total cost        | **19,499,641** | **20,339,641**        |
| Yields (t)        | 9,200      | 6,750                   |
| Price/kg          | 4,000      | 4,000                   |
| Gross income/season | **36,800,000** | **27,000,000**   |
| Nett income/season | **17,300,359** | **6,660,359**        |

| R/C ratio | 1.9 | 1.3 |

Data processed from 30 respondents

The policy of the Regional Government in controlling the attack of armyworms is distributed pesticides and disseminated information to farmers about how to use pesticides wisely. This is important because North Sumatra farmers are very dependent to chemical pesticides. In addition, the local government also disseminates information on Integrated Pest Management (IPM) technology. Karo is the largest corn producing district in North Sumatra (Fig. 2 and 3). Highest attack of FAW occurred in Karo due to monocultures of maize cultivation which resulted in abundant food supply for FAW. [13] In bio-climatically similar areas where farmers cultivate maize in large-scale
monocultures, FAW is a serious pest. Although FAW is a polyphagous pest, FAW prefers corn plants. This is in accordance with [14] The Fall Army is an invasive pest which is highly destructive primarily to Maize but has more than 350 host plants. Based on [15] In laboratory host preference studies examining larval feeding choices, maize and wheat were preferred above soybean and cotton. [16] stated that although FAW seemingly displays a very wide host range, the most frequently consumed plants are field corn, sweet corn and sorghum. [17] reported that among vegetable crops, only sweet corn is regularly damaged, but others are attacked occasionally.

FAW entry into Indonesia can occur through international trade. The pathways of the recent accidental introduction of the fall armyworm into West Africa might be due to increasing trade volume and easy air travel of people from one continent to another has amplified the phytosanitary risks of even multiple introductions [18]. Research to date suggests that both strains of FAW entered Africa, perhaps as stowaways on commercial aircraft, either in cargo containers or airplane holds, before subsequent widespread dispersal by the wind. [11] reported that the Fall Army Worm (FAW) is capable of migrating long distances on prevailing winds, but it can also breed continuously in areas that are climatically suitable.

In North Sumatra, FAW has attacked and caused damage to corn plantations in 15 districts. Extensive attacks due to FAW in several districts in North Sumatra (Fig 2) and Karo (Fig 3).

![Figure 2. Widespread attacked of FAW in North Sumatra](image1)

![Figure 3. Widespread attacked of FAW in Karo District](image2)
Maize plants are susceptible to fall armyworm (*Spodoptera frugiperda*) attack during practically all stages of its development cycle, and severe losses occur when the whorl is destroyed, reducing photosynthetic area and compromising the grain yield. It may also attack the basal portion of the ear, destroying the grain or favouring infection by microorganisms. Damage on maize may be observed on all plant parts depending on development stage. The extent of damage, however, depends on factors such as planting season, geographical region, cultivar planted and cultural practices inherent in and around the field. Symptoms of a FAW attack on corn can be seen in Figure 6.

FAW destroys maize plants by scraping leaves. Young larvae open leaf tissue and leave a transparent epidermal layer. The instars larvae 2 and 3 make a hole in the leaf and eat the leaf from the top edge inward. Late instars larvae can cause severe damage leaving only the vein and stems of maize plants. Usually, the larvae are on the lower surface that is passed by in groups. An average population density of 0.2-0.8 larvae per plant can reduce yield by 5-20%. Damage to plants is usually marked by larval scraping, which is a coarse powder that looks sawdust on the upper surface of the leaf, or there are shoots of corn. This is consistent with the statement [19] stated that young larvae initially consume leaf tissue from one side, leaving the opposite epidermal layer intact. By the second or third instars larvae begin to make holes in leaves and eat from the edge of the leaves inward. Feeding in the whorl of corn often produces a characteristic row of perforations in the leaves. Older larvae cause extensive defoliation, often leaving only the ribs and stalks of maize plants, or a ragged, torn appearance.

Larvae also will burrow into the growing point, destroying the growth potential of plants, or clipping the leaves. In maize, they sometimes burrow into the ear, feeding on kernels in the same manner as corn earworm, *Helicoverpa zea*. Unlike corn earworm, which tends to feed down through the silk before attacking the kernels at the tip of the ear, fall armyworm will feed by burrowing through the husk on the side of the ear. [20] studied larval feeding behaviour, and reported that although young (vegetative stage) leaf tissue is suitable for growth and survival, on more mature plants the leaf tissue is unsuitable, and the larvae tend to settle and feed in the ear zone, and particularly on the silk tissues. However, silk is not very suitable for growth. Larvae attaining the corn kernels display the fastest rate of development. Also, although the closed tassel was suitable with respect to survival, it resulted in poor growth. Thus, tassel tissue may be suitable for initial feeding, perhaps until the larvae locate the silk and ears, but feeding only on tassel tissue is suboptimal.

Based on climate data in two districts of corn centers in North Sumatra were rainfall and wind speed has a major effect on pest and disease attacked. Table 2. showed the positive and negative correlation on rainfall and wind speed with FAW attacked. Correlation of rainfall and wind speed to FAW attacked ≥ 70% from seven months of data for the January-July 2019 period.
Table 3. Correlation of FAW development with climate

| Climate     | Langkat | Karo   |
|-------------|---------|--------|
| RR          | 0.94**  | 0.87** |
| WSAVG       | -0.81** | -0.44  |
| WSMAX       | -0.70*  |        |
| WDAVG       | -0.31   |        |
| TTAIRMAX    | 0.06    | 0.33   |
| TTAIRAVG    | 0.04    | 0.47   |
| TTAIRMIN    | 0.04    | 0.34   |
| RHAVG       | 0.71*   | 0.16   |
| SRAVG       | -0.06   |        |
| SRMAX       | -0.25   |        |

Data source: Langkat and Karo Regency Agriculture Office and Sampali Geological and Geophysical Agency

4. Conclusion
1. The total area of FAW attacks in North Sumatra was 2,430.2 ha. Severe damage occurred in Karo and Simalungun. The area of the highest attack was 1,729.9 ha in Karo Districts.
2. The FAW attacked decreased corn production by 26.6% farmers' income (R/C ratio 1.9 to 1.3) wherein labour and pesticide costs increased by 50.0% and 71.4%, respectively.
3. Rainfall and wind velocity factors are respectively positively and negatively correlated to the development of FAW in North Sumatra, anticipation at the beginning of the plant growth period is essential.

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