

Farming the Floodplain: Ecological and Agricultural Tradeoffs and Opportunities in River and Stream Governance in New England's Changing Climate

BENJAMIN P. WARNER¹, RACHEL E. SCHATTMAN² AND CHRISTINE E. HATCH³

¹University of New Mexico, Department of Geography & Environmental Studies, Albuquerque, United States

²United States Department of Agriculture Northeast Climate Hub, University of Vermont Extension, South Burlington, United States

³University of Massachusetts, Department of Geosciences, Amherst, United States

Email: bpwarner@unm.edu

ABSTRACT In New England (United States) climate change models forecast increasingly intense, frequent floods. Communities in this region are already experiencing these changes, along with the negative consequences associated with them, such as inundation, erosion, natural habitat destruction, and property damage. As it is in many places around the world, agriculture in New England is often in floodplains, which means that farmers are at greater risk due to where they farm. These farmers are already adapting to the increased risk of flooding; however, some of their actions may affect communities downstream, both human and ecological. This case study examines the competing perspectives of farmers and other community stakeholders in New England as farmers work to adapt to increasing flood impacts. Our premise is that, considering the intensified pressures of climate change on agriculture near rivers and streams, we must find ways to allow farmers to adapt to protect their farms and downstream communities.

KEY MESSAGE

Farms along rivers often support local communities and ecosystems but climate change is forcing farmers to adapt to flooding in New England; sustainable adaptations must incorporate community members to ensure some are not made more vulnerable due to upstream adaptations.

INTRODUCTION

“Climate change adaptation” is used to describe a process, an outcome, a concept, or a goal. It has been used by politicians, media, and academics within the United States and around the globe. We use the following definition of climate change adaptation provided by the International Panel on Climate Change [1]: climate change adaptation is “the process of adjustment to actual or expected climate and its effects” [1, p.1758]. With its roots in ecological and biological sciences, climate change adaptation has historically been limited to biophysical and technological changes. In recent years, social and cultural factors have been increasingly included in widely used climate adaptation

frameworks [2]. Adaptation in socio-environmental research frameworks includes risks, impacts, and preemptive solutions that may allow individuals, communities, and organizations to avoid the negative consequences of climate change. The need to adapt to climate change is clear and is supported by the scientific consensus described by the IPCC [1, 3]. Specifically, changing climatic conditions will necessitate shifts in public services and infrastructure, policy and programming, and food production.

Agriculture is directly influenced by fluctuations in climate patterns from one season to the next. It can be argued that agriculture is one of the most directly vulnerable societal sectors in the United States because it is directly affected by changes in the climate [4]. This necessitates agricultural adaptation, now and in the future, if we are to maintain its benefits to society. The direct relationship between agriculture and global climate change, in concert with the shifting pressures of agricultural markets and local environmental regulation, makes it an ideal case study of the intersection of agriculture and natural resource governance, including

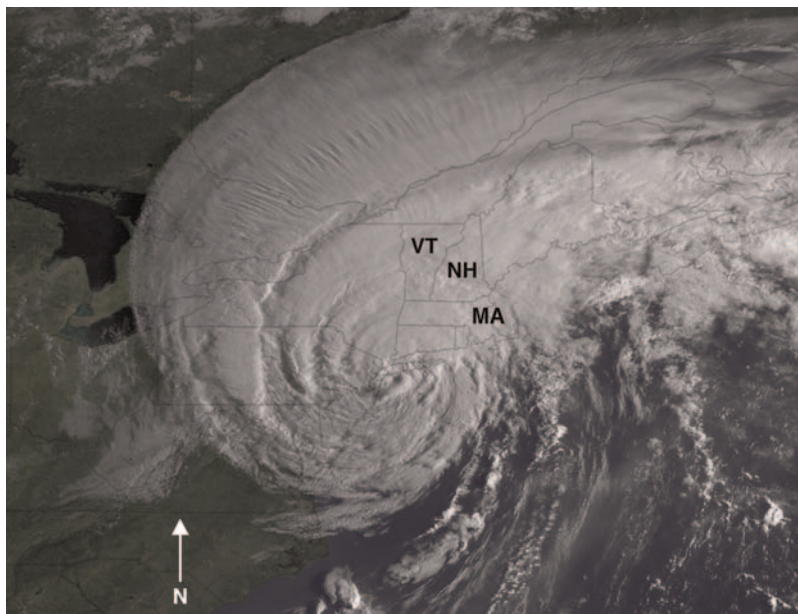


FIGURE 1. Size and location of Tropical Storm Irene as it made landfall in New England (source: NOAA Environmental Visualization Laboratory; www.nnvl.noaa.gov).

tradeoffs, challenges, and barriers to climate adaptation. We use the specific example of farms located in floodplains, with a focus on the tradeoffs between river ecosystem conservation and the goals of local residents and farmers as they adapt to protect themselves, their properties, and their businesses from floods. Navigating the inherent tradeoffs between the goals of farmers, those of surrounding communities, and the integrity of ecosystems is an excellent window into the type of complex socio-environmental issues that climate change introduces.

In this case study, we present the case of flooding in agricultural areas in New England. We rely on data collected throughout the Deerfield River watershed in Western Massachusetts because it is representative of New England geography; it is largely agrarian, and it has experienced severe flood impacts. We focus on three components of climate change adaptation: (1) the vulnerability of farms and surrounding communities, (2) river governance tradeoffs between the goals of farmers and other stakeholders, and (3) interventions that promote sustainable river and stream governance in an era of climate change. This case is useful for those interested specifically in the study and design of local watershed management solutions in agrarian areas. It is also appropriate for those interested in the overlap of competing socio-economic and conservation goals with natural resource management in an era of increasing

environmental changes. And, while we present data from New England, similar situations can be found across the globe in mountainous areas where farmland and urbanization compete for limited valley-bottom space.

CASE STUDY: OPPORTUNITIES AND TRADEOFFS IN FARMER ADAPTION TO INLAND FLOODS IN NEW ENGLAND

River flooding is a reoccurring concern among farmers in New England. Common causes of flooding include winter storms, called *nor'easters*, and hurricanes which deposit large amounts of precipitation in short time periods. Major floods that have caused significant damage to agriculture in this region occurred in 1927, 1936, 1938, 1955, 1968, 1984, 1987, 1991, 2000, 2011, and 2014. Perhaps the most significant rain and flood event in recent memory was Tropical Storm Irene. On August 22, 2011, Irene travelled up the east coast of the United States causing damages estimated in the billions of dollars [5]. The size and location of the tropical storm in relation to New England is shown in Figure 1. Although Irene was downgraded from a hurricane to a tropical storm before entering New England on August 28, 2011, it brought a period of intense rainfall with totals averaging up to 10 inches over Vermont and Western Massachusetts. The rainfall and resulting runoff caused rivers in the region to peak at record levels on

August 28–29, 2011. On September 3, 2011, a presidential disaster declaration (FEMA–4028–DR) was issued for the region [5]. Federal financial assistance to Western Massachusetts for recovery from Tropical Storm Irene exceeded US\$11 million for individual assistance and US\$53 million for public assistance [5]. In Vermont, the totals were US\$46.5 million for individual assistance and US\$211 million for public assistance [6]. Damages across the region were extensive. Homes, businesses, schools, infrastructure, and agricultural fields in the area were flooded. In Western Massachusetts alone, Irene damaged over 6,300 acres of farmland [7], and up to an estimated 9,100 acres in Vermont, with an economic impact in farm losses of approximately US\$20 million [8].

Irene's large impact on agriculture in New England was largely due to the location of farms in flood-prone valleys, which is common in the region due to the fertile soil that exists along rivers and streams. Geological features of the landscape make cropping on upland or hillside land difficult, expensive, and dangerous. It is one reason why grazing of livestock for dairy and meat production is a hallmark of agriculture in northern New England [9]. River bottom land across the globe is highly sought after for agricultural use. This land is particularly well suited for farming because historical floods have deposited nutrient-rich sediments that are ideal for plant growth. Ironically, the same flooding regime that produced these fertile soils and allowed agricultural production also threatens the present-day fields and infrastructure used by farmers to grow crops.

The impacts of flooding in valleys in New England, similarly to other areas in which farmland exists in mountainous river and stream valleys, extend beyond the oft-cited damages to structures and infrastructure in other sectors. Research on the impacts of flooding on agricultural land shows that flooding not only destroys crops grown during any one season, but also challenges farmers' ability to grow crops in that area in future years [10] because present-day floods deposit sediment that is often contamination by chemical and biological agents and physical debris that reduces the fertility of agricultural fields. In addition, recent large flood events have proven more damaging because they scour fields and remove the nutrient-rich sediments that were deposited over previous centuries. These impacts are likely to remain salient to farmers, especially in northern New England where increased frequency of flooding has already been documented. The region historically averaged two flood events per year (documented from 1940 to 1970), but this amount has increased to an average of five flood events per year (from 1971 to 2013).

New England farms are critically important to the region for multiple reasons. Half of the dairy products and 40% of the vegetables consumed in New England are produced locally. This decreases transportation costs and carbon dioxide emissions. Farming also generates billions of dollars for the regional economy in addition to maintaining the distinctive culture and iconic rural New England landscape. For these reasons, regional agriculture should be protected from flood impacts. Fortunately, farmers in floodplains in New England are already adapting to the increasing frequency of large floods, such as those that occurred during Tropical Storm Irene [11].

Adaptation to flood impacts is complicated. As farmers work to adapt, the management of their floodplain can increase or decrease potential flood impacts on lands and communities up and downstream. This relationship is often referred to as *hydro-connectivity* [12]. Many farmers choose to protect their lands from flood impacts by planting trees, changing crop types, or restoring riparian vegetation. These adaptations typically protect fields in floodplains from losing topsoil while also slowing floodwaters and minimizing flood impacts downstream. Almost all farmers included in this case study first attempt to adapt in these ways to maintain the natural flood regime cycle and enhance environmental integrity. However, in some instances, farmers have been forced to adapt in ways that alter the natural flood regime or face risk destruction from which they would not be able to recover.

Flood regime-altering adaptations on farms include building levies, straightening or dredging rivers or streams, or altering fields to more quickly drain water (through use of drains or other approaches). These adaptation strategies may change the hydrology of surrounding ecosystems and human communities in different ways. First, they may increase the flow of floodwaters, making flooding and accelerated river and stream flow downstream more likely [13, 14]. Second, some of these strategies remove or degrade wildlife and fish habitat [15]. Third, by draining fields quickly, large quantities of fertilizers, pesticides, nutrients and sediments may be introduced into rivers [16]. The type of adaptation to flooding that is used by a particular farmer in New England is determined by their vulnerability to flood impacts, which will be discussed in the next section.

Some nonagricultural stakeholders in our case study area—recreationalists/fishers, residents, natural resource managers, and environmentalists—are also effected by flood impacts and argue that to reduce flooding in downstream

areas in New England, we should return all land bordering rivers and streams to natural forest in the hope that more rainfall would be absorbed and downstream areas would be better protected from flooding. However, this would require the region to greatly limit or abandon agriculture. Farmland largely exists along rivers and streams in New England as shown in Figure 2, and in this scenario it is easy to see that a large amount of farmland would be lost, which would greatly affect regional food supplies and the local economy. Unsurprisingly, this scenario is in direct conflict with the goals of the agricultural community because it would greatly reduce the amount of productive cropland in the region. Furthermore, clear evidence does not currently exist that shows that a conversion of farmland to natural forest would reduce downstream flood impacts across the region. Nonetheless, some nonagricultural stakeholders place some of the blame for regional flooding on farmers, as shown in their perspectives provided in Table 1.

River managers and lawmakers throughout New England have been forced to walk a fine line between appeasing stakeholders such as those quoted in Table 1, and farmers. In Massachusetts for example, farmland and rivers are

recognized as resources vital to the Commonwealth, though it is acknowledged that, sometimes, when one is protected the other suffers. In 1972, the Massachusetts Legislature enacted the first river and stream protection laws in the nation. The Wetlands Protection Act, Massachusetts General Laws, Chapter 131, Section 40 (“WPA”), made precedent setting rules that protected rivers by making it illegal to dredge or levee rivers or streams in most situations. In addition, the law made it illegal to construct buildings in floodplains. However, while accomplishing this impressive legislative action, the Massachusetts Legislature also recognized that protection of farming and forestry was important. Accordingly, the Wetlands Protection Act exempts “work performed for the normal maintenance or improvement of land in agricultural uses.” The agricultural exemption employed by Massachusetts is also common in other state river management regulations. This approach is not without drawbacks, however. Nonagricultural stakeholders (like those quoted in Table 1) have historically rejected agriculture exemptions, saying that the exemptions undermine the intent of the law and increase flood risk for other stakeholders and communities.

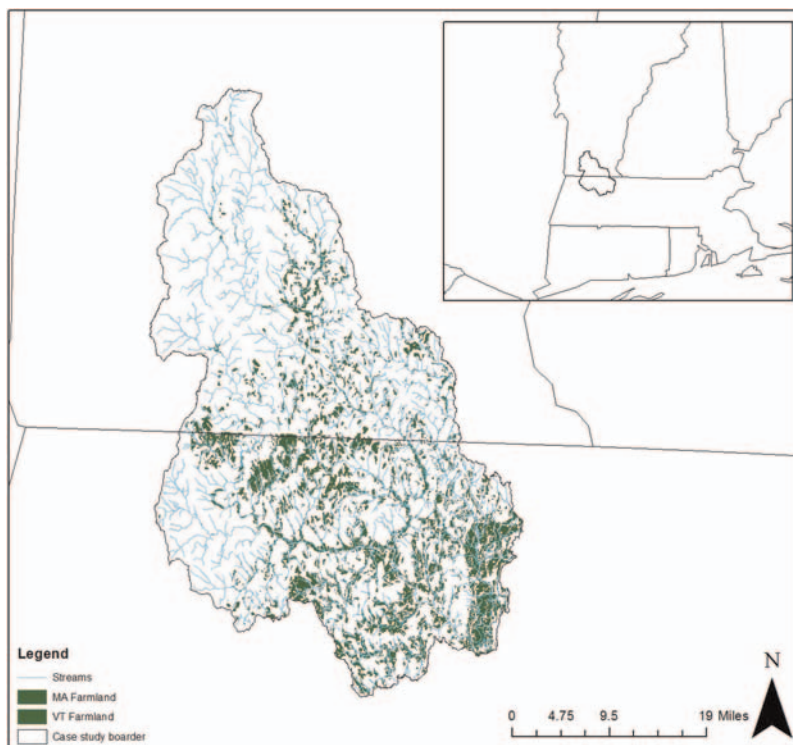


FIGURE 2. Map of the Deerfield River Watershed case study area showing productive agricultural land. It can be seen that a majority of the agricultural land follows river or stream valleys. Data presented here was collected using interviews with stakeholders in the Massachusetts portion of the watershed.

TABLE 1. Representative nonagricultural stakeholder perspectives on river and stream governance, collected in interviews conducted in MA in 2014–2016

Nonagricultural stakeholder group	Perspective on river and stream governance
Recreationalist/fisher	“Farmers destroy rivers. They dredge rivers, and that destroys all the fish habitat. The state should restrict farmers from using land near rivers.”
State river manager	“Flooding is a part of the natural world and the best thing we can do is to not make a problem for ourselves in the future, and not develop or build in flood prone areas. So, don’t put your barn right along the river because the land was really cheap, or because it was really pretty, or whatever. Don’t put permanent structural things in harm’s way, cause you’re gonna lose them. But maybe you can farm in a floodplain, as long as you accept the risk that your field may be flooded. What we need to do is strike a balance between flooding and farming.”
Environmentalism	“What I would like to see is environmental regulation that deals with a couple of things. One, the preservation of undeveloped land near rivers, and the second is to prevent farmers from using land that is very susceptible to flooding. This is for the best interest of the environment and hopefully for the best interest of the farmers.”
Resident	“There needs to be that level playing field so that people upstream and downstream can have input into what a given farmer does. If we’re talking about river systems, that’s a public trust resource! The farmer doesn’t own the stream; it’s the state that holds them in trust for everyone. Farmers shouldn’t be able to do things for their own direct benefit that is going to compromise other citizens.”

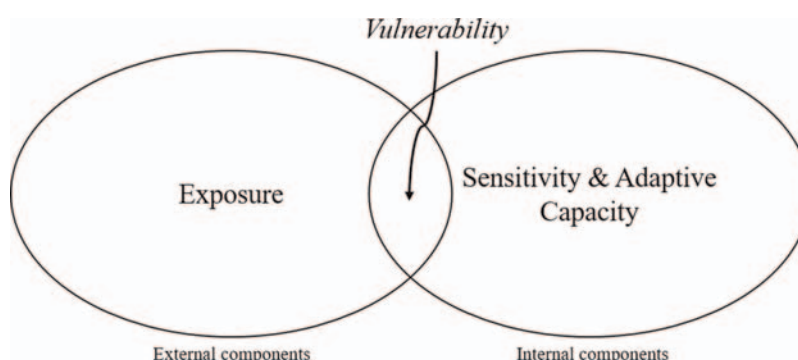


FIGURE 3. Components of climate change vulnerability.

In this section, we have considered the perspectives on flood management held by nonagricultural stakeholders. To better understand the complete picture and how river and stream governance persists as a contentious topic, we will now explore the ways in which New England farms are increasingly vulnerable to climate change and flooding. This deeper understanding will allow us to grasp the complex and often competing agendas of different groups.

VULNERABILITY TO CLIMATE CHANGE: A FRAMEWORK

Climate change vulnerability is the degree to which systems (farms and their surrounding communities in the instance of this case study) are susceptible to, or unable to cope with, adverse effects of climate change. These could include

climate variability and extremes (e.g., rainfall amounts and frequency, temperatures, etc.). Climate change vulnerability is a function of *exposure*, *sensitivity*, and *adaptive capacity* [1]. Climate exposure is the extent and magnitude of a climate and weather event. Sensitivity is the degree to which a farm (in this case) is susceptible to a climate impact. Adaptive capacity is the ability of the farm manager to adjust or respond to changing climatic conditions. These relationships are depicted in Figure 3. In the context of our case study, farmers work to restore and protect their lands and assets from flood impacts. Descriptions of flood vulnerability experienced by farms in Massachusetts are provided in Table 2. Column one describes the type of exposure a farm could experience because of a flood (e.g., inundation, erosion, etc.), column two describes type of vulnerability

TABLE 2. Flood impacts on farms in the region, collected in interviews with farmers conducted in MA in 2014–2016

(1) Exposure type	(2) Vulnerability	(3) Degree of sensitivity	(4) Farmer descriptions
Inundation	Equipment loss	High	"I lost some equipment. It flooded an out building of mine that was closer to the river and some equipment and materials that I had in there were just swept downstream. They're probably somewhere in the Atlantic by now."
Inundation	Crop loss	High	"We had about five or six acres that was just flattened and destroyed; the impact of the Irene was total loss of 40 acres of corn."
Inundation	Soil moisture	Medium	"The big issue was the land drying out, so I could get to it."
Erosion	Tree damage	Low	"We probably lost 50–75 big pine trees. They got pushed right over in sort of a line. I was afraid I was going to lose my whole sugar bush, and I'd be out of maple sugaring!"
Erosion	Soil erosion (riverbank)	High	"Oh Christ, I probably lost 2–4 acres in that . . . [Hurricane] Irene, probably 2–4 acres, it's gone."
Erosion	Soil erosion (topsoil)	High	"[Flooding] removed a significant amount of topsoil, and it removed almost of all of it, in considerable sections. This field's never going to recover from that, the potential on it has probably dropped by 30%, at least. It removed pretty valuable topsoil. Now the field profile from one side to the other doesn't have any uniformity to it at all. The soil type is just totally different for us. From an agricultural perspective, it's hard to figure out how to deal with it, because you have different soil types. All the fertilizer, and what you spray, is totally different."
Deposition	Sediment deposition	High	"[The flood] pretty much covered my vegetable field in two feet of sand, and I've finally finished digging it out [in 2014]."
Inundation	Invasive species spread	Low	"We have a knotweed problem. Anything (river water) that comes up on our farm brings knotweed."
Inundation	Chemical deposition-related health and safety concerns	Low	"The other thing that was terrible about the sand was that the sand was contaminated and made both of my dogs sick. They developed, uh, skin rashes, but I forget what the doctor called it. But anyway, they both had to go to the vet and, um, well I guess get shots to, um, to cure them of their rash. So it was dirty, dirty sand."
Inundation	Debris transport and deposition	Low	"Wood on the side of the river washed down. Metal from the trailer park has washed down. The hardest part of cleaning up after Irene was seeing peoples' lives ruined."
Deposition	Reduced soil productivity	High	"For a couple of years, the production was lower so it impacted our ability to grow crops on the property."
Inundation	Crop contamination	High	"All the debris came down, and it was deposited throughout the field. Because of the federal insurance on it, we had to destroy the crop. We had to go in there and plow it under, there's always a problem with toxins if you go to feed [the crop to] the cattle."

(e.g., equipment loss, crop loss, etc.), and column three describes the degree of sensitivity exhibited by the specific farmer quoted in column four.

There are a wide variety of adaptive actions that farmers can take to protect themselves and their businesses from increasingly frequent flood events. While some activities do not have negative impact on communities downstream, others do. For example, levees can protect a field from flooding, but they will often speed up floodwaters and worsen conditions for riparian habitat and downstream residents. Farm land use changes typically flow downstream flood waters and limit a farmer's flood-related financial losses, but this adaptation may also limit the type and number of crops that a farmer can grow. Examples of these different on-farm flood adaptations, and their potential tradeoffs, are listed in Table 3. As can be seen in farmer perceptions in Table 3, significant expenses associated with adaptation practices are common, and farmers often pay out of pocket and incur large amounts of debt. Additionally, these adaptations are often undertaken as investments in future production on the farm: unlike many natural resource industries, farmers have a strong reason to ensure the continued productivity of their land.

OVERCOMING TRADEOFFS TO ACHIEVE GOOD RIVER AND STREAM GOVERNANCE

Good river and stream governance requires that multiple stakeholder groups have their concerns and goals addressed

through collective action and/or regulation. In an era of increasing flood frequency due to climate change, it is important that all stakeholders be able to reasonably protect themselves from the negative impacts of flooding. In New England, agricultural and nonagricultural stakeholders agree that river management policy should be revised, though doing so is challenging. Farmers contribute in major ways to the regional economy and culture, and they often provide valuable environmental conservation and preservation projects. In some cases, to protect these contributions, a farmer may alter a river or stream which may change flood impacts for others. These other stakeholders sometimes blame farmers for changing a river and altering flood impacts even if they are unable to attribute flood impacts directly to a farm. A new governance system needs to be developed that clearly explains who has the right to manage river and stream corridors, which will determine the amount of flood risk faced by both farmers and downstream communities. However, this new governance system will need to account for uncertainties, some of which include a lack of understanding of the specific role of upstream agriculture in downstream flooding. Some nonagricultural stakeholders claim that by farming near streams and rivers, floodwater that would be otherwise absorbed and slowed by natural forests will inundate and impact downstream communities. But, given the increase in rainfall resulting from climate change and farmers' efforts to restore some riparian areas with natural vegetation, we

TABLE 3. Farmer adaptation practices, collected in interviews with farmers conducted in MA in 2015–2016

Adaptation practice	Reason	Tradeoffs	Farmer descriptions
Bank stabilization/ dredging	Protect crop and pasture lands from erosion; protect critical infrastructure	Increases downstream flood impacts; degrades river ecosystems	"I hired a fellow with a mini excavator and brought in stone and they built up the bank. . . it probably cost ten thousand dollars or more."
Land use change/ riparian restoration	Protect productivity of croplands by slowing flood waters and preventing soil erosion	Expensive for farmer and may reduce farm income	"We've been here since 1981. Probably by 1985 it was hay. Since then it's been hay. We plowed it that one time and we've never plowed it again, just for that risk [of flooding], because in the spring, the roots aren't deep enough if it floods in the spring, that's why we've never plowed that again. We have no intentions of ever plowing that again because you don't know. I don't need a 12-foot ditch in the center of the field."
Flood insurance	Protect livelihood from crop damage	Expensive for farmer	"I had to get flood insurance. In order for me to pay the [flood restoration] loan, they made me get flood insurance."

(continued)

TABLE 3. Farmer adaptation practices, collected in interviews with farmers conducted in MA in 2015–2016 (*continued*)

Adaptation practice	Reason	Tradeoffs	Farmer descriptions
Block flood water	Protect crops/fields from multiple flood impacts	Increase downstream flood impacts	"The farmer who had it before piled huge stones on the embankment up there Gosh, they've got to be 20 to 30 feet from the water. It's not like it's impacting the water, but it's forming that barrier [between the river and the field]."
Drainage infrastructure	Reduce cropland flooding	Increase downstream flood impacts; degrades river ecosystem	"We had to dig out a couple of drainage swales that were plugged up through agricultural fields after the flooding had happened."
Flood debris removal	Preserve/bolster cropland productivity; preserve/bolster agriculturalist land owner's health and safety	Expensive for farmer	"We spent a lot of time cleaning the crap out of the branches and pulling them back up straight and, staking them up so that they would grow the way I wanted them to."
Re-grading fields	Restore cropland productivity after deposition	Expensive for farmer	"I had [the contractor] repair all the damage that was done in my field, [like] filling all the holes."
Borrow on credit to conduct any of the above actions	Perform any of the above actions	Expensive for farmer	"I secured a loan from the small business administration to repair some of the damage. I had to do further work on bank stabilization. What [the contractor] did was excellent, but they essentially did the barebones to get access, and I had to do more to prevent some more erosion. I took out a substantial loan from them to get some other equipment operators in there."

do not yet know the role of upstream farming in downstream flood impacts. In addition, agriculture is not the only valley-based development that may impact downstream flooding. Urbanization is also occurring throughout the region with may greatly alter flood impacts downstream of such development.

CASE STUDY QUESTIONS

The following questions will help guide a discussion of ecological and agricultural tradeoffs and opportunities in river and stream governance in New England's changing climate.

1. What flood impacts do you think farmers are most worried about?
2. What do nonagricultural stakeholders value about streams and rivers in New England?
3. Of the adaptation practices used by farmers to manage flood impacts on their farms, which are most likely to cause concern among other stakeholders? Which would not cause concern among other stakeholders?
4. Could farmers successfully reduce their vulnerability by relying only on adaptation practices that would not cause concern among other stakeholders?
5. If farmers must modify streams and rivers to protect their farms, what strategies may allow them to do so while also addressing concerns of other stakeholders?
6. If New England states were to design new policies to manage rivers, what are the key conflicts between farmers and other stakeholders along rivers that they should address? What types of strategies should they implement to better manage these conflicts?

AUTHOR CONTRIBUTIONS

Benjamin P. Warner: Lead on conceptualization, data collection, analysis, original draft, review, and editing.

Rachel E. Schattman: Lead on conceptualization, original draft, review, and editing.

Christine E. Hatch: Support on conceptualization, review, and editing.

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

SUPPORTING INFORMATION

Slides. PPTX
Teaching Notes. Doc.

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