Study Brief 31: Impact

Have actions taken to control fall armyworm reduced the economic cost experienced in Ghana?

F Williams, S T Murphy, P Beseh, J Lamontagne-Godwin

Summary

The rapid spread of the invasive crop pest, the fall armyworm (*Spodoptera frugiperda)*, across Africa in recent years has attracted considerable interest, especially the effect on maize farmers. The purpose of this study is to understand and assess the economic costs of the fall armyworm invasion in Ghana under different control scenarios. Three different scenarios are modelled: one with no farmer applied control measures, one with limited control measures and one with proactive control measures that were used in Ghana in 2017. Maximum, minimum and mid-range estimates of losses are presented for the second and third scenarios. The study is based on data available from CABI surveys, the Ministry of Food and Agriculture in Ghana and FAOSTAT.

Highlights

- The model indicates that the coordinated control measures taken reduced the economic loss from an estimated mid-range of USD 25 M (min USD 19 M, max USD 31 M) to 10 M (min USD 3 M, max USD 16 M), a difference of approx. USD 15 M over 1 year.

Introduction

The rapid spread of the invasive crop pest, the fall armyworm (*Spodoptera frugiperda)*, across Africa in recent years and the resulting dramatic impact on crop production has attracted considerable media interest, especially the effect on maize farmers who have been battling to save their crops [1] [2] [3]. The crisis has led to substantial efforts by governments across Africa to help farmers control the pest and reduce the effect on the maize crop [4] [5] [6] [7]. The outbreak has also been reported in scientific publications; the latter also providing good reviews of the identification, biology, ecology and behaviour of the pest (see: Goergen *et al* 2016, Cock *et al* 2017, Abrahams *et al* 2017). However, little research has been carried out on the economic impact of the pest and whether concerted efforts to control FAW can limit the economic effect on smallholder farmers in Africa. Thus, the aim here is to focus on the economics of the pest in Ghana as a case example. We model three different scenarios to assess whether the actions taken to control FAW reduced the economic losses experienced within the country due to FAW.

Background

The fall armyworm (FAW) moth, *Spodoptera frugiperda*, is indigenous to the Americas. The pest was first reported to be seen in Africa in 2016 (Goergen *et al* 2016, Cock *et al* 2017,), with subsequent reports across the continent in 2017. It has now been reported in all but 10 African countries. This is a rapid increase from 12 African countries reporting the pest in April 2017 and 28 countries in September 2017 (Day *et al* 2017). Further to this, the FAW has also now invaded Asia and by May 2019 was found in India, Sri Lanka, Nepal, Bangladesh, Myanmar, Thailand, Japan, and China[8][9].

In its native range FAW is reported to attack at least 80-100 different plant species (Cock *et al* 2017, Day *et al* 2017) and in Africa it has had a significant effect on maize (Abrahams *et al* 2017). This is of particular importance given the primary status of maize as a staple crop in much of the continent. The severity of the yield loss depends on both the level of infestation and the growth stage of the maize plant (Hruska and Gould 1997, Marenco *et al* 1992, Ghidiu and Drake 1989, Cruz and Turpin, 1983). Considerable research has been done in the Americas on losses caused by FAW under different conditions, different varieties and with different control options (Dal Pogetto *et al* 2010, Cruz *et al* 2010, Kumar and Mihm 2002, Cruz *et al* 1999), with loss estimates varying between 5 - 100% (Lima *et al* 2010, Farias *et al* 2008, Kumar and Mihm 2002, Hruska and Gould 1997, Marenco *et al* 1992, Williams and Davis 1990, Hruska and Gladstone 1988, Harrison 1984, Cruz and Turpin 1983). So far there is limited evidence from Africa, with Kumela *et al* (2018) providing farmer reported yield losses ranging between 32% and 47%, Tambo *et al* (2018) giving a farmer reported estimate of 44%, and Day *et al* (2017) stating that farmer reported losses in Zambia of 40% and Ghana of 45%. Baudron *et al* (2019) estimate losses measured experimentally from FAW in Zimbabwe, at 11.57%.

---

[1] https://www.pulse.com.gh/news/business/fall-armyworm-permanent-dollar2billion-maize-deficit-looming-over-africa-due-to-fall/nx1hkg0
[2] https://uk.reuters.com/article/us-science-africa-crops-armyworm-idUKKBN15L003
[3] https://www.agrilinks.org/post/whats-place-technology-fall-armyworm-crisis
[4] https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Fall-army-worms-are-here-to-stay-Agriculture-Ministry-643106
[5] https://allianceforscience.cornell.edu/blog/2017/05/fall-armyworm-invasion-spreads-to-ghana/
[6] https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Ghana-loses-about-US-64-million-through-armyworm-infestation-642760
[7] http://agrihomegh.com/control-fall-armyworm/
8 http://www.fao.org/emergencies/resources/maps/detail/en/c/902959/
[9] https://www.ippc.int/en/countries/japan/pestreports/2019/07/report-of-first-detection-of-spodoptera-frugipedera-fall-armyworm-faw-in-japan/

Modelling approach

In order to understand whether the actions taken in response to the FAW outbreak in Ghana reduced the economic losses experienced by the country we model the economic cost to farmers due to FAW under three different scenarios:

1. value of loss if no control measures or actions were taken (the baseline situation)
2. value of loss if limited or uncoordinated actions were taken by farmers
3. value of loss if coordinated actions and control measures were taken

While it is unlikely that Scenario 1 would occur in reality, it forms a useful worst-case situation against which to compare the other more realistic loss scenarios. Scenario 2 is a situation where farmers observed the outbreak of the pest (caterpillars in their maize), and the damage that is being caused, but do not know the appropriate control options to adopt. This lack of information means that they either take no action, choose to spray an insecticide that they already have, or spray an insecticide that is not recommended for FAW and may not be as effective. Some farmers in Ghana were initially unaware of what control measures to use, and so this situation estimates the losses that could have occurred on a broad scale if scenario 3 had not occurred. Scenario 3 reflects what happened in Ghana in 2017 and 2018, where the government with partners undertook concerted actions to address the outbreak of fall armyworm, including pesticide distribution, research into control methods, and awareness raising campaigns focusing on preventive and curative actions. In order to compare these scenarios, it is also necessary to have a baseline situation, which will be taken as the average yield and average economic value of the maize crop in Ghana in the five years preceding the 2016 invasion of FAW.

Estimates of yield loss and economic value

A bioeconomic modelling approach was taken, combining data on the suitability of maize growing areas to be infested by FAW, estimated losses of maize due to FAW under different control conditions and the value of maize in Ghana. These data were used to provide value of loss estimates for the three different scenarios.

Data for the baseline scenario was taken from FAO Stats[10], the Ministry of Food and Agriculture Annual Report 2017 and Lima *et al* (2010). A five-year average was constructed for: maize yield before FAW (1778.38 kg ha^{-1}, FAO Stats); production value (USD 505,727,664 FAO Stats); maize area planted (976,093 ha MOFA 2017); and production value per kg of maize produced (USD 0.286 calculated). A five- year average was used to ensure that figures were not based on a single year's abnormal yield or market value but reflected the general yield or production value before FAW. 2016 data was not used as this was when FAW was first detected in Ghana.

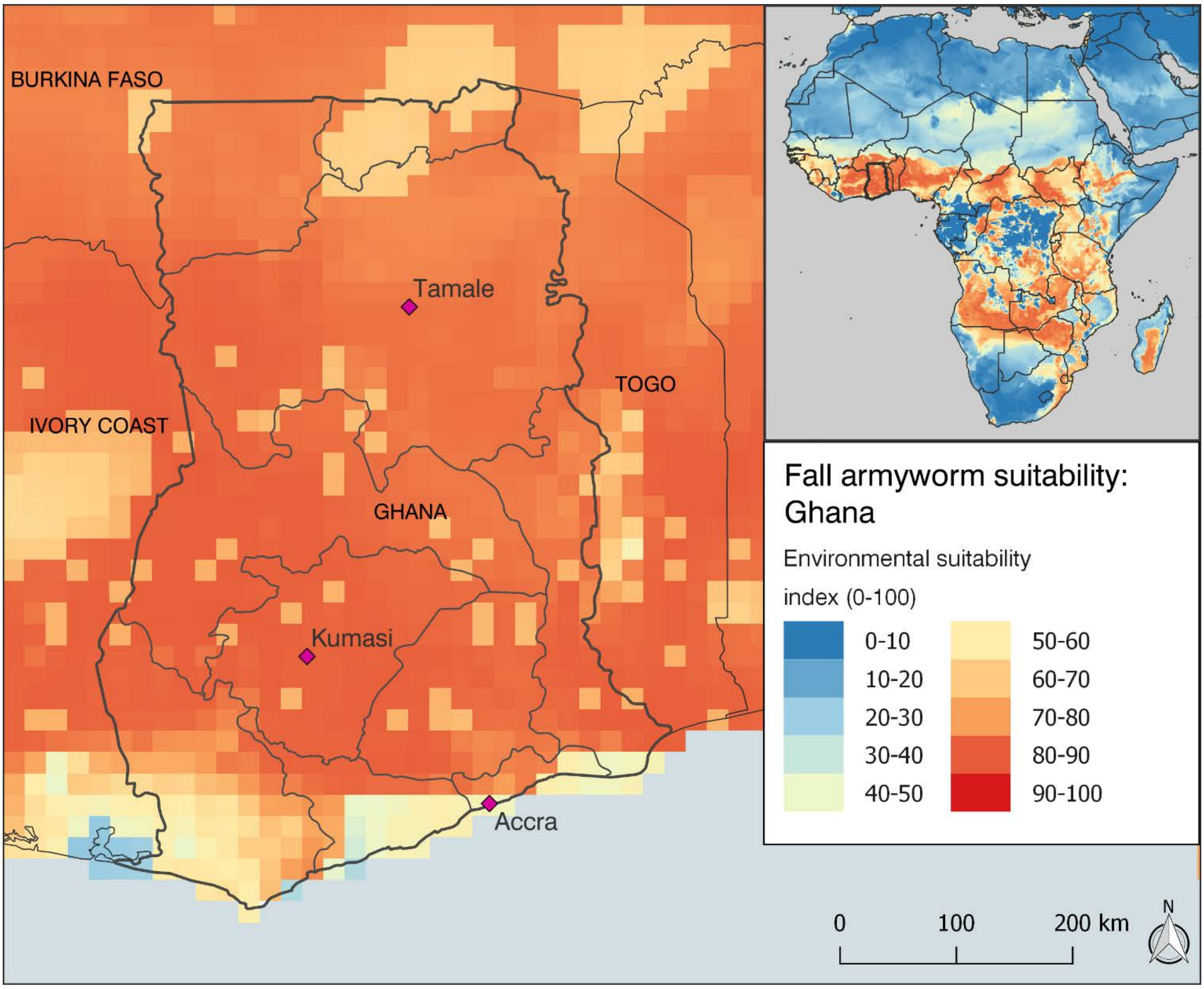
The considerable variety of yield loss estimates described above, under a great variety of conditions, led to challenges in choosing a realistic yield loss estimate that would be applicable to smallholder maize farmers in Ghana. The Lima *et al* (2010) estimate of 34% yield loss was considered to be low to mid-range of the many estimates provided in the literature (from 5% to 100%), and was not based on use of specific varieties, and not a result of specific experimental conditions. This figure was therefore used in the modelling as a standard expected yield loss due to FAW without control measures. The Lima *et al* (2010) is slightly lower than the farmer estimates of loss in 2017 in Ghana at 44% (Tambo *et al* 2018). However, as losses can be overestimated when reported by farmers, not measured, the Lima *et al* figure is considered to be a reasonable loss figure to use in this modelling.

---

[10] http://www.fao.org/faostat/en/#data

For scenario 1 it was assumed that production of all maize in Ghana was affected by FAW as all maize growing areas are considered environmentally suitable (Figure 1). This assumption was based on the biological modelling contained in Abrahams *et al* (2017) and Early *et al* (2018) which stated that the whole of Ghana was climatically suitable for FAW infestation and all regions (administrative areas) were reported as affected by FAW. The mean annual production (from 2011-2015) was reduced by 34% and the value of that production calculated at the average price per kg from 2011-2015.

Figure 1: Environmental suitability map for FAW in Ghana

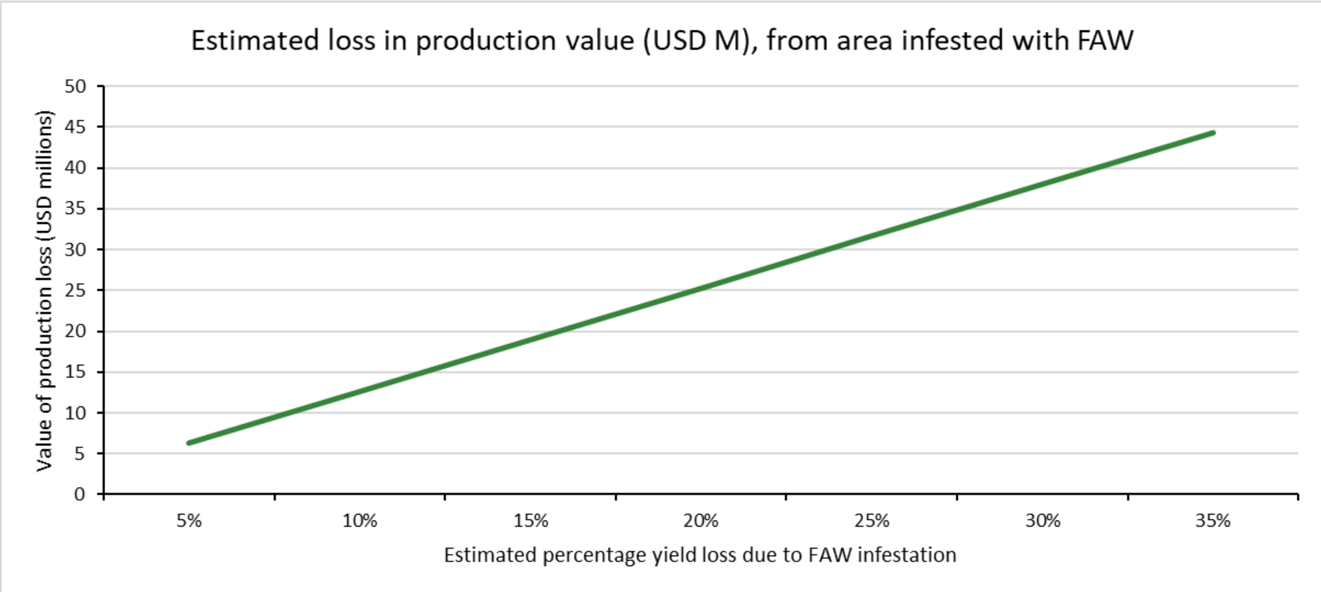


Scenarios 2 and 3 required yield loss estimates under conditions of little/no action or ineffective action by farmers (Scenario 2) and coordinated actions (Scenario 3). Limited data are available to provide these estimates. Abrahams *et al* (2017), Tambo *et al* (2018) and Kumela *et al* (2018) provide yield loss estimates based on farmer economic surveys, but Baudron *et al* (2019) comment that these figures are likely to be an overestimate, when compared to direct measurements in the field. Given this lack of clear data a range of yield losses and reduced production values between likely minimum and maximum figures were therefore calculated for Scenarios 2 and 3.

The value of the production loss estimates in Figure 2 were calculated from data in the MOFA 2017 report which gave an area of infested maize as 249,054 ha. The remaining maize growing area in

Ghana was excluded from this model. A pre-FAW production figure (kg) was calculated for the infested area using the average yield (kg/ha) from 2011-2015, as given by FAOSTAT. A monetary value was then calculated for the production using the average value of production per kg for the same five-year period. The next step was to estimate yield loss for the infested area at varying rates. Rates from 3% to a maximum of 34% were used and production loss (kg) calculated at these rates then subtracted from the overall production to give an amount for the infested area under the two loss scenarios. The value of this reduced production was then calculated using the FAOSTAT average value. The value of the lost production (USD) is given as the difference between the production value with no loss from FAW, and the production value under the different percentage losses.

Figure 2: Value of maize yield lost under different loss estimates



The paucity of yield loss data for FAW in Africa, and the challenges described above, mean an assumption on what range of yield loss figures to use for Scenarios 2 and 3 has to be made. Baudron *et al's* yield loss estimate of 11.6% was based on field situations where most farmers undertook little or no management for FAW so close to Scenario 2 where we assume farmers take little or no management actions for FAW. However, Baudron *et al's* data does include some field conditions where pesticides have been used and therefore does not reflect exactly Scenario 2 where little or no management actions are taken. To adjust for this, we increase the loss estimate slightly to 15%. In addition, as field loss estimates from the Americas are higher, we also provide figures for the value of the yield loss at rates of 20% and 25%. The values of loss at 15%, 20% and 25% are taken from Figure 2.

It is then necessary for Scenario 3 to estimate the yield loss for those farmers who undertook coordinated actions to manage FAW. Data from Abrahams *et al* (2017) and Tambo *et al* (2018) provide average yield loss estimates for those who undertook management actions and those who undertook little/no action. As discussed above it is likely that these farmer-reported estimates are high, but analysis of the data provides the difference in yield loss estimates between the two groups to be 12%. Therefore, for Scenario 3 we take the yield loss estimates for Scenario 2 and assume a 12% reduction, providing yield loss estimates of 3%, 8% and 13%.

The estimated national loss in production value for these two scenarios was compared with scenario 1, providing an estimated change in value of loss depending on what actions were taken to control FAW in Ghana.

Table 1: Estimates of economic losses

All values in USD		**Production value 5 year av***	**Estimated total production value**	**Estimated loss in production value**
Pre FAW		505,727,664		
Scenario 1 - No action taken			333,780,258	171,947,406
Scenario 2 - Limited/ uncoordinated action taken	Min		376,475,755	18,978,180
	Mid		354,330,122	25,304,240
	Max		332,184,489	31,630,300
Scenario 3 - Coordinated/ targeted action taken	Min		429,625,273	3,795,636
	Mid		407,479,640	10,121,696
	Max		385,334,008	16,447,756

* From FAOSTAT

Actions taken to control FAW

Since the confirmation of FAW in Ghana in November 2016, a number of actions have been taken including pest identification through DNA barcoding by Plant Protection and Regulatory Services Directorate (PPRSD) of Ghana, supported by the Plantwise programme [11] (Cock *et al* 2017, B. Oppong-Mensah pers. comm.). This identification confirms the earlier findings by Georgen *et al* (2016) of the strains of FAW found in West Africa. Further actions revolved around the development of an Action Plan in April 2017 (Godwin *et al* 2017), supported by the Action on Invasives programme[12]. The Ministry of Food and Agriculture/ PPRSD called together a stakeholder workshop in April 2017 involving representatives from different MOFA departments, as well as “five universities and research institutes, six civil society organisations, five information services, six key donors, as well as private sector producers and service providers” (Godwin *et al* 2017). Participants developed a FAW task force and multi-focused action plan targeting activities around coordination and collaboration of the FAW work; awareness creation and raising; surveillance; and management and research.

Action on these activities commenced in May 2017, with training of extension workers in early detection, as well as management of FAW (Godwin *et al* 2017), awareness raising of farmers through media campaigns (Perkins 2018), development and printing of factsheets, identification and management guides [13]. This information was disseminated across Ghana both in hard copy, and also through online mechanisms[14]. The Ghana government provided about 4 million USD[15], which was used for the provision of pesticides, training service providers and public awareness. These combined actions led to some control of FAW during the 2017 outbreak. Other actions focused on better surveillance efforts, making use of the Fall Armyworm Monitoring and Early Warning System (FAMEWS, developed by FAO) and research into the ecology, efficacy of pesticides and biopesticides and development of credible integrated pest management approaches for FAW (CABI 2018).

A follow up workshop of the FAW taskforce, held in October 2018 (CABI 2018) was attended by a broader stakeholder group, including government, the private sectors, NGOs, media services and

---

[11] www.plantwise.org
[12] https://www.invasive-species.org/actions/action-on-invasives/
[13] www.cabi.org/fallarmyworm
[14] http://www.plantwise.org/KnowledgeBank/
[15] https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Government-to-spend-GHS16m-to-fight-armyworm-invasion-536701#

academia, all of whom had been involved in delivery activities identified in the 2017 action plan. There was broad agreement that the format of the action plan, with activities in four key areas (collaboration; awareness; surveillance; and research and management) had led to progress in managing FAW within Ghana. The 2018 workshop recognised the need for continued coordination and harmonisation of activities to manage FAW, and in the information disseminated to farmers. The workshop findings also stated that contingency planning and responses should in future be proactive rather than reactive and the taskforce mandate, roles and responsibilities should be reviewed in this light. There was discussion around the need for a taskforce to be able to respond to future pest outbreaks, and also to establish regional or district level taskforces to enable a more localised response.

Discussion

Bio-economic modelling combines both biophysical and economic components (Flichman and Allen 2013, Kragt 2012) and can be used to predict optimal management strategies for crop growth in the presence of invasive species (Atallah *et al* 2018, Macpherson *et al* 2017, Carrasco *et al* 2010). In addition, Anderson *et al* (2017) use bio-economic models to identify cost-efficient eradication surveillance strategies. Biological modelling can predict the possible spread of a pest under a set of environmental conditions such as temperature, rainfall, altitude etc. The suitability of the climate for preferred host crops can also be included in the model, as can likely crop loss scenarios caused by the pest under varying environmental conditions. Once the biological suitability for the pest has been modelled, economic modelling can put a monetary value on the crop losses against a baseline scenario of crop value without the presence of the pest.

In order to carry out this modelling, considerable data is required including climate data, crop growth data under different environmental and climatic situations, crop yield loss data due to the pest, crop prices/ market data, information on control measures used and associated costs and ideally the price elasticity of the crop. In this work, the environmental/climatic data was available and used to produce sound biological models of areas in Ghana that are suitable for FAW establishment. However, there was little experimental maize yield loss data from the continent to use in the model. Therefore, farmer estimates were used which weaken the model. In addition, while market prices for maize were available, they were not adjusted in response to the price elasticity of maize. In addition, no data were available on the costs of implementing the actual control measures taken, or estimating the possible costs of control under the different scenarios presented. Inclusion of these elements would strengthen the model and provide a better estimation of the overall economic losses in Ghana under different control scenarios.

However, despite the paucity of data, especially in relation to crop yield losses due to FAW and control costs, the model is able to give some prediction of how the use of coordinated control actions can reduce the economic costs of a pest outbreak to a country. They demonstrate that when coordinated actions are taken they reduce the losses experienced by a country as compared to losses that might be experienced if the only actions taken are ad-hoc measures. This model shows that the difference if economic losses could be up to $15 million in a single year. As such this model can provide some degree of support to the conclusions reached in the 2018 FAW task force meeting. The task force reinforced the need to be prepared for new pest infestations by taking quick and coordination action through a multi-disciplinary group of stakeholders. Further refinement of the model should be undertaken when improved field loss data and control cost data are available, but despite the limitations of the current model, it still provides some support to the suggestion of the task force that they should aim to be proactive against new pest threats, to ensure quick responses and lower levels of economic damage caused by pests in the future.

References

Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., Colmenarez, Y., Corniani, N., Day, R., Early, R., Godwin, J., Gomez, J., Gonzalez Moreno, P., Murphy, S.T., Oppong Mensah, B., Phiri, N., Pratt, C., Silvestri, S. & Witt, A. (2017). Fall Armyworm: Impacts and Implications for Africa. Evidence Note (2), September 2017. Report to DFID.

Anderson, D.P., Gormley, A.M., Ramsey, D.S.L., Nugent, G., Martin, P.A.J., Bosson, M., Livingstone, P. and Byrom, A.E. (2017) Bio-economic optimisation of surveillance to confirm broadscale eradications of invasive pests and diseases. Biological Invasions 19, 2869-2884

Atallah, S.S., Gómez, M.I., and Jaramillo, J. (2018) A Bioeconomic Model of Ecosystem Services Provision: Coffee Berry Borer and Shade-grown Coffee in Colombia. Ecological Economics 144. 129-138

Baudron, F., Zaman-Allah, M.A., Chaipa, I., Chari, N. and Chinwada, P. (2019) Understanding the factors influencing fall armyworm (*Spodoptera frugiperda* J.E. Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe. Crop Protection 120, 141–150

CABI (2018) Workshop proceedings: 'Fighting the Fall Armyworm through cross-sectoral linkages and knowledge management'. CABI, Wallingford, UK

Carrasco, L.R., Mumford, J.D., Macleod, A., Knight, J.D. and Baker, R. (2010) Comprehensive bioeconomic modelling of multiple harmful non-indigenous species. Ecological Economics 69(6) 1303-1312

Cock, M. J., Beseh, P. K., Buddie, A. G., Cafá, G., & Crozier, J. (2017). Molecular methods to detect Spodoptera frugiperda in Ghana, and implications for monitoring the spread of invasive species in developing countries. Scientific Reports, 7(1), 4103.

Cruz, I., De Lourdes Corrêa Figueiredo, M., Braga Da Silva, R. and Foster, J.E. (2010) Efficiency Of Chemical Pesticides to Control *Spodoptera Frugiperda* and Validation of Pheromone Trap as a Pest Management Tool in Maize Crop. Revista Brasileira de Milho e Sorgo. 9(2), 107-122

Cruz, I., Figueiredo, M.L.C., Oliveira, A.C., and Vasconcelos, C.A. (1999) Damage of *Spodoptera frugiperda* (Smith) in different maize genotypes cultivated in soil under three levels of aluminium saturation. International Journal of Pest Management 45(4), 293-296

Cruz, I. and Turpin, F.T. (1983) Yield Impact of Larval Infestations of the Fall Armyworm (Lepidoptera: Noctuidae) to Midwhorl Growth Stage of Corn. Journal of Economic Entomology 76(5), 1052–1054

Dal Pogetto, M.H.F.A., Prado, E.P., Gimenes, M.J., Christovam, R.S., Rezende, D.T., Aguiar-Júnior, H.O., Costa, S.I.A., and Raetano, C.G. (2012) Corn Yield with Reduction of Insectidal Sprayings against Fall Armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Journal of Agronomy 11(1), 17-21

Day, R., Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., Colmenarez, Y., Corniani, N., Early, R., Godwin, J., Gomez, J., Pablo Gonzalez Moreno, P., Murphy, S.T., Oppong-Mensah, B., Phiri, N., Pratt, C., Silvestri, S., and Witt, A. (2017) Fall Armyworm: Impacts and Implications for Africa. Outlooks on Pest Management, DOI: 10.1564/v28_oct_02

Early, R., González-Moreno, P., Murphy, S.T. and Day R. (2018) Forecasting the global extent of invasion of the cereal pest *Spodoptera fruigperda*, the fall armyworm. NeoBiota 40, 25-50

Farias, P.R.S., Barbosa, J.C., Busoli, A.C., Overal, W.L., Miranda, V.S. and M. Ribeiro, S.M. (2008) Spatial Analysis of the Distribution of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) and Losses in Maize Crop Productivity Using Geostatistics. Neotropical Entomology 37(2), 321-327

FAO. (2017). FAO Advisory Note on Fall Armyworm (FAW) in Africa. FAO, Rome.

FAO. (2018). Integrated management of the Fall Armyworm on maize. A guide for Farmer Field Schools in Africa. FAO, Rome.

Flichman, G. and Allen, T. (2013) Bio-economic modelling: State-of-the-art and Key Priorities. Biosight Working Paper. IFPRI, Washington DC

Ghidiu, G.M. and Drake, G.E. (1989) Fall Armyworm (Lepidoptera: Noctuidae) Damage Relative to Infestation Level and Stage of Sweet Corn Development. Journal of Economic Entomology 82(4), 1197–1200

Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A., & Tamò, M. (2016). First report of outbreaks of the fall armyworm Spodoptera frugiperda (JE Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. PloS one, 11(10), e0165632.

Godwin, J., Hevi, H. and Day, R. (2017) Fall Armyworm response in Ghana. Stakeholder workshop. CABI. Wallingford.

Harrison, F.P. (1984) The Development of an Economic Injury Level for Low Populations of Fall Armyworm (Lepidoptera: Noctuidae) in Grain Corn. *The Florida Entomologist* 67(3), 335-339

Hruska, A.J. and Gladstone, S.M. (1988) Effect of Period and Level of Infestation of the Fall Armyworm, Spodoptera frugiperda, on Irrigated Maize Yield. The Florida Entomologist. 71(3), 249-254

Hruska, A.J. and Gould, F. (1997) Fall Armyworm (Lepidoptera: Noctuidae) and *Diatraea lineolata* (Lepidoptera: Pyralidae): Impact of Larval Population Level and Temporal Occurrence on Maize Yield in Nicaragua. Journal of Economic Entomology 90(2), 611–622

Kragt, M.E. (2012) Bioeconomic modelling: Integrating economic and environmental systems? in R. Seppelt, A.A. Voinov, S. Lange, D. Bankamp (Eds.)

http://www.iemss.org/society/index.php/iemss-2012-proceedings. 2012 International Congress on Environmental Modelling and Software)

Managing Resources of a Limited Planet, Sixth Biennial Meeting, Leipzig, Germany

Kumar, H. and Mihm, J.A. (2002) Fall armyworm (Lepidoptera: Noctuidae), southwestern corn borer (Lepidoptera: Pyralidae) and sugarcane borer (Lepidoptera: Pyralidae) damage and grain yield of four maize hybrids in relation to four tillage systems. Crop Protection 21(2), 121-128

Kumela, T., Simiyu, J., Sisay, B., Likhayo, P., Mendesil, E., Gohole, L. and Tefera, T. (2018) Farmers' knowledge, perceptions and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda)* in Ethiopia and Kenya. International Journal of Pest Management https://doi.org/10.1080/09670874.2017.1423129

Lima, M.S., Silva, P.S.L., Oliveira, O.F., Silva, K.M.B. and Freitas, F.C.L. (2010) Corn yield response to weed and fall armyworm controls. Planta daninha 28(1) http://dx.doi.org/10.1590/S0100-83582010000100013

Macpherson, M.F., Kleczkowski, A., Healey, J.R., Quine, C.P. and Hanley, N. (2017) The effects of invasive pests and pathogens on strategies for forest diversification. Ecological Modelling 350, 87-99

Marenco, R.J., Foster, R.E. and C. A. Sanchez, C.A. (1992) Sweet Corn Response to Fall Armyworm (Lepidoptera: Noctuidae) Damage during Vegetative Growth. Journal of Economic Entomology 85(4), 1285–1292

Ministry of Food and Agriculture (2017) Agricultural Sector Progress Report 2017, Ministry of Food and Agriculture, Republic of Ghana

Perkins, N. (2018) Evaluation of FAW Containment Campaign: Interim Report. CABI, Wallingford, UK

Tambo, J.A., Day, R., Lamontagne-Godwin, J., Silvestri, S., Beseh, P., Oppong-Mensah, B., and Phiri, N. (2018) Tackling the Fall Armyworm outbreak in Africa: An empirical analysis of farmers' control actions – unpublished

Williams, W. P. and Davis, F. M. (1990) Response of corn to artificial infestation with fall armyworm and southwestern corn borer larvae. Southwestern Entomologist 15(2) 163-166

Acknowledgements

CABI is an international intergovernmental organisation, and we gratefully acknowledge the core financial support from our member countries (and lead agencies) including the United Kingdom (Department for International Development), China (Chinese Ministry of Agriculture), Australia (Australian Centre for International Agricultural Research), Canada (Agriculture and Agri-Food Canada), Netherlands (Directorate-General for International Cooperation), and Switzerland (Swiss Agency for Development and Cooperation).

The authors would like to thank Justice Tambo for use of his analysis, Roger Day, Washington Otieno for their critical review of the manuscript.

Project donors

Plantwise is supported by:

Action on Invasives is supported by:

Project partners

Ministry of Food and Agriculture, Republic of Ghana

Authors

Frances Williams, Global Monitoring and Evaluation Manager

Sean T Murphy, Global Advisor IPM and Modelling

Patrick Beseh, Plant Protection and Regulatory Services, Ministry of Food and Agriculture, Ghana / CABI Associate Action on Invasives

Julien Lamontagne-Godwin, Programme Manager, Action on Invasives

How to cite this paper

Williams, F., Murphy, S. T., Beseh, P. and Lamontagne-Godwin, J. (2019). Have actions taken to control fall armyworm reduced the economic cost experienced in Ghana? CABI Study Brief 31 Impact. DOI: https://dx.doi.org/10.1079/CABICOMM-62-8108