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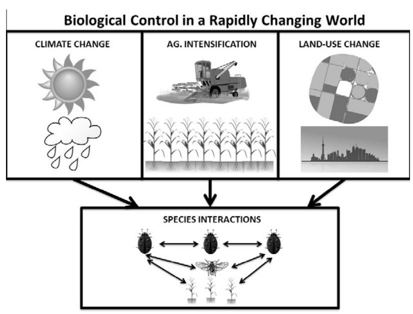
Editorial

Promoting biological control in a rapidly changing world

HIGHLIGHTS

- We highlight advances made by articles in this special issue.
- Farm-scale and integrative studies are needed in agroecosystems.
- Climate change studies need to consider more than temperature.
- We need more studies on yields and economics to promote biological control.

GRAPHICAL ABSTRACT



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ABSTRACT

Sustainable agriculture must provide for growing human demands for crops while minimizing impacts on ecosystems. This is a daunting challenge as agroecosystems have trended towards monocultures with intensive synthetic inputs. Moreover, agricultural landscapes often lack natural habitats that are necessary to support biodiversity. Furthermore, problems associated with agricultural intensification and land-use change may be exacerbated by climate change, which increases the frequency of disturbances, modifies the suitability of habitats, and changes the way species interact. To meet this challenge, farmers must increasingly rely on integrated pest management strategies, including biological control. Biological control of arthropods, weeds, and diseases can promote the stability and diversity of agricultural communities and aid in reducing synthetic inputs. Promoting biological control may thus help farming systems adapt to a rapidly changing world. This special issue considers how multiple global change drivers such as agricultural intensification, land-use change, and climate change affect biological control. Here, we discuss these papers and highlight concepts that remain relatively unexplored in the context of global change and biological control. Future research addressing these issues will promote biological control and enhance agricultural sustainability in a rapidly changing world.

1. Introduction

Agriculture covers nearly 40% of Earth's terrestrial land (Ramunkutty et al., 2008). Growth in agriculture has been spurred by rapid advances in crop breeding and technology over the past 50 years (Matson et al., 1997; Krebs et al., 1999; Benton et al., 2003). However, the expansion of agriculture has resulted in widespread loss and fragmentation of natural habitats, increased carbon emissions, and reduced biodiversity (e.g., Matson et al., 1997; Vitousek et al., 1997; Kleijn et al., 2006). A major challenge for agriculture is to continue to meet the demands of a growing human population while limiting these detrimental impacts. To meet this challenge, producers have increasingly adopted integrated pest management (IPM) practices that limit chemical inputs through effective use of cultural, mechanical, and biological controls (Pedigo and Rice, 2008). Indeed, IPM has improved yields and economic returns for many farmers (Pedigo and Rice, 2008). For example, cotton growers in Arizona save over $200 million per year by adopting IPM schemes that reduce insecticide use and increase yields (APMC, 2007).

Despite the abovementioned successes, biological control is threatened by rapid global change. Many predators and parasitoids rely on non-agricultural habitats for shelter, prey, alternate sources of nutrition (e.g., pollen and nectar), and overwintering sites (Landis et al., 2000; Bianchi et al., 2006; Rodriguez-Saona et al., 2012). Widespread conversion of non-agricultural habitats to

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farmland can therefore reduce the fitness of biological control agents and diminish their ability to disperse into agricultural fields (Bianchi et al., 2006). However, such habitats occasionally act as sinks for natural enemy populations (Bianchi et al., 2006). Similarly, biological control agents are often highly susceptible to synthetic pesticides and fertilizers (Pedigo and Rice, 2008; Roubos et al., 2014). Reductions in the density of biological control agents due to pesticide use can lead to reduced biodiversity, secondary pest outbreaks, and losses of crop yields (Pedigo and Rice, 2008).

Climate change, species invasions, and declines in biodiversity may also limit the effectiveness of biological control. For example, changes in climate can disrupt overlap between natural enemies and pests in space and time (Davis et al., 1998; Evans et al., 2012); such phenological mismatching can limit biological control. Invasive species might similarly be detrimental for biological control if they reduce the density of biological control agents through competition or intraguild predation (Crowder and Snyder, 2010). Sih et al. (2010) provided compelling evidence that traits of certain invasive herbivores make them well adapted to become pests during periods of human-induced rapid-environmental change. However, invasive predators may also thrive during periods of rapid change (Sih et al., 2010) and this might improve biological control if these species are particularly voracious (Crowder and Snyder, 2010).

This special issue considers many of the factors that may influence biological control in a rapidly changing world, with a particular emphasis on species interactions. Here, we review conceptual advances made by papers in this special issue and highlight key areas that need to be addressed. Our objective here, and in the special issue as a whole, is to promote research that will help adapt biological control to the challenges presented to agriculture in the 21st century.

2. Concepts covered in this issue

The papers in this special issue cover a range of topics, but in general can be grouped into the effects of three global change drivers: (1) agricultural intensification; (2) land-use change; and (3) climate change on agricultural communities and interactions between natural enemies, pests, and plants in agroecosystems (Fig. 1). Many of the papers cut across multiple areas (Fig. 1), and we highlight major concepts from each here.

2.1. Agricultural intensification and biological control

Agricultural systems around the world have intensified by producing more crops per unit area, or per unit time, to meet the demands of a growing human population (Matson et al., 1997; Vitousek et al., 1997). This presents challenges for biological control. Frequent applications of broad-spectrum pesticides for insect and weed control can kill predator and parasitoid species and alter their development and behavior (Croft and Brown, 1975; Cloyd, 2012; Roubos et al., 2014). A myriad of strategies exist to adapt biological control in a chemically-intensive world, including site-specific applications, low doses of pesticides, genetically-modified crops, increasing pesticide selectivity, and refuges of non-sprayed areas. Incorporating these practices in IPM systems will improve biological control in modern intensive agricultural systems.

Agricultural intensification can also influence biological control by altering the structure of natural enemy communities (Crowder and Jabbour, 2014). Intensive systems often have reduced natural enemy diversity, which can weaken biological control (Griffin et al., 2013). For example, more sustainable agricultural practices such as organic, biodynamic, or integrated agriculture might help mitigate this by promoting more diverse and effective natural enemy communities (Crowder et al., 2010, 2012; Crowder and Jabbour, 2014). Other environmentally-friendly practices such as conservation tillage or no-till that promote abundant and diverse natural enemy communities will also likely improve biological control.

2.2. Land-use change and biological control

Global landscapes are being modified due to agriculture and changing concentrations of human populations in urban areas (Burkman and Gardiner, 2014; Chisholm et al., 2014; Roitberg

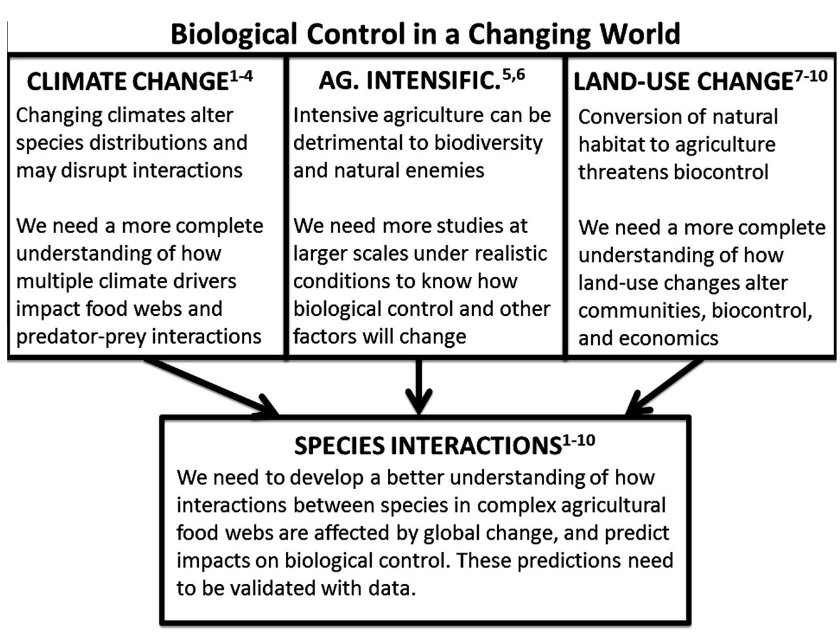

Fig. 1. Conceptual layout of the special issue, including the challenges facing biological control associated with each of three global change drivers: (1) climate change; (2) agricultural intensification; and (3) land-use change on biological control. Each of these drivers also affects species interactions. Including in each conceptual area are the papers in the special issue addressing those topics. 1. A'Bear et al.; 2. Schmitz and Barton; 3. Tylianakis and Binzer; 4. Welch and Harwood; 5. Crowder and Jabbour; 6. Roubos et al.; 7. Burkman and Gardiner; 8. Chisholm et al.; 9. Dreyer et al.; 10. Roitberg and Gillespie.