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Climate change adaptation in crop production: Beware of illusions

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ABSTRACT

A primary goal of studying climate change adaptation is to estimate the net impacts of climate change. Many potential changes in agricultural management and technology, including shifts in crop phenology and improved drought and heat tolerance, would help to improve crop productivity but do not necessarily represent true adaptations. Here the importance of retaining a strict definition of adaptation – as an action that reduces negative or enhances positive impacts of climate change – is discussed, as are common ways in which studies misinterpret the adaptation benefits of various changes. These "adaptation illusions" arise from a combination of faulty logic, model errors, and management assumptions that ignore the tendency for farmers to maximize profits for a given technology. More consistent treatment of adaptation is needed to better inform synthetic assessments of climate change impacts, and to more easily identify innovations in agriculture that are truly more effective in future climates than in current or past ones. Of course, some of the best innovations in agriculture in coming decades may have no adaptation benefits, and that makes them no less worthy of attention.

1. Introduction

The potential for adaptation to reduce negative impacts or enhance positive impacts of climate change is of widespread interest. For many, this interest stems from a desire to quantify the risks that unabated climate change presents to society, in order to properly evaluate the costs and benefits of reducing greenhouse gas emissions. For others, interest in agricultural adaptation comes primarily from a desire to identify actions and investments that can help to improve the future prospects for food production and food security.

The wide and diverse interest in adaptation has inevitably resulted in many different working definitions of climate adaptation. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." Others have preferred much broader definitions of adaptation, which characterize adaptation as any action that improves the welfare of society enough to compensate for losses related to climate change (World Bank, 2010, Mani et al., 2008). This perspective has the obvious appeal of including activities that may not be a direct response to climate change, but nonetheless a more effective use of scarce resources to improve welfare or some other outcome of interest.

The fatal problem with broad definitions, however, is that they lose all meaning for a key purpose of defining adaptation, which is to assess the impacts of greenhouse gas emissions. Thus, in this paper I will use adaptation to mean simply an activity that is "impact-reducing," in the sense that it reduces negative (or enhances positive) impacts of climate change. I will focus on the somewhat narrow question of impacts on crop yields and crop production, rather than outcomes such as farmer or consumer welfare, partly because estimating impacts on the latter require assumptions about future wealth and discount rates that are beyond the scope of most crop impact studies.

The central thesis of this paper is that actions that are truly impact-reducing are relatively rare in agriculture, and significantly rarer than they are often presented or thought to be. To be clear, many truly adaptive actions do exist, and are likely occurring each day. Moreover, I make no attempt here to argue that impacts from climate change without adaptation represent the primary threat to global food security. However, in my experience much of the quantitative work on adaptation turns out, on further inspection, to be lacking in one or more ways to qualify as convincing evidence of adaptation. In other words, many apparent adaptations turn out to be illusions. The danger in these illusions is that the costs of climate change are undervalued, particularly by non-experts who look to the literature when compiling estimates across sectors. There is also some risk that policy makers relevant to food security are misled to think that adaptation is easier than it actually is, and thereby underestimate the challenge that climate change presents. Finally, there is a risk that truly successful adaptations get lost amid bogus claims of adaptation.

The goal in what follows is to lay out the reasons behind these illusions so that others may be quicker to recognize and avoid

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them. In the rest of the paper, I will lay out a simple conceptual model of adaptation, discuss three related causes of confusion, and finally offer some conclusions. Because direct measurements of climate change adaptations are rare, this paper largely focuses on evidence from studies that use crop simulation models to explore climate change impacts and adaptation, these studies comprising the majority of the quantitative literature on climate adaptation.

2. A schematic of adaptation

Fig. 1 presents a simple schematic of how the impacts of climate change and the moderating effects of adaptation can be calculated for two examples. In both cases, there is a shift in the climate distribution towards higher levels of stress, and at the same time there is a new technology (T_2) that replaces an older technology (T_1). For the purposes of the example, a new technology can refer to anything that affects the relationship between a given stress and yield, including simple agronomic adjustments like sowing date changes, new genetically improved crop varieties, or changes in policies that influence on-farm input use. In the first case (panel A), the technology improves yield performance equally at all levels of stress. As a result, yields at the new stress levels that occur with climate change are higher than they would have otherwise been. However, the impact of climate change, measured as the yield change from point C to point A, is unaffected by the technology since it is the same as the distance under the old technology from point D to point B.

In the second case, the new technology has little impact at the former levels of stress, but offers significant yield improvements at the new levels of stress. In this case, the new technology represents a truly impact-reducing activity. In both panels, the technology has a clear positive effect on outcomes, and both would likely be adopted by farmers. However, the distinction between the impact-neutral change in Fig. 1a and the impact-reducing change in Fig. 1b is critical from the perspective of estimating the impacts of climate change. The lack of an adaptation "label" for the technology in Fig. 1a would undoubtedly frustrate its proponents, especially since the impact on absolute yields is as large as or even larger than in Fig. 1b. The change represented in Fig. 1a might also be attractive in several other aspects, such as being affordable to the poorest farmers, reducing input use, and reducing greenhouse gas emissions. It may well be the most important innovation in agriculture in decades, but it would have been just as useful in the former climate, and therefore in our discussion does not qualify as adaptation.

3. Illusions from faulty logic

The most common way of exaggerating adaptation benefits is the failure to make the calculations illustrated in Fig. 1. That is, many studies simply count the difference between point C and D as the benefit of adaptation, without considering the difference between points A and B. Indeed, most studies never actually calculate point A, but instead start with some reference yield scenario (point B), proceed to add climate change (arriving at point D), and then test various adaptations to arrive at point C. In both panels of Fig. 1, this would result in an estimate of adaptation that is larger than the initial impact, turning the net change in yield from negative to positive. Such a scenario is commonly reported in the literature, with the estimated benefits of adaptation exceeding 10% even if initial impacts were only a few percent (Challinor et al., 2014).

The types of adaptations considered vary by study. Most frequent are simulations of shifts in sowing dates and cultivar maturity rating (Challinor et al., 2014). The former can be used to help avoid heat or drought stress occurring at particularly important development stages, whereas the latter can help to compensate for acceleration of development with warmer temperatures. Thus, there are good reasons to believe that both would be beneficial adaptations, and it is not surprising when studies find this to be the case. Many well cited studies have reported sow date and cultivar shifts to be effective at improving yields in future climates, at both regional and global scales (Müller et al., 2010; Deryng et al., 2011; Tao and Zhang, 2010). In many of these cases, the impacts without adaptation are first estimated using some estimate of current sow dates and cultivar choices, and then only after climate change is invoked do the models attempt to find the optimum sow dates and cultivars. Deryng et al. (2011) differ in that they do not base adaptation on a search for optimum sow date and cultivar length, but use an equation based on present-day relationships between temperatures and these practices.

However, longer maturing varieties and shifts in sowing dates can also often have benefits in current climate. For instance, recent yield growth in Chinese maize and rice systems is largely associated with a longer post-flowering growth period (Chen et al., 2013; Tao et al., 2013), and recent wheat yield trends in India can largely be explained by benefits of recent trends toward earlier sowing (Lobell et al., 2013b). Failure to consider the benefits of potential changes in current

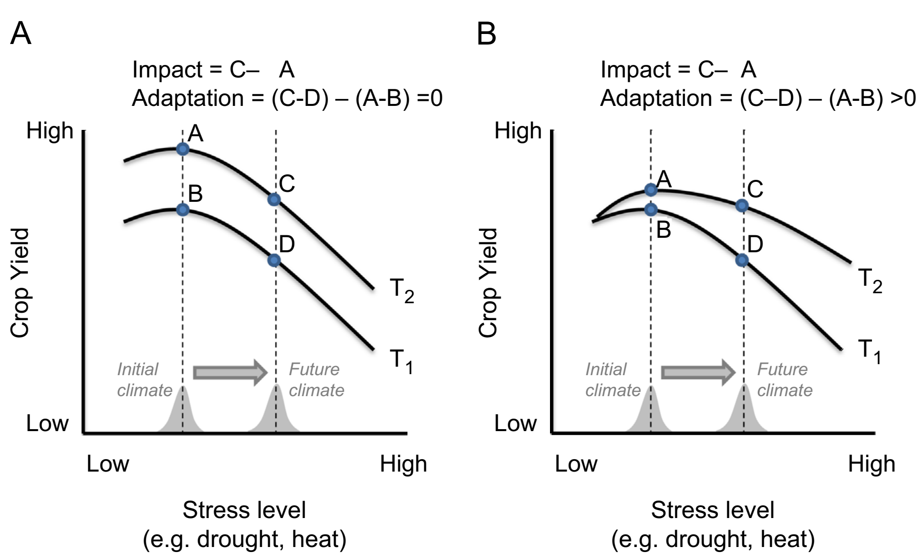

Fig. 1. A schematic of how adaptation should be calculated for new agricultural technologies.

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