

and Reisig, 2022). In the southwestern United States, a combination of Bt cotton and integrated pest management strategies, including the release of sterile moths, has successfully eradicated the pink bollworm, a major pest (Tabashnik and Carrière, 2019). These successes highlight the practical benefits of Bt crops in reducing pest-related crop damage and increasing agricultural productivity.

3.1.3 Resistance management

One key challenge in using Bt crops is the evolution of pest resistance. However, strategies such as planting refuges with non-Bt crops and using pyramided Bt crops that produce multiple Bt toxins have effectively delayed the development of resistance (Carrière et al., 2016). Cooperative management among government regulators, growers, and other stakeholders plays a critical role in effectively managing pest resistance (Figure 1). For example, in Australia, Bt cotton using Cry1Ac and Cry2Ab toxins helps manage resistance in the cotton bollworm (*Helicoverpa armigera*) (Tabashnik, 2015). Additionally, combining Bt crops with other pest management strategies, such as crop rotation and the use of non-Bt host plants, has been shown to enhance the sustainability of Bt crops by slowing the development of resistance (Gassmann, 2021).

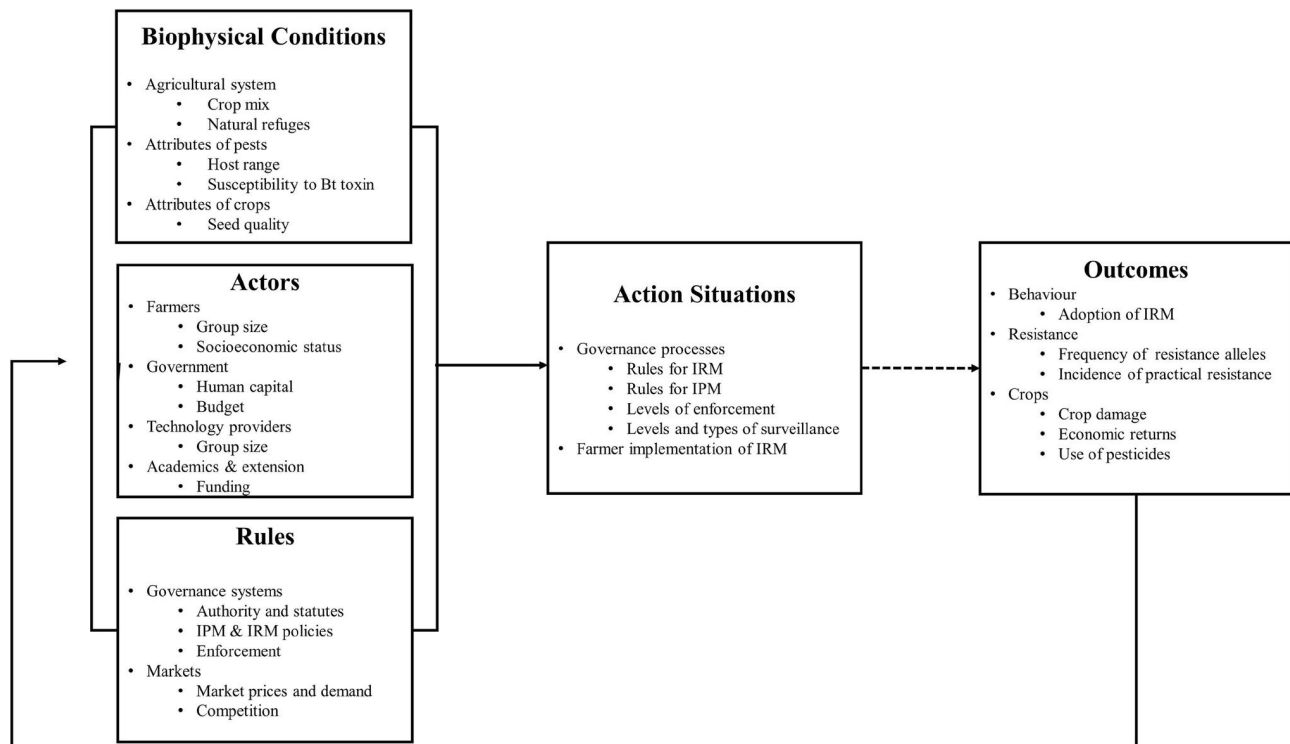


Figure 1 Overview of the Institutional Analysis and Development framework for governance of Bt crops (Adopted from Carrière et al., 2016)

The Institutional Analysis and Development (IAD) framework for the governance of Bt crops demonstrates how biophysical conditions, rules, and the actions of different stakeholders interact to influence resistance outcomes. Figure 1 emphasizes the importance of considering ecological and socio-economic factors when formulating and implementing resistance management policies. It underscores the integrated roles of government agencies, growers, and the industry in managing resistance to Bt crops to ensure sustainable pest control and long-term agricultural productivity.

3.2 Environmental benefits

Bt crops offer significant environmental benefits by reducing the need for chemical insecticides, which can have harmful effects on non-target organisms and the environment. The adoption of Bt crops has led to a decrease in insecticide use, thereby reducing the environmental footprint of agricultural practices (Xiao and Wu, 2019; Gassmann and Reisig, 2022). Moreover, Bt crops contribute to biodiversity conservation by preserving beneficial