Construction of an Area-wide Management System for Transboundary Pest: The Case of Global Coordination and Its Implications for China

Abstract: Transboundary pests have posed a serious threat to food security in recent years, with outbreaks and rapid spread all over the world. For this reason, global transboundary pest management has made some progress with the support of the Food and Agriculture Organization of the United Nations (FAO). However, unresolved issues remain, such as the lack of relevant incentive and constraint rules, availability and long-term effectiveness of the technology to be improved, and lack of funds and financing mechanisms. Therefore, at the global level, relevant incentives and constraint mechanisms, increasing aid to developing countries, and the formulation of long-term global area-wide pest management programs should be developed. Furthermore, China's domestic area-wide pest management system and farmland ecological diversity should be developed to alleviate the dilemma of global cooperative transboundary pest control caused by common-pool resources.

Keywords: Area-wide pest management, Global coordination, Transboundary pests, Fall armyworm, Common-pool resources

I. INTRODUCTION

As climate change intensifies, so do the outbreaks and spread of transboundary pests threaten global food security[1]. The fall armyworm alone, a transboundary pest, is at risk of destroying approximately 80 million tons of maize in Africa, Asia, and the Middle East[2], contributing to food crises and social unrest in many African countries. Similarly, the same amount of food as 35,000 people per day is consumed by a small group of desert locusts (approximately 1 square kilometer)[3]. Therefore, if the population of transboundary pests is not controlled, food and agricultural production will decline significantly, posing a major risk to food security.

The fact that transboundary pests can fly long distances further complicates this matter (as shown in Fig. 1). Under certain conditions, fall armyworm can fly more than 100 km with the wind[4]. With the help of low-altitude winds, desert locusts can fly approximately 150 km per day with a maximum diffusion area of 28 million square kilometers[5,6]. Therefore, neighboring countries share transboundary pests, and crop damage is dependent not only on the pest population of a given country but also on that of the area. Thus, area-wide pest management (AWPM) has been proposed by plant protectionists, because transboundary pests cannot be effectively controlled by individuals[7,8]. AWPM, a strategy in which individual actors coordinate their management actions across property boundaries to target the entire pest or pathogen population within an area, is a common recommendation for plant pests and diseases with a high dispersal potential[9-11]. Numerous studies have validated the socioeconomic benefits of AWPM[12,13], and the problem of collective action of AWPM has recently been noted[9,14]. They found that the management of transboundary pests was similar to that of common-pool resources[14,15]. Thus, free-riders and opt-out economics questions would apply transboundary pests management research[15-17]. However, few studies have addressed transboundary pest management from the perspective of global collective action.

The following questions were addressed in this study. What is the current global collaborative management system and the main operating mechanism for dealing with transboundary pests given the common-pool resources problems? Second, what are the specific constraints on global collaborative transboundary pest management? Third, in view of the above problems, how can we further alleviate these constraints and develop a global collaborative transboundary pests management? Finally, as a major global food producer and consumer, how can China respond to transboundary pests and promote collaborative global pest control?
**Figure 1** Global multipoint outbreak and rapid spread of fall armyworm  
**Source:** FAO. (2020). The global action for fall armyworm control: action framework 2020-2022.

**I. MANAGEMENT AND OPERATION MECHANISM OF GLOBAL ACTION ON TRANSBOUNDARY PESTS**

**A. Management mechanism of global action on transboundary pests**

The fall armyworm is one of the most influential transboundary pests, threatening global food security and sustainable agricultural development[18]. Under the proposal of Director-General Qu Dongyu in 2019, a Global Action (GA) was launched by the United Nations’ Food and Agricultural Organization (FAO) to strengthen collaboration among stakeholders. Numerous stakeholders can be included in the collaborative framework by building a platform for dialogue on the fall armyworm. This is depicted in the figure below.

**Figure 2** Logic framework of global action on fall armyworm  
**Source:** FAO. (2020). The global action for fall armyworm control: action framework 2020-2022.
From a vertical perspective, a global-to-regional steering committee was established to coordinate the control of the fall armyworm. First, a global steering committee was established to discuss the next steps of the GA program and to approve the implementation of action and investment plans. The Global Steering Committee is chaired by the Director-General of the FAO, and vice-chaired by the Chief Scientist of the United States Agency for International Development (USAID), Director-General of the International Centre for Insect Physiology and Ecology, President of the Chinese Academy of Agricultural Sciences, Director-General of the International Centre for Alkaloids, and President of the Brazilian Agricultural Research Corporation. The committee is made up of representatives from organizations such as the Bill and Melinda Gates Foundation, European Commission, and Crop Life International. Second, a technical guidance committee is responsible for providing technical consultation to the GA project steering committee. Chaired by USAID’s Chief Scientist and vice chaired by the FAO’s Assistant Director-General, its members include 50 global agricultural technology leaders, such as the Advisory Group on International Agricultural Research, the Chinese Academy of Agricultural Sciences, and USAID. Third, a project secretariat was established to manage the daily GA activities. The Secretary-General is the FAO Director of the Division of Plant Protection and Production. The members are the Deputy Director of the Division and the Fall Armyworm Control Coordinator. Four working groups were established to coordinate technology integration and dissemination, knowledge exchange and dissemination, and partner and resource mobilization. Fourth, a regional steering group was set up to coordinate the control of fall armyworm in the region. A regional steering group was established in Africa, the Middle East, Asia, and Oceania, headed by the FAO regional representative and composed of key stakeholders in the region. Finally, subregional steering groups, chaired by FAO regional coordinators, were set up in some large regions to coordinate the implementation of the subregional AWPM.

B. Main operational mechanisms of global action on transboundary pests

1) Strengthen the monitoring of transboundary pests formation using big data

First, the grassroots agricultural extension agents’ knowledge on transboundary pests prevention and control measures should be improved. Approximately 125 agricultural technicians have been trained by Yemen’s Ministry of Agriculture and Irrigation in various provinces to accurately identify fall armyworm[19]. Second, mobile terminal applications can be used to upload, analyze, and share data on transboundary pests. To understand the dynamics of fall armyworm spread and accelerate expert research, mobile terminals have been developed by FAO, such as the FAW Monitoring and Early Warning System (FAMEWS) application. This is the primary tool used by farmers, community contacts, and agricultural technicians to share the relevant information. In addition, to ensure the accuracy and effectiveness of the uploaded information, agricultural extension agents were trained to use FAMEWS to collect data from field reconnaissance and traps, review information collected by farmers, and communicate prevention knowledge and outbreak dynamics to farmers.

2) Assist countries in the prevention and control of transboundary pests training

First, farmer field schools or days can be organized to provide a platform for them to learn and experiment with. At the Malawi Field Day event, local lead farmers witnessed the effects of different control techniques against fall armyworm used by field school trainer students, such as the use of “push and pull” technology, cultivation of peas to attract the fall armyworm’s natural enemies, and application of biomedical agents. They choose locally appropriate control methods and share them with their village’s farmers, thereby facilitating transboundary pest management at the village level. Second, the awareness of farmers and the public regarding prevention and control should be improved. The harm caused by the fall armyworm, as well as important points on its prevention and control, should be publicized using television, text messages, and relevant print media. The public should be urged to cooperate with the government to control fall armyworm. Furthermore, the public should be urged to inspect their plots regularly and remove surrounding host crops in a timely manner.

3) Promote the spread of integrated pest management in developing countries

To sustainably control the fall armyworm, integrated pest management (IPM) was promoted by FAO by encouraging countries to conduct field schools and providing a rotating list of pesticides to avoid fall armyworm resistance, thereby reducing the fall armyworm population size. For example, parasitoids that preyed on fall armyworm eggs and larvae were mass-produced and released by Kenya, working at the International Centre for Insect Physiology and Ecology (ICIPE) to reduce population density[20].
II. DIFFICULTIES AND CHALLENGES OF GLOBAL ACTION ON TRANSBOUNDARY PESTS

The first major challenge of global action toward controlling transboundary pests is the lack of relevant incentives and constraint rules. Although FAO’s approach is aimed at solving the transboundary pest issue and is making efforts to promote AWPM, the establishment of a preliminary dialogue and consultation mechanisms, these mechanisms basically stay on meetings and information exchange, and lack cooperative behavior lack of binding. This is because GA on transboundary pests is essentially common-pool resources, and rules are needed to solve the collective action problem[21]. However, rules regarding GA in transboundary pests are currently lacking. In other words, if a country does not actively implement prevention and control, there is no corresponding punishment; similarly, if a country actively implements its control measures, there is no incentive for them to continue. For example, after some countries reported epidemics of transboundary pests, they did not receive any international recognition. As a result, they did not actively participate in GA for transboundary pests out of consideration for their own interests.

Second, there are shortcomings regarding the availability and long-term effectiveness of important control technologies. Introducing the insecticidal protein Bacillus thuringiensis (Bt) gene into maize seeds via maize genetic modification can prevent fall armyworm from damaging crops, reduce the use of insecticides, protect the pest’s natural enemies, achieve food security goals, and increase farmers’ incomes. However, among the African countries that have approved the cultivation of genetically modified (GM) maize, only large farmers have access to them, while smallholder farmers—who account for more than 98% of African maize growers—have difficulty obtaining them because of high prices and lack of adequate supply channels[22,23]. In addition, there is uncertainty regarding the long-term effects of GM corn. Fall armyworm populations in American countries have developed resistance to some Bt transgenic maize varieties[24].

Third, there is a lack of capital and financing. Due to difficulties in accessing financial resources, relevant prevention and control funds emerged relatively late in developing countries, with less extensive coverage than expected. First, owing to the lack of funds, many towns can only provide limited plant protection services and agricultural extension agents only visit farms that are close to their offices[25]. Second, researchers studying transboundary pests control have been delayed while waiting for government research funds, which has significantly affected the speed of research and development[26,27]. Thus, these researchers look to the international community for funding, which indirectly influences their research direction. In addition, a lack of funding also affects AWPM within countries. In many developing countries, for instance, the standard AWPM system differs significantly, as monitoring equipment is donated by multiple entities, increasing the difficulty of data analysis and aggregation.

III. STRATEGIES TO PROMOTE GLOBAL ACTION ON TRANSBOUNDARY PESTS

First, the consensus of countries regarding the GA on transboundary pests should be strengthened. Transboundary pests pose a threat to food security worldwide. Attempts by some countries to “free ride” or passively prevent and control transboundary pests will only undermine confidence in GA, resulting in a vicious circle. The concept of passive or no control should be resisted, and effective control by neighboring countries is as important as fully realizing their control. To this end, in-depth communication and exchange should be increased by countries and international organizations through FAO and other multilateral cooperation mechanisms to enhance mutual trust.

Second, an incentive mechanism for GA on transboundary pests should be established. We first explore the establishment of a compensation mechanism for upstream countries. Owing to the prevention and control measures of the countries upstream of the annual migration routes, the food security and agricultural development of downstream countries have a guaranteed role. Therefore, active control by upstream countries generates positive externalities that benefit the downstream countries. Following common-pool resource management, downstream countries can transfer relevant prevention and control funds to upstream countries according to the size of their benefits[28]. This compensation mechanism should be institutionalized and the rights and obligations of both parties clarified, such as the means of compensation and quality standards for the relevant performance of the contract. Second, countries that actively cooperate in the control of transboundary pests should be internationally recognized, making them a benchmark for global or regional transboundary pests control. This will allow other countries to understand the positive effects of GA on food security, agricultural production, and social stability.
Thirdly, a constraint mechanism for GA on transboundary pests should be developed. However, on the international scale, it is difficult to take punitive measures above the state level, as severe punishments will generate negative incentives. Therefore, the restraining mechanism of GA on transboundary pests should consider enforceability and potential consequences to ensure that it plays an optimal role. For example, to build international public opinion, countries that do not effectively control transboundary pests should be urged to do so. To accomplish this, FAO can create a credit file for the GA. Countries that refuse to implement transboundary pests control can be included in the file and penalized by reducing international assistance, or asked to pay the FAO special control costs. Finally, an administrative arbitration system for global transboundary pests should be established. This will quickly and effectively resolve disputes arising from a country’s transboundary pests control negligence.

Fourth, assistance for developing countries should be increased. With the rapid spread of transboundary pests, the poor plant protection systems and finances of developing countries are facing severe challenges, and the gap in control materials and financial resources is constantly widening. Therefore, it is necessary to strengthen the material, financial, and technical assistance provided by the developing countries. First, necessary control substances should be provided by countries, such as pesticides, machinery, and monitoring equipment, free of charge to developing countries to reduce the spread of the epidemic caused by a shortage of control substances. Second, financial assistance should advance steadily to developing countries. With the slowdown of global economic growth, contraction of foreign aid, and rise of international unilateralism, assistance to developing countries is expected to become increasingly limited. Therefore, changes must be made to the mode of financial assistance for developing countries. In accordance with the “principle of common and differentiated responsibilities,” a suitable proportion can be collected according to the economic development level of each country, as a GA fund for transboundary pests control.

Technical assistance to developing countries should also be improved. For developing countries, simply receiving financial assistance does not necessarily enable them to develop effective prevention and control capabilities, but international technical assistance can help them achieve this goal. Simultaneously, it is also necessary to continuously improve the research capacity of developing countries to prevent and control transboundary pests. Collaborative research and innovation teams in developing countries and the formulation of systematic collaborative innovation programs should be established in key areas by developed countries in developing countries. Finally, when developing countries undertake relevant technologies, their confidentiality and refraining from publishing or selling relevant information should be protected.

Fifth, long-term plans should be formulated to promote sustainable development of GA for transboundary pests. The permanent-coordinated control of transboundary pests should be established worldwide. For example, the FAO can establish a global coordinated control command center with the goal of global control integration to formulate a long-term plan for AWPM and ensure food security. This can specifically focus on enhancing countries’ sense of responsibility for coordinated prevention and control and strengthening coordination among countries. Additionally, efforts to improve the global capacity to deal with sudden outbreaks of transboundary pests, global ecosystem restoration, and biodiversity conservation should be considered for long-term work.

IV. DISCUSSIONS AND IMPLICATIONS FOR CHINA

Although the national population’s normal food consumption demand has been met in China, it should be recognized that the transboundary pests risk has increased globally. Therefore, the external risks it faces should be scientifically evaluated, transboundary pests management should actively cooperate with neighboring countries, and its “internal work” should be improved to contribute to food security at home and abroad. First, GA should be promoted in China by actively cooperating with the FAO, proactively informing international organizations and society, and publishing data on the FAMEWS application. Moreover, excellent prevention and control experiences should be shared with the international community, such as a unified control plan, establishment of ecological barriers, and hiring special agricultural extension agents. Second, key documents related to China’s prevention and control experiences, including technical plans, could be translated into multiple languages and sent to neighboring developing countries via international organizations for reference. Third, expert guidance groups can be sent to least-developed countries (LDCs). This is because many such countries lack the capacity to cope with the sudden emergence of transboundary pests, owing to deficiencies in prevention, monitoring, and control. Furthermore, to prevent the further global spread of transboundary pests, plant protection experts should be sent...
to LDCs to engage in technical cooperation and assist with their control. Fourth, global collaborative innovation should be implemented in the major prevention and control technologies. Limited by their economic and technical conditions, LDCs have relatively weak access to pest resistant varieties, monitoring means, and control technologies, thereby urgently needing support from the international community. Working with other major world powers to carry out collaborative innovation to control varieties and pesticides of transboundary pests, and actively sharing results with developing countries should be enhanced by China.

Second, domestic systems and mechanisms should be improved. A cross-departmental AWPM system was constructed for transboundary pests. A relatively complete plant protection system has been established in China; however, transboundary pests have a strong flying ability, and host plants are common. This not only requires the efforts of the Department of Plant Protection, but also that of the Customs, Transportation, and Environmental Protection Departments. For example, the green land on both sides of the highway was managed by the Traffic Department; parks, green spaces, and scenic spots were managed by the Architecture and Tourism Department; landfill sites, incineration plants, and resource recovery sites were managed by the Environmental Protection Department; and the spot inspection of goods from epidemic areas was managed by the Customs Department. Therefore, a cross-county AWPM mechanism for transboundary pests needs to be developed. Previous control actions in a single county or city have ignored the characteristics of common-pool resources for transboundary pests control. This is because the grain loss of a county not only depends on the density of transboundary pests within the county but also on the population of transboundary pests within a certain region. In other words, local grain loss and pests density depend on the population of transboundary pests within the region. To eliminate transboundary pests, it is necessary to build a regional and cross-county AWPM mechanism and utilize a unified control plan involving pesticide application during the control window period in centralized contiguous planting areas.

The ecological diversity of farmlands in China should be enhanced. In recent years, natural biomes have often been transformed into large areas for planting single crop species to maximize yield or revenue in modern farmland ecosystems. Although agricultural specialization has been improved by this, the mechanism of mutual restriction has been also disturbed in the biological community, reducing the self-protection ability and facilitating the spread of transboundary pests; a recent study discovered a fall armyworm preference for human farming land, especially annual crops and grazing pastures[29]. However, farmland ecological diversity has hardly improved, and as farmland ecological diversity has certain public good characteristics, no individuals around the area can be excluded as beneficiaries. Additionally, because it is non-competitive, the extra cost for any individual to benefit from it is zero. Therefore, if farmland ecological diversity were regulated by the market, there would likely be a free-rider problem. Furthermore, farmland ecological diversity within land plots should be improved by governments playing a role when the market is unable to allocate resources effectively.

V. CONCLUSIONS

This review draws attention to the serious threat of transboundary pests to food security in recent years. It indicates that although global AWPM has made some progress with FAO’s support, certain issues remain, such as lack of relevant incentive and constraint rules, technological availability and effectiveness, and lack of funds and financing mechanisms. This review makes a significant contribution to the literature because it proposes strategies, such as developing relevant incentive and constraint mechanisms, increasing aid to developing countries, and formulating long-term global pest management programs, to address the threat of transboundary pests. In addition, this review demonstrates that China's domestic area-wide pest management system and ecological diversity of farmland should be enhanced to alleviate the dilemma of global cooperative transboundary pest control caused by common-pool resources.

DECLARATIONS

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